MODERN ARTILLERY

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THE

PRINCIPLES AND PRACTICE

OF

MODERN ARTILLERY

INCLUDING

ARTILLERY MATERIAL, GUNNERY

AND

ORGANIZATION AND USE OF ARTILLERY IN WARFARE

By LIEUT.-COL. C. H. OWEN, R.A.

PROFESSOR OF ARTILLERY, R. M. ACADEMY, WOOLWICH
AUTHOR OF 'ELEMENTARY LECTURES ON ARTILLERY' 'THE MOTION OF PROJECTILES FROM RIFLED ORDNANCE' ETC. ETC.

With Numerous Illustrations

SECOND EDITION

LONDON
JOHN MURRAY, ALBEMARLE STREET
1873

TO

HIS ROYAL HIGHNESS

FIELD-MARSHAL THE DUKE OF CAMBRIDGE

K.G. G.C.B. K.P. G.C.M.G.

COLONEL OF THE ROYAL REGIMENT OF ARTILLERY

UNDER WHOM

AS GOVERNOR AND PRESIDENT OF THE R. M. ACADEMY, WOOLWICH

THE WRITER HAS HAD THE HONOUR TO SERVE

This Work is

BY HIS ROYAL HIGHNESS' GRACIOUS PERMISSION

Dedicated

PREFACE

TO

THE FIRST EDITION.

Artillery is a complicated subject; but the statement sometimes made, that it consists merely of a vast amount of detail, is not correct. It is quite true that ordnance stores are very numerous and subject to many changes; but the principles of gunnery, and the use of artillery in war, which require only comparatively slight modifications from time to time, and are of great practical importance, must also be studied—a knowledge of them being essential in order to obtain the full results of which the arm is capable. It is of little use to complain of a complication which must be faced and mastered to render an artillery service thoroughly efficient; careful instruction, over a long period, is the only way out of the difficulty.

This work, written to assist such instruction, is to some extent a reprint of the 'Lectures on Artillery;' but, unlike the latter, which was written in connection with Boxer's 'Treatise on Artillery,' it is complete in itself. It will be found that the treatment of the subject is, in most respects, different from that followed in any of the works on Artillery published in this country or abroad.

The attempt has been made, it is hoped with success, to lay a solid foundation in each branch, and to provide, by ample references to the best books, the means of pursuing either of them by further study. Whenever possible, mere opinions have been avoided, as unsuitable to a work dealing chiefly with the results of practice and the principles to be derived from them.

Part I. gives a general description of the construction and objects of the different guns, carriages, and kinds of ammunition now used, without which the subsequent parts would be but imperfectly understood. To simplify the subject, naval stores and small arms have been omitted, occasional reference being however made to the former in the foot-notes; for the same reason, most of the large tables have been placed in the Appendix. In Part II. long mathematical investigations have been avoided, but references have been given to where they may be found; and the methods of calculating practical gunnery questions have been fully explained. Part III. treats of a subject too little studied in this country, but which is of great importance, and commands apparently at the present time a growing interest.

The idea has recently been broached that a large force of field artillery is a necessity, but that any deficiency in garrison artillery can be supplied by militia or volunteer troops. It is, however, hardly necessary to point out that for garrison service a far greater knowledge of gunnery and stores is required than for field service; and that although valuable assistance may be given by reserve forces, a strong body of thoroughly trained gunners, commanded by well-instructed officers, is absolutely required to deal effectively with the complicated *matériel* now used, not only in garrisons and coast batteries, but in sieges—operations in which the British army is especially liable to be engaged.

To Professor Bashforth, Lieutenant-Colonel F. Miller, R.A., Captains W. H. Noble, and O. H. Goodenough, R.A., I am much indebted for kindly looking over many of the proof sheets, and offering valuable suggestions. I have also to thank the Committee of Council on Education for kindly allowing me the use of the blocks for some of the woodcuts, which appeared previously in my 'Report on the Artillery exhibited in Paris in 1867.'

C. H. O.

WOOLWICH: *January* 1871.

PREFACE

TO

THE SECOND EDITION.

For intelligent and fair criticism I am always thankful, and have in the present edition availed myself of several suggestions made by the reviewers of the first edition, and by private correspondents who have kindly written to point out inaccuracies or defects. I must confess I was rather surprised when a reviewer of the former edition, in a leading morning newspaper, accused me of not quoting the sources from which I had derived information, as I was particularly careful to give every writer credit, by means of a foot-note, for anything in the way of information or suggestion that I had referred to; so much so, that another reviewer set the work down as a compilation, which those who read either the first or this second edition may see is an inaccurate description of a book containing not only a large number of facts, for which references are necessary; but the arrangement, discussion, and reduction when practicable to definite rules and principles, of these facts.

Another reviewer, the drift of whose remarks in the *Athenæum* any one acquainted with the subject could perceive, endeavoured by the repetition of similar expressions to condemn me for saying that the principles of gunnery are permanent and unchanging; and he misquoted my Preface to lay a foundation for this assertion. 'Slight modification' were not my words, but 'comparatively slight modifications.'

He also condemned me for not entering into manufacturing questions which I distinctly stated were not within the scope of the work, but were treated elsewhere. Had it been otherwise, I could not have thrown any light, as he wished me to do, upon 'the preposterous system of constructing guns by inserting thin tubes of steel into blocks of cast iron, upon which large sums of money have been, and still are being, expended at Woolwich Arsenal and in private firms under Government contracts,' considering such a system is not carried out in any Government ordnance.

On other points, such as breach and muzzle loading, he drew erroneous conclusions from what I said; but I am not afraid of any one who takes the trouble to read the book being led astray by such criticism.

A reviewer of my first edition complained that I did not make sufficient use of the experience of the late war; and another advised me to cut out the examples from the Crimean campaign and substitute others from the wars of 1866 and 1870-71. At the time that edition was published, the last war was unfinished, and no trustworthy literature had been published; for I could hardly be expected to take the newspaper correspondence, however valuable and interesting, as a guide for accurate details. It may be seen that in this edition I have made use of a large number of works written since the war, and have endeavoured to sift from them what is of the greatest value to an artilleryman.

Respecting the war of 1866, there is little of special value to notice relating to the organisation or employment of artillery, which were inferior to those of the French in 1859. With regard to the Crimean campaign, I have not followed the reviewer's advice; on the contrary, I have rather increased the matter before given, as I conceive our own experiences in that war, although little studied in this country, are of great value. After the Crimean War, in which the formidable power of artillery fire was so clearly demonstrated, there was as much interest taken in artillery questions as there is now; the fruits of this appearing in the use made by ourselves in India and by the French in Italy of artillery, and in the commencement of an unparalleled series of artillery experiments in this and other countries. Few of our younger officers probably ever heard of the pamphlet, 'Artillery the Principal Arm,' and of others written about that time, advocating the importance of artillery in warfare. Just previous to the last war (1870–71) some of our military critics adopted (from Chalons, I think) peculiar ideas as to the employment of field artillery, one of their axioms being, 'Concentrate your fire but not your guns;' now they are for 'massing guns,' apparently under the impression that such a practice is a Prussian discovery, instead of being a necessary development of artillery tactics, as shown in the first edition of this book and in some other works.

As to the last war, the following caution, so well expressed by Lieut. F. Maurice, R.A., in his able 'Wellington Prize Essay,' should be remembered: 'We cannot therefore judge absolutely of the future practice of the German generals from either period of the late war. For in the first portion they had not learnt the necessities of the new condition of things; in the latter, other circumstances had rendered even these new conditions of comparatively secondary importance.'

Although necessary alterations have been made in this edition, the chapters are in the same order as before, and the paragraphs have been kept as nearly as possible like those of the first edition. Major O. H. Goodenough, R.A., has kindly looked over some of the proofs, and Capt. W. Barlow has corrected the table of projectiles for ML.R. guns; but I have especially to thank Captain A. Ford, R.A., and Captain H. Brackenbury, R.A.; the former for assisting me to correct the proofs of Part II., and for offering some useful suggestions; the latter for similar assistance with Part III. I need hardly say that their ability and knowledge of the respective subjects is generally acknowledged; but I may add that I do not wish to hold them responsible for anything I have written.

An apparent attempt to discredit scientific enquiry, in a paragraph in the *Pall Mall Gazette*, has been dealt with in the last Appendix.

In conclusion, I may be allowed to point out that by the establishment of the School of Gunnery at Shoeburyness, and of the various classes at the R.A. Institution, Woolwich, His Royal Highness the Duke of Cambridge—to whom this work is dedicated—gave some years ago ample opportunities to the officers of the Royal Regiment of Artillery for carrying forward the instruction commenced at the R.M. Academy in both the practice and the science of Artillery; and that the appointment I hold was about the same time raised to its proper footing, on an equality with the Professorship of Fortification, with the sanction of His Royal Highness, who fully recognised the growing importance of the study of artillery.

C. H. O.

WOOLWICH: *June* 1873.

Errata.

Page 111, line 17 from top, *for* 'The carriage can be' *read* 'The platform can be'

" 205, " 2 from top of Note 3, *for* 'Flat projectiles' *read* 'Flat Trajectories'

" 218, " 10 from top, *for* '$\therefore -\frac{wv^2}{2\cdot g} - \frac{wv'^2}{2g}$,' *read* '$\therefore \frac{wv^2}{2g} - \frac{wv'^2}{2g}$,'

" 238, Note 1, *for* 'U. R. S. Institution' *read* 'R. U. S. Institution'

" 505, line 18 from top, *for* 'Gatlin' *read* 'Gatling'

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ABBREVIATIONS.

SB.	Smooth-bored.	SS.	Sea Service.
R.	Rifled.	GS.	General Service.
BL.	Breech-loading.	L.G.	Large grain.
ML.	Muzzle-loading.	R.L.G.	Rifle large grain.
LS.	Land Service.	F.G.	Fine grain.

P. Pebble.

PRINCIPLES AND PRACTICE OF MODERN ARTILLERY.

PART I.

ORDNANCE, CARRIAGES, AND AMMUNITION.

CHAPTER I.

CONSTRUCTION OF ORDNANCE.

Terms and Definitions: 1. Different parts of a gun.—2. Trunnions and preponderance.—3. External ornaments.—4. Calibre and Windage.—5. Vent.—6. Measurement of lengths of guns. General Principles: 7. Principles of construction.—8. Calibre.—9. Length of bore.—10. Windage.—11. Chambers.—12. Rifling of a gun.—13. Strains upon the metal of a gun.—14. Experiments to determine the strain upon the metal of a gun.—15. Unequal strain upon the exterior and interior of a cast gun.—16. Methods adopted for equalising the strains upon exterior and interior portions of metal of a gun.—17. Increased strain upon ordnance of large calibre.—18. Effect of elevation upon strain.—19. Amount of metal in a gun.—20. Trunnions.—21. Vent.

Terms and Definitions.

1. Before proceeding to consider the general principles to be observed in the construction of ordnance, it is desirable to explain the meaning of the different terms used to distinguish the various parts of a gun.

A gun of ordinary construction is conical in general form, for as the strain upon the piece when discharged decreases from breech to muzzle, the thickness of metal may be reduced towards the latter. A smooth-bored cast gun is divided into five principal parts (Fig. 1):—The Cascable; First Reinforce; Second Reinforce; Chase; Muzzle.

The heavy built-up ML. rifled ordnance, and the light bronze rifled guns cast for India, are not thus divided by rings

B

into distinct parts, but the above terms, excepting the reinforces, are applied to the corresponding portions of them. The BL. rifled guns have no cascable.

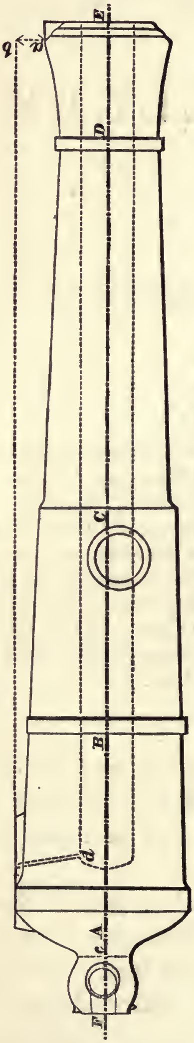


Fig. 1.

Cast-Iron S B. 32-pr. Gun (58 cwt.).

F A Cascable. A B First Reinforce. B C Second Reinforce. C D Chase.

D E Muzzle. c d Breech. a b Dispart.

The *breech* of a gun extends from the bottom of the bore to the neck of the cascable.

The projection behind the breech is called the *button*, and it generally has a breeching loop through it.

The increase in the thickness of metal at the muzzle is called the *tulip, or swell, of the muzzle.* It increases the strength of a part very liable to be struck by an enemy's shot, and affords a good position for a sight. It was formerly much ornamented. The built-up rifled ordnance, both BL. and ML., have been made without tulips, with the exception of a few ML. 64-prs. for naval service and the ML. 9-prs.

2. The cylindrical pieces of metal on each side, by means of which the gun is supported in its carriage, are called the *trunnions.* Those of a gun or howitzer are placed a little in front of the centre of gravity of the piece, to allow the breech to preponderate; this is necessary, in order that the gun may rest steadily on its carriage. The excess of weight in rear of the trunnions is termed the *preponderance,* and it is desirable that this preponderance should be as small as possible, in order to avoid unnecessary labour in raising the breech of a gun when elevating. The preponderance of a piece of ordnance can be practically ascertained by resting the trunnions on knife edges,

and suspending weights at the muzzle until the gun balances on the edges. The preponderance of the guns now made in the Royal Arsenal is found by placing an ordinary weighing machine with a wedge of wood on it under the breech, each trunnion being supported by a block of wood having a small rectangular steel bar on the top of it. The preponderance thus obtained will not therefore exactly correspond with the above definition.

3. It was formerly the custom to ornament the exterior of a gun with rings, astragals, &c., but ordnance are now made without them, as they would increase the expense of manufacture: in cast guns they were said to decrease the strength of the metal.[1] The built-up rifled ordnance are made without projecting rings on the exterior surface.

4. The diameter of the bore is termed the *calibre* of the gun. The difference between the diameter of the bore of the gun, and that of its projectile, is termed the *windage*.[2] It is necessary that the diameter of the bore of a muzzle-loading gun should be slightly larger than that of its projectile, in order that the piece may be loaded without difficulty; allowance must also be made for imperfections in form, for increase in the diameter of the projectile from incrustation of rust or from its expansion when heated,[3] and for the fouling of the bore after continued firing.

5. The *vent* of a piece of ordnance is a small channel, by means of which it is fired, passing through the metal from the exterior surface on the top of the breech into the bore. The vents of service ordnance are made $\frac{2}{9}$-inch in diameter, and the

[1] Mr. Mallet points out in his work *On the Construction of Artillery* that 'in castings of iron the planes of crystallisation group themselves perpendicularly to the surfaces of external contour,' p. 9,—and 'that every abrupt change in the form of the exterior—every salient, and every re-entering angle, no matter how small, upon the exterior of the gun or mortar, is attended with an equally sudden change in the arrangement of the crystals of the metal, and that every such change is accompanied with one or more planes of weakness in the mass,' p. 11.

[2] Objection has been made to this definition, but as long as *linear* windage is given in all official tables of ordnance, it must be retained. The *windage* is strictly the difference between the area of a section of the bore at right angles to its axis, and the area of a great circle of the shot.

[3] The expansion of the diameter of spherical shot when heated, is from about $\frac{1}{80}$ to $\frac{1}{100}$.

tubes with which they are fired $\frac{2}{10}$-inch, the latter therefore fitting readily into the former. The vent is not drilled in the metal of the gun, but in a copper *bouch*, which is screwed into the piece, copper being used, as it withstands the action of ignited gunpowder better than most other metals.

6. The respective lengths of the different kinds of service ordnance are measured in three ways.

(1) That of a SB. cast piece is measured along the axis from A behind the base ring to E at the face of the muzzle (Fig 1.)

(2) ML. Built-up ordnance, whether rifled or SB., have their lengths measured from the neck of the cascable A to the face of the muzzle B (Fig. 36).

(3) The length of the BL. rifled guns (either screw or wedge) is measured from behind the breech to the face of the muzzle, taking in therefore the total length of the construction, not however including any part that can be detached—as a breech screw (Fig. 33).

General Principles.

7. The practical conditions to which attention must be paid in order that a piece of ordnance may be fitted by its form, calibre, or weight for any particular service will be pointed out in another place. It will only be necessary here to consider briefly the most important general principles which should be observed in the construction of any gun, so that the charge may perform its work upon the projectile, that the metal may withstand the strain to which it will be subjected, and that the piece may be attached to its carriage or bed in such a manner that the working of the gun may be performed with facility and with as little injury as possible to the carriage.

The physical properties and relative advantages or defects of the different materials for ordnance [4] do not come within the scope of this work, and the following remarks will therefore

[4] These are given in *Short Notes on the Manufacture of Ordnance, Carriages, and Ammunition* by the writer of this work; also in *A Text Book of the Construction and Manufacture of Rifled Ordnance*, by Capt. F. S. Stoney, R.A., and Lieut. C. Jones, R.A.

be confined to a consideration of, (1) the *bore*,—its diameter, and length, windage, and modification of the form of bore by chambers or rifling; (2) the *strains* to which the metal of a gun is subjected; (3) the *amount of metal* in a piece of ordnance; (4) the *preponderance* and position of trunnions; (5) the *vent*.

8. When gunpowder is ignited within the bore of a gun, its conversion into gas although apparently instantaneous is gradual, the rate of combustion of a given charge depending not only on the size, shape, or glazing of the grains, but also on the diameter of the bore. The diameter and length of the bore should be so regulated that there may be no *waste* of powder, and that the force of the gas may be expended in giving *velocity* to the projectile with as little *strain* as possible on the metal of the gun.

The general form of a projectile being that of a sphere or cylinder (pointed), it is obvious that the bore of a gun should be cylindrical in shape, except when modified to a certain extent by a chamber or rifling. The calibre of a piece of ordnance depends upon the form and nature of the projectile. Thus, a rifled gun requires a less calibre than a smooth-bored piece, if both are intended to fire projectiles of equal weight; for with the former—elongated projectiles can be used, but with the latter, only spherical shot or shell; for instance, the calibre of the 12-pr. smooth-bored gun is 4·62″ and that of the 12-pr. rifled piece only 3″. Again, if from a rifled gun long range or great penetration are wanted, a small calibre is advantageous, for of two elongated shot equal in weight, the one with the smallest diameter will oppose the least surface to the resistance of the air or to that of the material into which the projectiles are fired. A gun intended only for shell firing has a large calibre in proportion to its weight, capacity of shell for bursting charge being requisite; thus a smooth-bored shell gun of 10″ calibre weighs 86 cwt. but a solid shot gun of only 8″ calibre weighs 95 cwt.

The calibre must also be suited to the charge. As the diameter of the bore is decreased, so with a given charge must the length of the cartridge be increased, and the conversion of the powder into gas be retarded, unless the cartridge be pierced like a tube; with the longer cartridge the strain will be thrown forwards. In two guns of different calibres the useful effect of a given charge is probably the greatest in the bore of the higher calibre as regards the *initial velocity* of the projectile, for as the gas exerts a certain pressure per square inch on the base of the shot, the projectile with the largest base will receive the most pressure. As the calibre of the gun is increased, so will the bottom of the bore receive a greater, and the metal surrounding the charge a less, proportional strain for a given pressure per square inch. From recent experiments (June 1872), it would appear that by increasing the bore of an 18-ton gun from 10 to 11 inches, the same weight of projectile could be fired with a larger charge, giving a higher velocity, but with a reduced strain.[5]

9. The length of the bore of a piece of ordnance must be such as to allow of the decomposition of its whole charge, a certain time being necessary for its complete combustion. If the bore be not of sufficient length for this purpose, a considerable portion of the charge will be blown out unfired, and therefore wasted. The initial velocity of the shot increases with the length of bore up to a certain point, viz., when the retarding forces of the friction of the ball against the sides of the bore, and the resistance of the column of air in front of the ball (which increases with the velocity) are equal to the accelerating force of the gas. Experiments have been made with smooth-bored guns at different times to ascertain the most advantageous length for their bores; these are described in Boxer's Treatise on Artillery, pp. 63–71, and a curious law is also noticed from the Tables of Practice given, 'That guns of certain lengths, in calibres, give relative maxima ranges;' this law would only apply to smooth-bored ordnance. In the experiments of 1801, relative maxima ranges were obtained from guns of 12, 15, and 19 calibres in length. The length of

[5] Results of experiments are quoted in a Paper *On the Construction of Heavy Artillery*, by Mr. Bashley Britten, printed by the Institution of Civil Engineers. A more extended series of experiments would be needed to establish the proper relations of calibre to charge and weight of projectile; and it would be necessary in connection with them to determine the length of bore adapted to these conditions when varied.

the bore will, however, be limited by several practical considerations, such as the *weight* of the piece and the *space* it will have to occupy.

The proper length of bore for a rifled gun has not been satisfactorily determined, so many different points requiring numerous and careful experiments in order to furnish sufficient data for the proper consideration of the subject. It may, however, be remarked that the length of the bore of a rifled piece, intended to fire a given charge and weight of projectile, should depend upon the calibre and system of rifling adopted; if two rifled guns are required to fire equal charges, but one has a less calibre than the other, the same amount of work will not probably be done upon the shot in the two bores, unless the respective lengths of the latter are nearly proportional to the lengths of the cartridges, and so equal expansion is allowed to the gas in both bores.

The following figures will show the number of expansions allowed to the gas in the respective bores of guns of different kinds:—

	Gun	Length of Bore	Cartridge			No. of Expansions in Bore
			Charge		Length	
		ins.	lbs.	oz.	ins.	
Smooth-bored	10 in. Gun	121·16	12	0	8·5	14·2
	8 in. do.	118·7	10	0	10·2	11·6
	68-pr. (95 cwt.)	113·9	16	0	11·5	9·9
	32-pr. (58 cwt.)	108·65	10	0	10·75	10·1
	do. (50 cwt.)	103·08	8	0	9·2	11·2
	24-pr.	107·41	8	0	10·5	10·2
	18-pr.	101·75	6	0	9	11·3
BL. Rifled	7 in. (82 cwt.)	99·5	11	0	10·5	9·47
	64-pr.	92	8	0	12·5	7·36
	40-pr.	106·375	5	0	12·5	8·5
	20-pr.	84	2	8	10·37	8·1
	12-pr.	61·375	1	8	8·5	7·22
	9-pr.	52·5	1	2	6·25	8·4
ML.R.	16-pr.	68·4	3	0	9·75	7
	9-pr.	63·5	1	12	9·25	6·86

In the heavy ML.R. guns [6] the expansions are:—

Gun	Battering Chge. Pebble.	Full Chge. R.L.G.	Gun	Battering Chge. Pebble.	Full Chge. R.L.G
12 in. (25 tons)	6·6	9·6	9 in.	5·4	7·5
11 in.	5·68	7·6	8 in.	5·5	7·1
10 in.	5·7	8·08	7 in. (7 tons)	6·6	9·0

[6] The charges and lengths of cartridges of these guns will be found in a Table, § 22 Chap. ix. of this PART.

From these it will appear that the rifled guns are shorter in the bore for their charges than the smooth-bored pieces; some of them are probably too short to develop the full power of their charges, but this has arisen in certain cases from the length of gun having been limited by the space allowed in the service for which it was made. It must not, however, be forgotten, that as the elongated projectile in a rifled gun offers more resistance to motion than the ball in a smooth-bored piece, a larger amount of powder is consumed before the shot moves, the expansion of the gas is retarded, and more work is done in a rifled gun in the same length of bore.

In some systems of rifling, a greater force is required to move the projectile than in others, and consequently more of the powder is converted into gas before the shot starts; also in most of the BL. rifled guns there is no windage, and, there being no loss of gas, greater force is exerted in a given space than when there is more or less windage. An experiment was made by the late O. S. Committee to ascertain, by cutting off successive portions of a rifled gun, the effect of length of bore on velocity; the results will be found in the chapter on initial velocity.

10. The disadvantages arising from windage in a *smooth-bored* gun are—

(1) The loss of a certain portion of the force of the charge, from the escape of gas round the projectile.

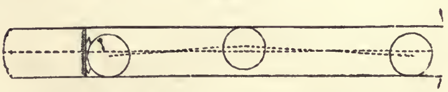
(2) Irregularity in the flight of the projectile.

(3) Injury to the bore of the gun.

With regard to the first point, as there is a loss of a certain portion of the gas, there will also be a proportional loss of initial velocity.

Irregularity in the flight of the projectile, in consequence of the windage, arises from the fact that the centre of the ball is below the axis of the piece, and therefore, the elastic gas acts in the first instance upon the upper portion of the projectile, driving it against the bottom of the bore; the shot re-acts at the same time that it is

Fig. 2.



impelled forwards by the charge, and strikes the upper surface of the bore some distance down, and so on, by a succession of rebounds, until it leaves the bore in an accidental direction, and with an uncertain rotation, depending chiefly upon the last impact (Fig. 2).

The bores of smooth-bored guns, but especially those of bronze guns, are more or less injured by the rebounds of the shot in passing through them;[7] these rebounds increase materially with the windage. The first impact, viz., at the seat of the shot, is of the greatest importance, as, from its position, it is the most likely to render the piece unserviceable. This injurious effect is in a measure prevented by the use of wooden bottoms or sabots, which are attached to shot for SB. bronze pieces, as well as to all spherical shells.

Windage is objectionable in a *rifled* gun.

(1) Because injury to the upper surface of the bore arises, when large charges are used, from the rush of gas over the projectile producing what is termed *scoring* or *erosion* of the bore.

(2) Because, unless some effectual means are taken to *centre*[8] the projectile, its axis will not be steady in moving through the bore; this unsteadiness of axis will tend to impair the accuracy of fire at short ranges, and to increase the wear of the bore.

A great advantage of windage is, that it allows of the passage of the flame round the projectile, and so of the ignition of a time-fuze when the gun is discharged. No more windage should be given than will allow of the easy loading of the piece.

11. The chamber of a piece of ordnance is a cell or cavity

[7] An experiment was made a few years since at Shoeburyness in order to determine how far the bore of a bronze gun is protected from injury by the use of the sabot. Two 9-pr. guns were fired, one with loose shot, and the other with shot having sabots riveted to them in the usual way. The former was declared unserviceable at the 90th round, its bore being very much indented, and the exterior bulged and even slightly cracked over one part of the indentation; moreover, at the last round the shot broke, owing no doubt to its jamming, in consequence of the bore being so much deformed in shape. The latter gun, with which sabots were used, was uninjured at the 100th round.

[8] The object of, and methods adopted for, *centering* the projectiles of rifled guns will be explained further on.

at the bottom of the bore to receive the charge of gunpowder. SB. mortars, howitzers, and shell-guns, which have comparatively small charges, are provided with chambers, as a greater useful effect is thereby obtained from the powder.[9] There are two forms of chamber in our service smooth-bored ordnance, viz., the *cylindrical* (Fig. 32), and the *conical* or *gomer* (Figs. 30, 31). The cylindrical chamber is best adapted to very small charges, and the gomer to larger charges.[1]

Rifled guns usually have a powder chamber, into which the grooves of the bore do not extend, as they would only weaken the metal, and are there of no use; in some R. pieces the chamber is cylindrical, and of about the same diameter as the bore; in others conical at the bottom. The cylindrical is the better form, and when the contraction is considerable the bottom of the bore is liable to fissure from the peculiar action of the gas upon it.

12. A rifled gun has two or more spiral grooves cut in the surface of the bore into which the projections or soft metal coating of the shot are made to enter, so that as the projectile is driven out of the bore a rotatory motion is imparted to it. The chief object of giving this rotatory motion is to secure accuracy of fire. The spaces between the grooves are called the *lands.*

The groove of a rifled gun is simply a portion of the thread of a female screw having a very long pitch.

[9] This point is explained in Boxer's *Treatise on Artillery*, p. 82. With a chamber there is less escape of gas by windage, the force acts through the axis of the shot and not on the top, which would give it a rotation tending to decrease the range, and less heat is extracted from the gas by the metal of the gun.

[1] The cylindrical chamber may be regarded as obsolete, the only SB. pieces having this form of chamber being the 24-pr. iron howitzer, the coehorn howitzer, and carronades (Fig. 32). All shell-guns, mortars, 8-inch and 10-inch howitzers, and brass howitzers, have gomer chambers. The gomer chamber was originally proposed for mortars, and it possesses the following advantages—that when the projectile is *home* all windage, until the shot has moved, is destroyed; also, that the axis of the projectile in this case is in the same line as the axis of the bore of the piece, the force of the charge therefore acting uniformly upon the projectile, or through its axis. Should the bore of a gun, having a gomer chamber, be horizontal or nearly so, the shot will rest upon the bottom of the bore, and the above advantages will not be obtained.

Let A B C (Fig. 3) be a right-angled triangle in which
B C = circumference of the bore of a gun,
A B = length of the bore.

Now suppose the triangle A B C to be wrapped round the surface of the bore as in Fig. 4, so that B and C meet,—A C will be the *helix* or curve of the groove. Now in Fig. 4 the groove makes a complete turn in the length of the bore, but in ordinary rifled guns the *twist* is more gradual, making less than one turn in the bore. The *twist* is the term generally used to express the inclination of the groove, and it is measured by the length or distance is which one complete turn is made. Thus, the twist of the rifling in the 12-pr. Armstrong gun, having a 3″ calibre, is one turn in 38 calibres; and in Fig. 3, if A B represents the length of the twist (not the length of the bore),

Fig. 3.

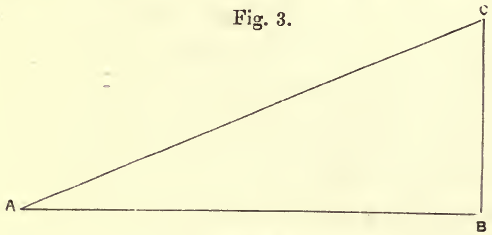
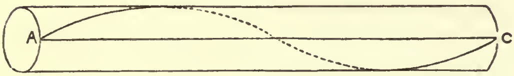


Fig. 4.



$$BC = \pi 3,$$
$$AB = 3 \times 38.$$

Now C A B is called the *angle of twist*, and its tangent is

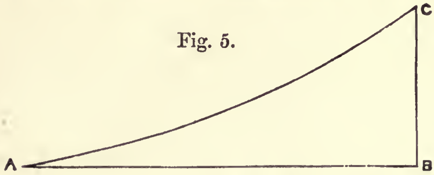
$$= \frac{BC}{AB}.$$

Or, if a = angle of twist,
d = calibre,
l = length of twist.

$$\tan a = \frac{\pi d}{l}.$$

When A C is a straight line, the twist is said to be *uniform*, but if A C be curved, as in Fig. 5, the groove, described by wrapping A B C round the bore, would have what is termed an *increasing* twist, its angle gradually increasing from breech to muzzle. With an increasing twist a high angular velocity is more gradually imparted to the projectile than with a uniform twist, and the strain may thus be slightly diminished at the lower part of the bore. Whether the decrease of strain, due to the less resistance of the shot to motion with an increasing twist, is sensible, or of practical importance, has not been decided by experiment, but the grooves of the heavy service rifled ordnance, of 8 inches calibre and over, have been given increasing twists with the object of reducing the strain, and of lessening the blow of the stud upon the driving side of the groove near the bottom of the bore.

Fig. 5.



The velocity of rotation given to a projectile varies with both the charge and the twist of the grooves.

If V = initial velocity of shot,
l = length of twist,
n = number of revolutions per second,
ω = angular velocity,

$$n = \frac{V}{l},$$

$$\omega = 2\pi n.$$

Taking again the 12-pr. Armstrong gun; the segment shell fired from it has an initial velocity of 1184·4 ft. per second, and $l = 38 \times 3'' = 9{\cdot}5$ ft.

$$n = \frac{1184{\cdot}4}{9{\cdot}5}$$

$$= 125{\cdot}3 \text{ revolutions per second.}$$

It will be shown that the velocity of rotation required depends upon the form, length, weight, and position of the centre of gravity of the projectile.

The form of the grooves and their number vary very much according to the method of rifling.

13. When a charge of gunpowder is ignited in the bore of a gun, the gas exerts equal pressure in every direction, and therefore, neglecting windage, the pressure on the bottom of

the bore is equal to that on the base of the shot, and the pressures on the top and bottom as well as those on the sides of the bore balance each other. The metal of a gun is subjected to two principal strains, one a *transverse* or *tangential*, which tends to rend the metal lengthwise or from end to end,

Fig. 7.

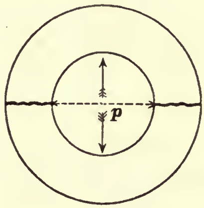
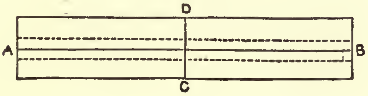


Fig. 6.



through A B, Figs. 6 and 7, and the other a *longitudinal*, tending to fracture the gun across, as through C D, Fig. 6, or to drive out the breech.

And if a = length of a portion of the bore,

d = calibre of the gun,

p = mean pressure of gas per square inch in the length (a),

The tangential strain $= adp$

The longitudinal strain $= \frac{\pi}{4} dp^2$.

As the projectile moves towards the muzzle, so will the space in which the gas is confined be increased, and the pressure be decreased; and the portion of metal surrounding the space originally occupied by the cartridge, and a little in front of it, is that upon which the *maximum pressure* from the gas is exerted; the maximum pressure will be influenced by the nature of the powder, the resistance offered by the projectile to motion, and by the absence or amount of windage.

The strain upon the metal of a rifled piece will be much greater than upon that of a smooth-bored gun, if both are fired with similar proportional charges; for the elongated projectiles of the former are much heavier than the spherical shot or shell of the latter, and they are fired with less windage or none at all, according to the mode of rifling, the escape of gas being therefore diminished or prevented; the elongated projectile, also, instead of merely rolling through the bore, will experience considerable friction at those parts which enter the grooves, and must have a motion of rotation as well as of progression, a greater force being consequently required to move it, the gas being more condensed, and exerting a greater pressure in the gun. The highest strains exerted in the bore of an 8-inch gun when firing elongated and spherical projectiles respectively were found to be [2]—

Projectile.	Charge (L. G. Powder.)	Strain.
Elongated 180 lbs.	30 lbs.	28 tons per square inch.
Spherical 69 lbs.	15 lbs.	$17\frac{2}{3}$ do.

It will be seen that, by using a different powder, the strain with the elongated projectile is considerably reduced.

In some rifled pieces, as in the Armstrong BL. gun, the shot is retained until sufficient force is exerted not only to overcome the friction of the shot, but also to compress the soft coating into the grooves, so that time is doubtless given for the ignition of the greater part of the charge, and, as there is no windage and therefore no loss of gas, the maximum strain upon the metal must be much greater than in a smooth-bored piece, or in a rifled gun where less resistance is offered to the motion of the shot.

To allow for the increase of strain, the charges of rifled guns are much less than those used with smooth-bored ordnance, the former being about $\frac{1}{10}$ to $\frac{1}{6}$, and the latter about $\frac{1}{4}$ to $\frac{1}{3}$ of the weight of the projectile.[3]

14. Experiments were carried on some years ago in America, to determine the gradual decrease of strain upon the metal of a piece of ordnance, from breech to muzzle; the experiments are thus described:—'By perforating a gun in several places, from

[2] *Progress Report of Committee on Explosives*, Jan. 1871, p. 7. The 10-inch gun was fired both as a smooth-bored and a rifled piece, and the strain was found to be about the same in each case. But elongated shot were fired with equal charges both before and after rifling, thus giving no idea of the comparative strains in SB. and R. guns, as they are usually fired; and the strain would obviously be increased before rifling, from there being no grooves through which the gas could escape.

[3] The charge of the ML.R. 16-pr. and the battering charges of some of the heavy ML. R. guns are as much as $\frac{1}{5}$, but the latter would only be used for firing at iron defences.

the exterior to the bore, at right angles with the bore, and successively screwing a pistol barrel, containing a steel ball, into each perforation, and discharging the gun with the pistol barrel at the different perforations, the relative velocities with which the pistol ball (received by a pendulum) is forced out at these different positions, indicate the force exerted there to burst the gun; and, consequently, the relative strength of metal necessary in the various parts to resist explosion. The results of these experiments are relatively as follows, in decimal parts:—

	Calibre
'At one calibre in rear of centre of shot	·9758
„ centre of shot	1·
„ 1 calibre in front of shot . .	·8149
„ 2	·6767
„ 3	·6163
„ 5	·5291
„ 7	·4393
„ 9	·3988
„ 11	·3667
„ 15	·2858

'These decimals show the relative strength necessary at different parts to resist explosion.'[4] The dimensions here given are intended to apply to cast-iron ordnance, which it is assumed should have a thickness of one calibre round the shot where the greatest strain is exerted.

Another series of experiments[5] was also made in America by Major Rodman, to determine 'the absolute pressure of the gas in the bore of a gun,' the metal of which was, as in the former case, perforated at different distances. Into each hole was screwed a *pressure gauge*, consisting of a piston, an indenting tool, and a disc of copper; when the piece is fired, the piston, being exposed to the pressure of the gas, is forced outwards, and presses the tool, having a broad but thin point, into the copper disc, the indentation made being compared with that

[4] *Ordnance, Gunnery, and Steam.* By Lieut. Ward, U.S.N.

[5] These are described in a *Report of Experiments on the Properties of Metals for Cannon and the Qualities of Cannon Powder.* 1861.

obtained in a testing machine with the same tool, and a piece of copper cut off the same bar.

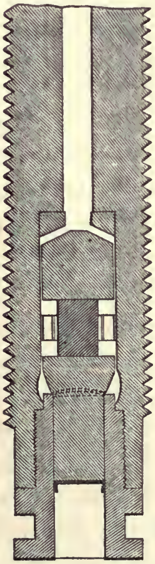
The pressures per square inch due to proof charges in the SB. 42-pr. gun were, at the bottom of the bore:—

Charge	Shot	Wad	Pressure
21 lbs. .	2 .	1 .	64,510 lbs.
14 .	2 .	1 .	55,622
21 .	1 .	1 .	47,785.

In other experiments with the 15-inch SB. gun, the pressure gauge was wholly within the bore, being inserted in the bottom of the cartridge.

Experiments are now being made in this country with superior apparatus to that formerly employed in America, and the results already obtained are of great importance, chiefly with respect to the action of different powders in the bore of a gun, both in exerting strain upon the metal and in imparting initial velocity to the projectile. The guns used are heavy built-up pieces, of 8 and 10-inch calibre respectively, which have been fired first as SB. and then rifled, but in both cases with elongated projectiles. One of the instruments used is a *chronoscope*[6] of rather complicated construction, which is in connection with the wires in a number of plugs passing through the gun, from the exterior surface to the bore, at different distances in front of the cartridge. A small cutter projects from the plug into the bore, and as the projectile passes each in succession, it raises the cutter, which thus severs the wire in the plug, and produces a spark on the edge of one of a set of discs in the chronoscope; the number of discs is equal to the number of plugs, and, as the former are made to revolve with very great rapidity on the same axis, the different positions of the sparks indicate the times taken by the projectile in passing over the spaces between the plugs. The velocities can be easily calcu-

Fig. 8.



[6] See Appendix.

lated, and from them the strains exerted at the different points along the bore. The other instrument is an improvement upon the Rodman pressure gauge, and is called a *crusher-gauge* (Fig. 8), the pressure of the gas being ascertained by the compression of a copper cylinder[7] upon an anvil by the piston. With powders burning slowly and regularly, the results obtained by the chronoscope and the crusher are said to be nearly alike.

The following results have been selected for comparison.[8]

Calibre of Gun	Weight of Shot	Charge	Velocity	Maximum Pressure (tons per square inch)	Powder
inches	lbs.	lbs.	feet	tons	
10	400	60	1313	53	R. L. G.
do.	do.	do.	1298	15	Pebble
do.	do.	70	1432	21	do.
8	180	30	1324	29·8	R. L. G.
do.	do.	35	1374	15·4	Pebble

It may be observed from the Table, that the maximum strain may be greatly reduced by the substitution of Pebble for R. L. G. powder, and that a higher velocity may be obtained with reduction in strain by the selection of suitable powder. From these experiments it also appeared that while with a rapidly explosive powder, as R. L. G., the force partook of the nature of a blow, with a powder, such as the Pebble, burning slowly and regularly, it more resembled a pressure, a conclusion very similar to that arrived at by Major Rodman. These points will, however, be entered upon more in detail in the remarks on the forces which act upon a projectile within the bore of a gun.

In these experiments three crushers have been used—A, at the bottom of the bore in the axis of the piece, B over the centre of the charge, and C in front of the cartridge; and in some cases a crusher has also been placed in the base of the pro-

[7] Captain Simpson, U.S. Navy, stated at the Institution of Civil Engineers, that silver has lately been substituted for copper in America, the former being found to give more uniform results. Paper *On the Construction of Heavy Artillery.* By Bashley Britten, p. 82.

[8] Memo of Committee on Explosives, July 12, 1870.

jectile.[9] The following results[1] give the pressures in a 10-inch ML. R. gun fired with a 400-lbs. projectile, and a 64-lbs. charge of pebble powder.

	Tons (Square Inch)		Tons (Square Inch)
A crusher . .	29·0	C crusher . .	22·8
B do. . .	21·7	Projectile do. . .	22·0

The pressure on A crusher has been found to be almost always greater than those on the others, and in some instances, especially with quickly burning powder, the A crusher has indicated very high strain at the bottom of the bore; various causes have been assigned for these abnormal pressures, such as,—the conical form of the chamber, the irregular action of the powder, or the over-riding of the studs, and from a recent experiment (June 1872) it would seem that they occur when the charge exceeds a certain amount for a given calibre and weight of projectile. Thus in the 10-in. ML. R. gun with 400 lbs. shot the highest and lowest pressures on A crusher in three rounds with each charge (pebble powder) were:—

	Highest tons	Lowest tons	Difference tons
70 lbs. . . .	18·8	16·3	2·5
85 lbs. . . .	46·0	28·8	17·2

The method, recommended by the Committee, of determining the battering charge for a gun is:—'To increase the charge gradually until distinct wave pressures are exhibited, the highest charge employed without these local pressures appearing should then be accepted as the battering charge.'[2]

From a recent experiment it would appear that the pressure increases with the *weight* of projectile up to a certain point, but that beyond this the pressure does not rise materially, although the weight of projectile may be greatly increased.[3]

[9] Should this projectile crusher prove satisfactory, it would furnish a convenient test, no fittings in the gun being required.

[1] *Progress Report of Committee on Explosive Substances*, Jan. 1871, p. 9. Table quoted by B. Britten. *Construction of Heavy Artillery*, p. 137.

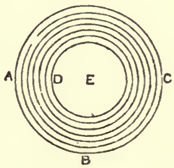
[2] *Progress Report of Committee on Explosive Substances*, April 1872, p. 3. The results with a piece of 12-inch calibre have not been so regular as those obtained in the 8- and 10-inch guns.

[3] In the ML. R. 10-inch gun fired with 70 lbs. of pebble powder, and with projectiles of from 300 to 1,200 lbs. weight; the maximum pressure was rather

It was also observed that with a suitable charge of pebble powder no wave action (abnormal pressures) is caused by increased weight of projectile; and that with R. L. G. powder the wave action is not affected by such increase. With greater weight of projectile the time for which a pressure is exerted is obviously longer.

15. If a gun be cast in one mass, as in the case of an ordinary cast-iron gun, the external portions of the metal do not bear an equal share of the strain (from the discharge) with the interior portions. If A B C (Fig. 9) represents the transverse section of a gun, 1 foot (or any other unit) in length, let us suppose the thickness of metal A D to be divided into a number of concentric rings.

Fig. 9.



It is evident that the greater the distance of any ring from the axis of the gun E, the less will it be stretched by the expansion of the bore when the piece is discharged; and, consequently, the less will it contribute to the general strength of the gun.

If the strain upon the bore from the discharge be considered merely as a pressure (statical force), the resistance offered to it by any two rings will be inversely proportional to the squares of their circumferences or distances from the axis of the gun.[4]

It will therefore appear that there is a certain limit, beyond which it would be useless to increase the thickness of metal, viz. when the force exerted upon the surface of the bore would be sufficient to rupture the interior portions of the metal before the strain acted to any extent upon the exterior.

16. In order to obtain the requisite strength with a moderate thickness of metal, it would be desirable to equalise, as far as possible, the strains upon every portion of the metal; this would be accomplished by giving the exterior portions a certain initial *tension*, gradually decreasing and passing into *compression*, towards the interior.[5] Considerable practical

over 22 tons with 600 lbs. projectile, the pressure not increasing with the heavier projectiles except very slightly in one case, viz., 23 tons with 1,200 lbs. shot. (*Proceedings of Department of Director of Artillery*, vol. x. p. 84.)

[4] Barlow, *On Strength of Materials*, p. 203.

[5] In ordnance cast solid the exterior portion of metal is denser and stronger

difficulties arise in carrying out this principle, but many experiments have been made during the last few years for this purpose. This equalisation of the strain upon the metal of a gun has been attempted in various ways, viz., by *shrinking* or *driving* on rings or tubes of wrought iron or steel over an iron (cast or wrought) or steel cylinder; or by winding iron wire over an inner tube of cast iron or other material. In shrinking —tubes are put on hot, but contract when cool, and thus compress the inner portions of the metal over which they are placed; at the same time these outer tubes will evidently be in a state of tension. This principle is carried out in the construction of the built-up guns now in use.[6]

17. The larger the calibre of the gun, the greater will be the strain exerted upon it from the explosive effects of the charge, the density and form of shot being alike, and the weight of charge bearing always the same proportion to that of shot. For with a smooth-bored gun, the weight of the ball increases as the cube of its diameter, the strain from its reaction being in the same ratio; also with any piece, as the calibre is greater, the mass of the charge increases more rapidly than the surface of the bore upon which it acts, the former increasing as the *square of the calibre*, and the latter as *the calibre;* and with increase of calibre less heat in proportion is extracted

than the interior, for as the former cools and sets first, *extension* is produced in the *interior*. A great deal of the inferior metal is bored out, but the metal round the bore, which will have to bear the most severe strain, is weaker than the outer portion, which takes but little strain. To obtain more uniform contraction in cooling, and a better condition of metal to withstand strain, the Americans cast their guns hollow on a core kept cool by a stream of water inside, while a fire is made round the outside of the mould. The cooling of the interior is thus retarded, and that of the exterior accelerated. This method was proposed by Major Rodman.

[6] Ordnance constructed at an early date (as 'Mons Meg' of Scotland, in the fifteenth century) were sometimes made by shrinking iron hoops over longitudinal bars or staves of iron; this construction is defective, for the longitudinal staves take but little of the strain, and are liable to be separated by the penetration of the gas between them. A monster mortar of 36 in. calibre was constructed in 1857 by Mr. Mallet, by shrinking a number of wrought iron rings one over the other, and strengthened on the outside by longitudinal bars. At the first experiment the mortar was ruptured after a few rounds, with a comparatively small charge, in consequence of the imperfect welding of the rings; at the second trial, the rings stood well, but the bolts which secured the longitudinal bars, not being sufficiently strong, gave way.

from the gas by the cold metal of the gun; in addition, the proportional loss of force from the escape of gas by windage is less as the calibre is greater, the windage (linear) being the same.[7]

18. It is generally said that the strain upon the metal of a piece of ordnance increases with the angle of elevation at which it is fired; this may be accounted for in two ways. First—when the axis of a gun is horizontal, the gas in moving the shot has merely to overcome the friction between it and the bore; but when the axis has elevation, the shot must be raised as well as propelled, and the additional resistance doubtless gives time for a larger portion of the charge to ignite before the projectile moves. Another reason for the strain increasing with the angle of elevation is, that as the angle is greater so the gun is less able to recoil; a part of the work, therefore, which at a low angle would be expended in giving motion to the gun is exerted destructively upon the metal.

19. The amount of metal in a gun must depend upon the *charge*, the *weight* and *form of the projectile*, the *material* used, and the *method of construction.*

In designing a gun it is necessary, in the first place, to endeavour to determine what thickness of metal is required for that part of the gun at the breech surrounding the charge, for it is here where the greatest strain from the explosion of the charge will be exerted. No precise rules can be laid down for the regulation of this thickness in various kinds of ordnance, as so much depends upon the physical properties of the material used; the general results of experience, or of experiments carried on for the purpose of establishing this point, can alone furnish us with the requisite data.[8]

The following Table gives the weight of metal in the gun to the weight of projectile, and the ratio of the weights of charge and projectile in different classes of cast *smooth-bored* ordnance.

[7] See Mallet's work *On the Physical Conditions involved in the Construction of Artillery*, p. 3.

[8] Certain rules adhered to formerly in casting smooth-bored ordnance are given in the first edition of this work, p. 18.

Nature of gun		Weight of metal in gun to 1 lb. of projectile	Ratio of weights of charge and projectile
		cwt.	
Bronze (smooth-bored)	guns (medium)	About $1\frac{1}{2}$	$\frac{1}{3}$ [9]
	,, (light)	,, 1	$\frac{1}{4}$
	howitzers	,, $\frac{6}{7}$	$\frac{1}{7}$ to $\frac{1}{6}$
Cast iron (smooth-bored)	shot guns	From $1\frac{3}{4}$ to 4	$\frac{1}{3}$
	shell ,,	,, 1 ,, $1\frac{1}{3}$	$\frac{1}{7}$ to $\frac{1}{6}$
	howitzers	Rather less than $\frac{1}{2}$	$\frac{1}{12}$
	carronades	,, more ,, $\frac{1}{2}$	$\frac{1}{12}$
	mortars, SS	About $\frac{1}{2}$	$\frac{1}{10}$
	,, LS	From $\frac{1}{6}$ to $\frac{1}{5}$	$\frac{1}{24}$ to $\frac{1}{22}$

In the *built-up* guns which are made of wrought iron, or of wrought iron over a steel tube, the proportion of metal to projectile varies very much, and it is difficult to deduce from their respective weights any general rules; the following are roughly the proportions in the different pieces.

In BL. R. guns from $\frac{1}{2}$ to 1 cwt. of metal to 1 lb. of projectile, with charges of $\frac{1}{8}$ the latter.

In the heavy ML. R. guns—rather over 1 cwt. of metal to 1 lb. of projectile in the 7-inch guns, but the proportion decreases with the calibre till in the 12-inch (25 tons) it is only about $\frac{3}{4}$ cwt.; in the 12-inch of 35 tons the proportion is, however, 1 cwt. to 1 lb. of projectile. Service charges vary from $\frac{1}{10}$ to $\frac{1}{8}$ of the projectile, the battering charges from nearly $\frac{1}{5}$ for the 7-inch to rather over $\frac{1}{10}$ for the 12-inch gun.

20. The trunnions are placed on a gun so as to allow the requisite preponderance to the piece, but they are cast on to the breech of a mortar (fig. 31), this being a convenient position as regards the mounting of the mortar on its bed for firing at high angles.

The trunnions should be of equal diameter, and have one common axis perpendicular to that of the gun; they are usually about one calibre in diameter and length.

In the smooth-bored guns of the service, the axis of the trunnions is placed below that of the piece, which causes the impulse exerted upon the elevating screw, and the destructive effect upon the carriage from the discharge of the piece, to be much greater than if it were placed in the same plane with the

[9] Charge of 9-pr. decreased to $2\frac{1}{2}$ lbs., when windage was reduced.

axis of the piece; this will be fully explained when considering the effect of the discharge of a gun upon its carriage.

Various reasons have been given for thus placing the axis of the trunnions below that of the piece, among others the following:—that the trunnions are strengthened by being placed in this manner; that the gun can be laid more readily by means of the quarter sight; and that the recoil of the gun-carriage is lessened: these reasons would scarcely be considered of much importance at the present day. In America, France, and several other countries, the axis of the trunnions is placed in that of the piece, and it was proposed[1] to do the same in cast guns for the service; the axis of the trunnions of the ordnance now made passes through that of the piece.

21. In determining the best position for the vent of a piece of ordnance, the chief points to consider are—the effect of igniting the cartridge in different places, both as regards the strain upon the metal of the piece, and the velocity imparted to the projectile; to diminish the former the vent should be near the end of the cartridge at the bottom of the bore, but for high velocity it should be further forward, about the middle of the cartridge; the reasons for these effects will be explained in the first Chapter on Gunnery.

The vent is slightly inclined to the rear in smooth-bored cast guns, and enters the bore very near the bottom; the vents of heavy built-up guns are now bored vertically or inclined to right or left, and in 'such a position as to strike the cartridge at *four-tenths of its length* from the bottom of the bore, it having been ascertained by experiment that the ignition of the cartridge at about this point realizes the greatest projectile force which can be produced by a given charge.'[2]

Formerly the vent was simply drilled through the metal of the gun, but copper bouches have been in use for many years. The copper bouch is, as before said, screwed into the piece, but as the metal of the latter is liable to be fissured round the bottom of the bouch from the gas penetrating between it and the bouch, the lower portion of the copper is coned (see Figs.

[1] By Colonel (now Major-General) Eardly-Wilmot, R.A.
[2] W. O. Circular, Oct. 3, 1864, § 900.

36, 37) so that when it is screwed well home a perfectly tight fit is obtained. All guns in the service have *coned* bouches (or *vents* as they are generally now termed) except the screw BL. and the Palliser converted pieces. The BL. guns have one plain length of copper, which is secured by another piece screwed in over it; the vents of the wedge guns have a bottom piece of copper, which is coned the reverse way, that is with the larger end downwards. The Palliser converted guns have what are termed *through vents* which are screwed in but have no cone, the bottom being set up into a recess to seal the junction of the copper and iron.

Steel vents lined with copper, and both with and without platinum tips, were tried for ML. R. 10-inch guns, but not proving satisfactory, they were abandoned. In guns of 18 tons and over, the threads of the bouch extend only to 6 inches above the cone; and the vent is inclined at an angle of 45° to the axis, on the right side in land service and broadside, and on the left in turret guns, so that it may be more readily served than if it were vertical.[3]

[3] List of Changes, § 1688.

CHAPTER II.

SYSTEMS OF RIFLING.

1. Objects of rifling.—2. Systems of rifling.—3. First class.—4. Second class.—5. Third class.—6. Fourth class.—7. Centering the projectile.—8. Conditions to be fulfilled in a system of rifling.—9. Relative advantages and disadvantages of breech and muzzle-loading ordnance.

1. It may be as well, before describing the service ordnance, to make a few observations on the different methods or systems of rifling as applied to ordnance.

The objects of *rifling* a gun are—to increase its accuracy of fire, and, by enabling elongated to be substituted for spherical projectiles, to obtain from it longer ranges.

To ensure accuracy of fire, a rotatory motion should be given to the projectile round an axis parallel to or coincident with that of the bore; the axis of the shot should be stable on leaving the bore; and the velocity of rotation imparted to the projectile should be sufficient to counteract the pressure of the air tending to turn the shot over or render it unsteady in flight. The principles of gunnery upon which these conditions are based will be explained in their proper place.

2. Much confusion of idea prevails as to the meaning of the term *system of rifling*, as applied to guns, inventors often claiming principles which are as applicable to one as to another system. It may then be as well to point out, that the *system of rifling* consists essentially in the *means of giving rotation to the projectile*, but that the twist of the grooves, the length, diameter, or form of the projectile, must depend upon the purpose for which a gun is required, no matter upon what system it may be rifled. As regards precision of fire, one system will give as good results for all practical purposes as another, provided the conditions of charge, projectile, and twist of grooves

are alike, and the rifling of the bore and the manufacture of the projectiles have been performed with the same amount of care and skill in both cases.

Great numbers of rifled guns with projectiles to correspond have been proposed, but most of the *systems* of rifling that have been adopted by any service, or tried on the practice ground, may be divided into the following classes :—

(1) Muzzle or breech-loading guns, having projectiles of hard metal, fitting the peculiar form of the bore mechanically.

(2) Muzzle or breech-loading guns, with projectiles having soft metal studs or ribs to fit the grooves.

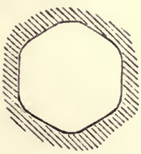
(3) Muzzle-loading guns with projectiles, having a soft metal envelope or cup, which is *expanded* by the gas in the bore.

(4) Breech-loading guns, with projectiles having a soft metal coating larger in diameter than the bore, but which is *compressed* by the gas into the form of the bore.

3. Of the First Class, the *Whitworth* and *Lancaster* guns may be taken as types.

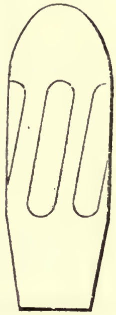
The *Whitworth* gun has a hexagonal spiral bore, the corners of which are rounded off (Fig. 10). The form of the bore is not, however, strictly hexagonal, and has been thus described by Sir J. Whitworth :—'The interior of each gun is first bored out cylindrically, and, when the rifling is completed, a small portion of the original cylindrical bore is retained along the centre of each of the sides of the hexagonal bore, and the other parts of each side recede or incline outwards towards the rounded angles, hence the diameter of the hexagonal bore is greatest at the rounded angles. This description will readily be understood by reference to the diagram (Fig. 12) representing the section of the bore of a 7-in. gun.' The reasons for thus modifying the general form are—to facilitate the loading and thus allow of a reduction of windage, and to ensure, if possible, the bearing of the sides of the projectile on surfaces instead of on mere lines,

Fig. 10.



as would be the tendency with a plain hexagonal bore having windage.

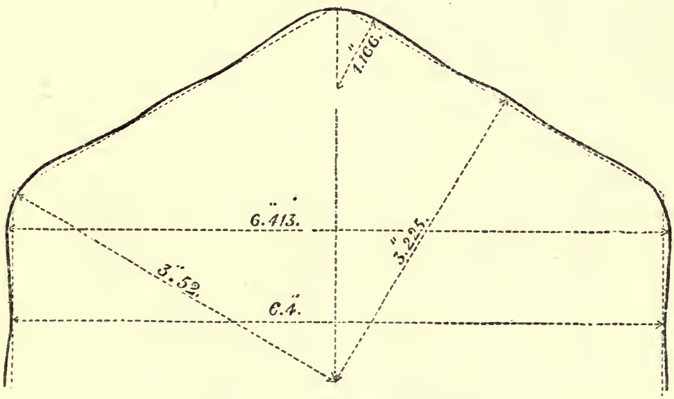
Fig. 11.



The projectile is made of one metal alone, iron or steel, without studs or coating of any kind, and is turned accurately by machinery, to correspond with the bore, except that the sides of the projectile are not inclined outwards, or curved in the middle, but are straight with rounded corners (Fig. 11).

The Whitworth gun with which the first experiments were made was a BL. piece, those afterwards tried against the Armstrong pieces were ML. guns, but recently a BL. gun of novel construction has been fired at Southport with favourable results.[1]

Fig. 12.



Section of Bore of Whitworth 7-inch Gun.

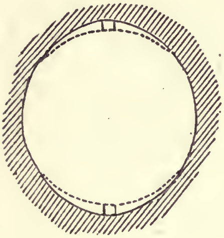
The form of the bore (Fig. 13) of the *Lancaster* gun may be described as a twisted or spiral ellipse; the projectile is similar in shape to the bore, and like the Whitworth is made of only one (hard) metal.[2]

[1] A brief description of this BL. gun will be found in *Naval Science*, No. 1, and in Chap. IV. Part I. of this work.

[2] It is necessary to state here that the Lancaster guns employed in the Crimea were merely service cast-iron pieced rifled on Mr. Lancaster's principle; one strengthened at the chase and muzzle with wrought iron, was fired a great number of rounds at Shoeburyness without injury. The jamming of the shot no doubt

This has been termed 'the two-grooved rifled gun in disguise,' for if the corners of the groove of such a piece be chamfered away, the bore will become elliptical in form.

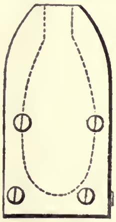
Fig. 13.



The great advantages of either of these systems are — economy, simplicity, and durability of projectile; of the Whitworth—the large bearing surface for the projectile if the windage be small; and of the Lancaster—the absence of grooves which weaken the metal of the gun. The chief objections, that both projectile and bore being hard. fracture of one or other is liable to occur; or if a ML. gun, the loading may be stopped, in consequence of the shot *jamming*, a tendency to which has been shown by both in experiments; and that unless the bore be made of very hard material, it will be rapidly worn by the friction of the projectiles on it.

4. The *French* or the *Woolwich* systems, which are nearly alike, may be taken as examples of the Second Class. There are six spiral grooves in the bore of the French rifled field piece and the projectile has six corresponding rows of zinc studs (Fig 14), two in each row; the sides of the grooves are angular, and there is a peculiarity about them which will be explained further on.[3]

Fig. 14.



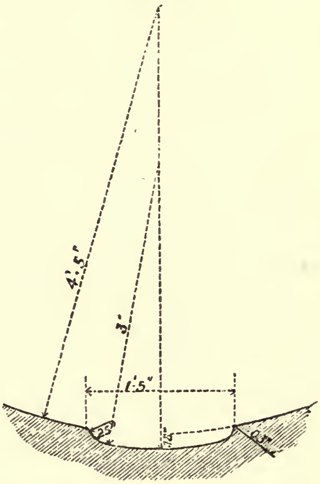
The Woolwich system is applied to the ML. R. service ordnance, but the form of the groove has been modified, so as to *centre* the projectile, in the guns for the field artillery. The grooves in the bore are three or more in number, according to the calibre of the piece, and they have rounded sides (Fig. 15); the projectiles have gun-metal studs, only two in each row, both being equal in size

arose in consequence of the grooves having an *increasing* twist, and the projectiles being made without any *spiral form* to correspond with that of the bore, so that the axis of bore and projectile could neither be coincident nor parallel; the shells were made of wrought iron, for cast iron would not stand. In the Lancaster (experimental) guns now made the grooves have a *uniform* twist, and the shells have a spiral form to fit the bore.

[3] The Austrian bronze rifled guns are muzzle-loading, with what have been

for the projectiles of the 7-inch and lower natures of gun, the grooves of which have a uniform twist; but, for the 8-inch and higher calibres, the top stud in each row is smaller than the bottom stud, so as to allow of the studs accommodating themselves to the varying angle of the grooves, which in these guns have an increasing twist. The number of rows of studs is necessarily equal to the number of grooves in the gun.

Fig. 15.

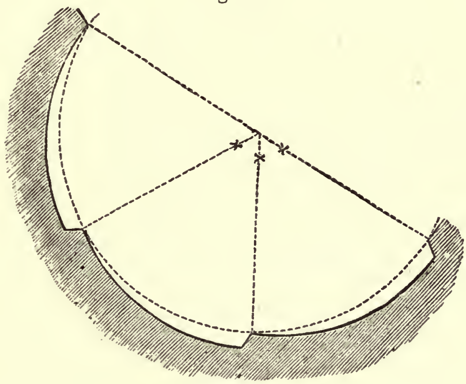


Groove of British ML. R. Gun (9-in.).

In such systems, the studs being soft, the bore is not liable to injury from the shot, if, as should always be the case, the height of the stud is rather greater than the depth of the groove, so that the projectile moves through the bore on the studs alone. On the other hand, the studs cause additional expense in manufacture,

termed *saw-shaped* grooves (fig. 16). The projectiles are coated with tin and zinc, but they have ribs of this soft metal to fit the grooves. The system may there-

Fig. 16.



Groove of Austrian Field Guns.

fore be said to belong to the second class, with the soft coating to prevent wear of the bore.

give but small bearing surface, and they are liable to injury in transport or store; the latter can be prevented by slightly hardening the studs, as with those of the projectiles for the heavy service rifled ordnance. With these systems, or with those in the first class, as there is windage, the gas will force its way over the top of the shot, and, with large charges of quick burning powder, injure the bore above by *scoring*, which however, may be lessened to some extent by placing a wad of proper material between the cartridge and the base of the projectile. The windage will also cause, according to its amount, more or less unsteadiness in the axis of the projectile at starting, unless some effectual method of *centering* be adopted. If the projectile be provided with ribs instead of studs, a greater bearing surface is obtained; but, to prevent injury to the grooves, the ribs must be faced with soft metal on the driving side, as were those of Capt. Scott's projectiles.[4]

5. Mr. Britten's system may be taken as an instance of the Third Class. The gun has five shallow grooves (Fig. 17), and

Fig. 17.

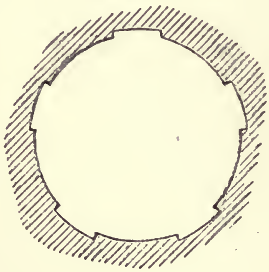
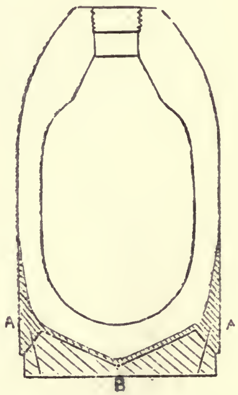


Fig. 18.



the projectile is *expanding*, being made of iron, but having a lead envelope (A) and a wooden sabot (B), (Fig. 18).

[4] Commander W. Dawson, R.N., in a paper read at the R. U. S. Institution, on *Naval Guns*, February 19, 1872, criticises severely the Woolwich system of rifling, and condemns the *gaining twist*, which, however, is no part of the system, and is only applied to the grooves of guns over 7 inches in calibre. He objects to the depth and width of the grooves, causing so much erosion and weakening the

The shell loads easily, being less in diameter than the bore, but when the gun is fired, the gas drives the sabot against the envelope and expands the lead into the grooves, so that the shot acquires a rotatory motion.[5]

Both the Northern and Confederate States, in the late American War, rifled their ordnance chiefly on the expansion system. The projectiles of the Parrott guns (Fig. 19), of which

Fig. 19.

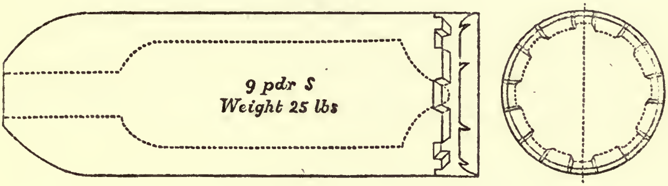
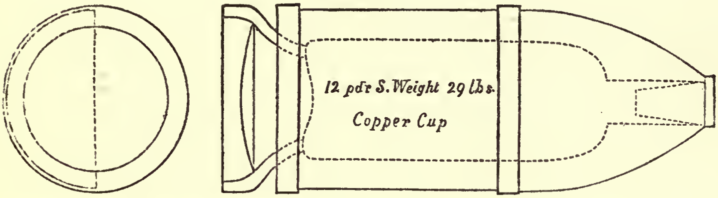


Fig. 20.



most of the rifled ordnance of the North consisted, have a brass ring fitted on to the base, round which are projections radiating towards, but not extending to, the centre, to prevent the ring turning round without the shot.

metal of the gun; to the absence of *centering*, causing wear of the bore and unsteadiness in the axis of projectile on leaving; to the studs being incapable of standing a more rapid twist requisite to give long projectiles sufficient rotation. Capt. Scott's system would, as Commander Dawson took pains to prove, bear favourable comparison to the Woolwich (in the large guns) in some respects. He is, however, wrong in stating that the increasing spiral was abandoned for the 7-inch gun, as it was never adopted for that piece; and he is hardly just in attributing the publication of the 'Extracts of Artillery Proceedings' to a desire to keep officers ignorant. The information they contain is often valuable, although not necessarily complete. Before their publication it was most difficult for an officer not specially employed to obtain any of the results of experimental practice.

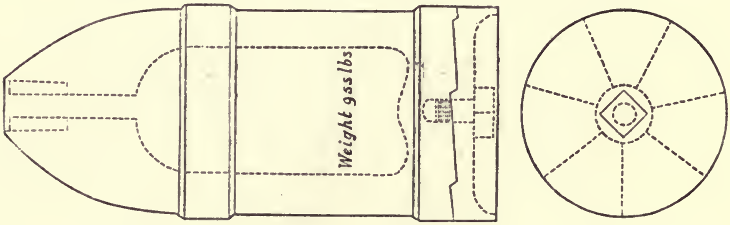
[5] Mr. Britten now substitutes for the wooden *sabot* an iron *shoe-piece* which is soldered to the soft metal envelope; it is not liable, like the *sabot*, to partial separation, and serves to protect the soft metal.—*Heavy Rifled Ordnance.* By B. Britten, p. 134.

In the Reed system, used by the Confederates for siege and field guns, the projectiles (Fig. 20) had an expanding ring or cup on the base of iron, copper, or lead, but not of brass.

Another Southern system (Fig. 21), which gave good results, and was largely used for Brooke's 7-inch guns, consisted in attaching to the base a copper-cupped plate termed a *ratchet-sabot*, which was firmly held in its place by radial grooves.[6]

The advantages of such systems are—that the axis of the projectile will be steady in passing through the bore, and that the latter will suffer neither from the contact of hard metal, nor from the rush of gas over the shot. Besides being more or less expensive, these systems are open to the following objec-

Fig. 21.



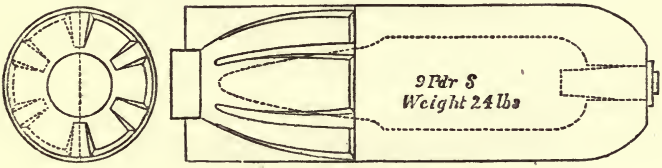
tions. They will rarely stand high charges; the windage being stopped up, the strain is increased, and an ordinary time fuze will not always be lighted by the flame from the charge of the gun; liability of advanced troops to injury from fragments of the sabot; this latter might not probably apply to Britten's system, the lead being soldered to the iron and not merely cast on it.

Other substances than metal have been tried for the sabot. As long ago as 1856, General Timmerhaus, of the Belgian service, proposed a paper sabot, and, in the *Schenkel* system employed by the North, the projectile (Fig. 22) received rotation in the same way by an expanding sabot of papier-mâché. The *Mackay* gun also belongs to this class. The bore has a large

[6] A description of the different systems employed in the late American War will be found in a Paper on Siege Artillery. By Brigadier-General R. J. Abbott, U.S.A.

number of grooves with a very sharp twist, and the projectile is reduced in diameter at the base; a quantity of sawdust is placed between the cartridge and the shot, so that, being forced

Fig. 22.

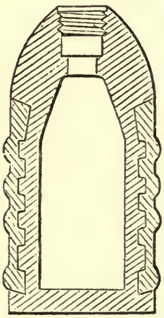


into the grooves and jammed on to the shot, the latter receives rotation.

6. The Armstrong and Prussian breech-loading systems may be taken as examples of the Fourth Class.

The Armstrong BL. gun will be described in detail in the proper place; it will, therefore, be sufficient to say here, that it has a polygroove bore with two chambers at the bottom, one for the charge and the other for the projectile, which has a coating of lead attached by zinc solder,[7] and is larger in diameter than the bore; the gas has, therefore, to compress the coating into the grooves before the shot can move.

Fig. 23.



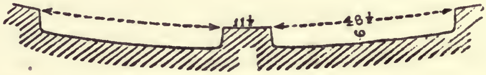
The projectile for the Prussian BL. gun is cast with undercut projecting rings round the body, and the lead coating is cast over and between them, the mould giving to the outer surface of the lead a number of grooves, to allow space for its being drawn down in passing through the bore (Fig. 23); the attachment of the lead by zinc solder has, however, been lately adopted. The grooves are wider at the bottom of the bore than at the muzzle, so that the compression of the lead is gradual (Fig. 24). The chief advantages of these systems are, that the wear of the bore from rush of gas over the shot, or from any irregular movement of the latter, is prevented, and

[7] As proposed by Mr. B. Britten.

that the axis of the projectile must be steady on leaving the bore. The objections are, that on account of the absence of

Fig. 24. Groove of Prussian Gun.

Section at Muzzle.



Section at Shot Chamber.

windage and of the requisite compression of the projectile, the strain caused by a given charge will be proportionally very great; that no flame from the charge can pass the shell to light its fuze, thus entailing the necessity of some percussion arrangement; and that the ammunition is expensive.

7. It has been pointed out that steadiness of the axis of a projectile in the bore is one condition of accuracy of fire, and it is evident that it must also prevent, or at any rate decrease, the wear of the metal of the bore; in some systems of rifling, as in those of the Third and Fourth Classes, stability of axis is obtained, if the guns and projectiles are properly constructed. In a gun having windage there may be an irregular rotatory motion of the axis of the shot, but in order to ensure stability in such a case, several devices have been adopted to what is termed *centre* the projectile,[8] or cause it to fit the bore tightly on leaving it, so that the accuracy of fire may be improved and the wear of the bore decreased. In the Armstrong shunt system, which may be thus described, the projectile is *centered.*

It may be seen from the form of groove as shown in Figs. 25, 26, and 27, that its depth on one side near the muzzle is decreased, and that an incline leads up from the bottom of the groove to the *high level* portion or shallower part, and it may also be observed that the groove is very wide at the muzzle,

[8] General Didion claims to have first proposed the *centering* of a shot in the bore of a rifled gun as far back as 1850. See *Traité de Balistique*, p. 425.

but that it is contracted at E (Fig. 25) some distance down the bore, below the bottom of the incline.

Fig. 25.

Groove of Shunt Gun.

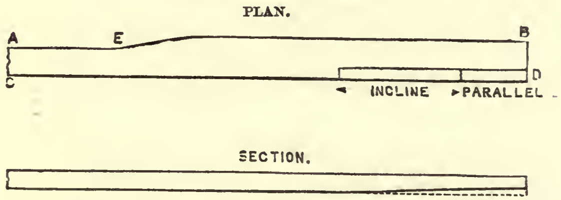
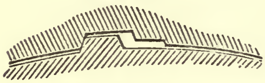
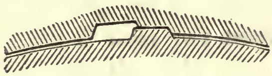


Fig. 26.



Shot going in.

Fig. 27.



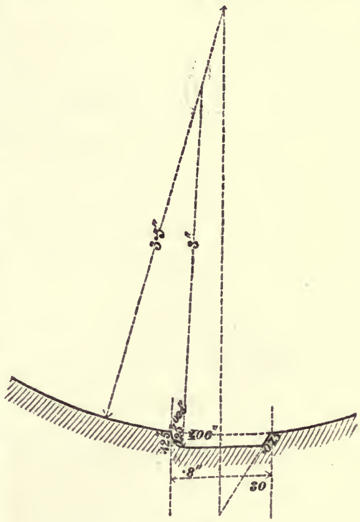
Shot coming out.

The projectiles first used with the shunt gun had long ribs (soft metal on the driving side), but now copper studs are substituted for the ribs; the studs are of such a size that they fit easily into the broad and deep part of the groove at the muzzle.

When a projectile passes down the bore of a rifled gun from the muzzle, its studs press against one side of the grooves, but on being forced out by the gas they press against the other side (Figs. 26, 27); when the shunt gun is loaded, each stud presses against the (*loading*) side A B of a groove, and so runs easily home, being *shunted* on its way down into the narrow portion of the groove; but on coming out again it presses against the (*driving*) side C D, and near the muzzle rises up the incline into the shallow part, or on to the *high level*, and so is slightly compressed; the projectile therefore leaves the bore fitting tightly, and with its axis stable. It has been objected to this method, that the projectile is not *centered* till it has passed through the greater part of the bore, and not until it has attained about its maximum velocity; that the angular edges of the grooves are liable to split, and that the studs, from their small bearing surfaces, are liable to override the grooves.

In the rifled gun of Capt. Scott, R.N. (Fig. 28), with which good results were obtained in 1863, 1865, the groove is adapted to centre the projectile; the depth of the groove is less on the *loading* than on the *driving* side, and the latter is curved so as to allow the stud to rise up it when the projectile moves forward.

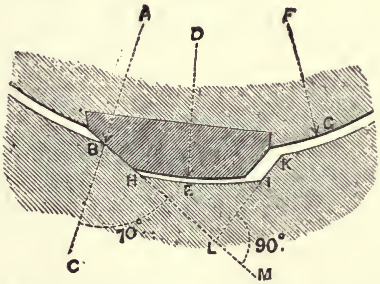
Fig. 28.



Groove of Scott's ML. R. Gun.

The French, in their bronze rifled guns, give a less inclination to the driving than to the loading side of the groove, so that when the shell is forced by the gas through the bore towards the muzzle, the studs rise up the *driving* sides of the grooves, and the projectile is thus *centered* (Fig. 29).[9] The same principle has been carried out in the bronze guns adopted for Indian service,[1] also in the ML.R. 9- and 16-pr. iron pieces, but the lower edges of the grooves are rounded off.

Fig. 29.



Section of Stud and Groove, French Field Rifled Ordnance.

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[9] See Major-General Lefroy's 'Contributions to the Technology of Foreign Rifled Ordnance.'—*Proceedings R. A. Institution*, vol. iv. p. 343.

[1] Both initial velocity and uniformity of range were increased by the adoption of the centering grove.—*Report of Committee on Field Artillery Equipment for India*, p. xii.

8. The conditions that are especially desirable in a *system of rifling* for ordnance are —

(1) Accuracy of fire.

(2) Simplicity and durability in both projectile and gun.

(3) Non-liability of projectile to jam in the bore in loading or firing.

(4) The means adopted for giving rotation must not cause too great strain.

And, for heavy ordnance, it must allow of the use of large charges.

It may be observed that in many of the systems of rifling in use, one or more of these conditions have been sacrificed to some extent, doubtless to secure a closer compliance with others thought to be of greater importance or of easier attainment.

9. Before closing these remarks on the different systems of rifling, it may be as well to say a few words on the respective advantages and disadvantages of muzzle- and breech-loading rifled ordnance.

Various opinions are held as to the relative advantages of breech- and muzzle-loading ordnance, but the latter would appear to be the best adapted to general service, as they are stronger for equal weights of metal and simpler in construction. The advantages of loading cannon at the breech are:— That a projectile of larger diameter than the bore can be used, and its axis will consequently be stable, and the fire be accurate; that with the soft coating and no windage the bore will not suffer from *scoring* or irregular motion of the projectile through it;[2] that the gun can be loaded when run up, the gunners being, therefore, less exposed; that the gun can be worked in a smaller space (than a ML. piece); the cleaning of the bore can be more readily effected, and any ignited substance left in the bore can be seen and removed; also there is no danger of the shot not being *home.*

[2] Some BL. R. guns, as for instance the heavy Naval French ordnance which fire studded projectiles with windage, would be just as liable to wear of bore as a ML. R. gun fired under the same conditions.

Breech-loading is, however, attended with the following disadvantages, viz., that the construction is more complicated than that of a muzzle-loading piece, and skilled labour is requisite to keep it serviceable; that both gun and ammunition are more costly; that if the gun be of large calibre, the breech-loading apparatus, when sufficiently strong and heavy, will be unwieldy; that with the same weight of metal the breech-loading is a weaker and less enduring construction than the muzzle-loading: also that if soft-coated projectiles larger than the bore be used, the strain is much increased, and, there being no windage, a more complicated and dangerous fuze is necessary.

On the other hand, a muzzle-loading gun has a simpler, less costly, and stronger construction, which requires no peculiar care to keep it in working order; the ammunition is less costly; and a simple fuze without percussion arrangement can be used. The bore is, however, liable to injury from scoring, and from the irregular motion of the projectile if it be not centered; and in the latter case there would also be a tendency to impair the accuracy of fire; the gun detachment is more exposed than that of a BL. gun,[3] and if loaded carelessly the shot may not be rammed *home*, thus causing difficulty and delay in the practice.

[3] If the ports or embrasures be protected by iron and very much reduced in size, or if the gun were mounted on a Moncrieff carriage, this disadvantage would not be experienced.

CHAPTER III.

SMOOTH-BORED ORDNANCE.

1. Classification of ordnance.—2. Classification of SB. guns.—3. Cast-iron shot guns.—4. Cast-iron shell guns.—5. Bronze guns.—6. Built-up smooth-bored guns. —7. Mortars.—8. Cast-iron mortars.—9. Bronze mortars.—10. Howitzers.— 11. Cast-iron howitzers.—12. Bronze howitzers.—13. Carronades.

1. ALL ordnance employed in the service may be divided into three classes, viz.,

Guns, mortars, and howitzers.

Carronades are nearly obsolete, although a certain number are still supplied to the navy, and a few will be found mounted in some garrisons and coast batteries. Ordnance may also be divided into *smooth-bored* and *rifled*, and the latter into *muzzle-loading* and *breech-loading*.

2. Guns are used for projecting shot and shell, horizontally, or at very low angles, and as they are fired with large charges of powder, which are fixed for each nature of gun, very great strength and considerable weight are required in their construction.

Smooth-bored guns are of two kinds, viz. (solid) shot guns and shell guns. The former (Fig. 1.) from which both shot and shell are projected are, whether of cast or wrought iron or other metal, distinguished by the weight of the solid (cast-iron) shot and the weight of the gun, thus [1] :—

'68-pr. cast-iron gun of 95 cwt.'

Smooth-bored shell guns from which solid shot cannot be fired are designated by the calibre in inches and the weight of the piece, thus :—

'10-in. cast-iron gun of 87 cwt.'

[1] War Office Circular, Oct. 3, 1864, Art. 899.

Some guns have been classed as heavy, medium, and light, but these terms apply in but few cases.

3. The different natures of cast-iron shot guns are—6, 9, 12, 18, 24, 32, 42, and 68-prs.; the 6, 9, and 12-prs. may be considered obsolete, although a few are still mounted in some garrisons for saluting purposes.[2]

68-pr. There are two 68-prs. in the service—

68-pr. of 112 cwt.
do. „ 95 „

The first was intended exclusively for land service, being considered too heavy for naval armaments. The second, which also gives long range and accuracy for a SB. piece, was used either as a pivot gun for steamers and men-of-war, or for coast batteries.

42-pr. The 42-prs., of which there are two descriptions, of 84 and 67 cwt. respectively, varying considerably in weight,

[2] 56-prs. have been withdrawn from the service. A certain number of cast-iron guns in the service were re-bored to a calibre greater than that with which they were originally cast. 'The practice of *reaming-out* guns, or boring them up, first took place in the British Service in the year 1830, when about 800 guns, 24-prs. 7 feet 6 inches long, which had been made according to the construction recommended by Sir W. Congreve, and about as many more guns, also 24-prs., of Sir T. Blomefield's construction, were bored up to 32-prs. for the navy. The practice was afterwards extended to iron guns of all natures, from the 9-pr. to the 32-pr. inclusive, by enlarging the bore of each to the next and, in some cases, to the second higher calibre, and leaving reduced windages. This may be considered as a temporary expedient to increase the weight of metal projected from such guns as were then on hand in this country, at a time when the advantages of large calibred ordnance were not absolutely decided on, and when the Government was not prepared to sanction the expense of casting new guns for projecting the heavier natures of shot and shell.' (Sir H. Douglas's *Naval Gunnery*, p. 165.) Sir W. Congreve proposed a 24-pr. gun of conical form in 1813, which had a much greater thickness of metal at the breech than those of the old construction; the extra thickness was by him supposed to give a re-acting power to the gun, which, however, is an erroneous idea, not supported by facts. He assumed, 'That the propelling or re-acting power of a piece of ordnance may be increased by augmenting the quantity of metal about the charge, though a greater quantity be taken from other parts; and, consequently, that a lighter gun may have a greater propelling power than a heavier one, by a judicious distribution of metal.'

Mr. Monk of the Royal Arsenal proposed to increase the thickness of metal of guns at the breech, and diminish it in the chase, without however adding to the amount of metal in the piece; some 56-pr. guns were cast in 1838 upon his principle, and 32-prs. afterwards. Col. Dundas introduced guns of somewhat similar form to those of Monk, but not so conical, having a greater thickness of metal in the 1st and 2nd reinforces.

were intended for the navy. The lighter 42-prs. have been put into block ships, for the defence of the dockyards.

32-pr. Guns of this nature are in general use in the land and naval services; there are no fewer than eleven descriptions of 32-prs., varying in length and weight to suit the different classes of vessels for which they have been introduced from time to time. The following are generally employed for land and naval service, viz.:—

Dundas'	. .	32-pr. of	58	cwt. (Fig. 1.)
Blomefield's	. .	do.	56	,,
Monk's	. A	do.	50	,,
do.	. B	do.	45	,,
do.	. C	do.	42	,,

Those of 58 and 56 cwt. are used in fortresses and coast batteries; the A gun of 50 cwt. was sent to the East in 1855, as a siege gun, and in many respects was a more useful gun than the 24-pr. of 50 cwt. for siege equipments, being equal to it in point of range, with similar weight of metal, but having the advantage of increased calibre; in addition to which, ammunition could on an emergency be supplied for this gun by the navy, when carrying on joint operations. No piece of a lower calibre than a 32-pr. is used by the navy as a broadside gun.

24-pr. There are four different kinds of 24-prs. in the service; they have generally been used in fortresses and coast batteries, and as siege guns.

18-pr. There are four different kinds of 18-prs., two of which are bored up from smaller calibres. They were formerly used as siege guns, but latterly that weighing 38 cwt. has been considered a gun of position, and was employed for that purpose in the Crimea and India. 18-prs. are also used as pivot guns for small steamers.

12, 9, and 6-prs. There are two patterns of 12-prs., two of 9-prs., and one 6-pr. still in the service, but when mounted would rarely be used except for saluting.

4. Cast-iron shell-guns, which are merely long howitzers, were

introduced for naval service;[3] the advantage gained by using such pieces was, that large projectiles (shells of great diameter and capacity) could be fired from comparatively light guns. There are two different natures of shell-guns in the service, viz. the 10- and 8-inch: a certain number of them are associated with the usual armament of vessels of war, the weight of gun depending upon the class of vessel; these guns are also employed in fortresses, coast batteries, &c.

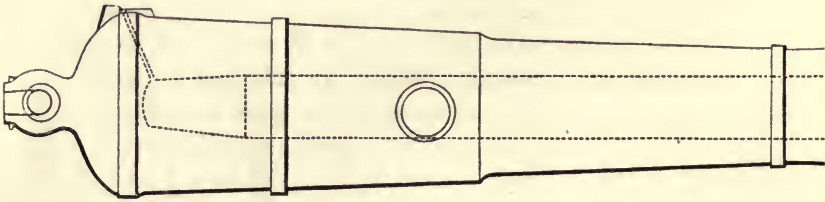
10-inch. There is now only one 10-inch gun in the service, which weighs 86 cwt.

8-inch. There are three different 8-inch guns, but those generally used are the

8-inch gun of 65 cwt.
do. 54 „ (formerly called 52-cwt. gun.)

The latter was associated with the 24-pr. of 50 cwt. in the first siege trains sent to the East, in 1854. This gun (by order

Fig. 30.



Cast-iron SB. 8-inch Shell Gun (54 cwt.).

dated Nov. 28, 1859) is the most suitable piece for the armament of caponnières and flanks of works (Fig. 30).

5. Bronze guns, of which there are four different natures, viz. 12, 9, 6, and 3-prs., were, on account of their comparative lightness, suitable for field purposes. These pieces were associated with bronze howitzers of nearly equal weights respectively, there being four guns to two howitzers in a battery.

[3] The 10-in. gun was first cast in this country in 1824, the 8-in. in 1825. (Sir H. Douglas, *Naval Gunnery*, p. 184, and Major (now Lt.-Col.) Miller's *Equipment of Artillery*, p. 293). General Miller, R.A., has had the credit of their introduction into our service, but the proper use of shell-guns was first pointed out by General Paixhans, in his *Nouvelle Force Maritime*, published in 1822, and they were adopted by the French before 1824.

12-pr. gun	accompanied	32-pr.	howitzer	in a heavy battery.
9-pr. do.	do.	24-pr.	do.	in a horse artillery or field battery.
6-pr. do.	do.	12-pr.	do.	in a horse artillery battery.
3-pr. do.	do.	$4\frac{2}{5}$-inch	do.	for mountain service.

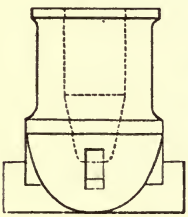
6. There are two natures of heavy built-up smooth-bored guns in the service, the 150- and the 100-pr. The principles of construction and general arrangement of the different portions are similar to those of the heavy built-up rifled ordnance.

The 150-pr. weighing 240 cwt. is made entirely of wrought iron. The 100-pr. of 125 cwt. is constructed of wrought iron except the bore, which is a steel casting: in both guns the cascable is screwed into the breech-piece.

These powerful smooth-bored guns are intended for naval service and are provided with a proportion of steel projectiles to fire against ironclad vessels.

7. Mortars are short pieces of ordnance, used to throw shells at high angles (vertical fire), generally 45°, the charge varying with the range required; they are distinguished by the diameters of their bores. Mortars are made of cast iron or bronze; the former being principally intended for garrisons, battering trains, the navy, &c., and the latter, which are of small calibre, and very light, are chiefly employed in sieges (Fig. 31).

Fig. 31.



Cast-iron SB. 8-in. Mortar (L. S.)

8. The cast-iron mortars for land service are,

13-inch	of 36	cwt.
10	,, 18	,,
8	,, 9	,,

For sea service,[4]

13	,, 100	,, (two patterns)
10	,, 52	,,

These mortars are found most effective in the bombardment of towns, forts, or works of any kind, the shells from them

[4] There are a few 13-inch SS. mortars of 81 cwt.

possessing great penetration, in consequence of the high angles at which they are fired; also, the large body of flame liberated on the explosion of these shells will frequently ignite any combustible material near which they fall, setting fire to buildings, endangering the safety of powder magazines, and creating the most terrible moral effect, especially from the fact of ordinary parapets affording no secure protection against the nearly vertical descent of the shells.

9. The bronze mortars are

$5\frac{1}{2}$-inch, royal of $1\frac{1}{4}$ cwt.
$4\frac{2}{5}$,, coehorn $\frac{3}{4}$,,

They are very useful in the advanced trenches in the attack of fortified places, as they can be moved with great facility to different parts of them, if required; they are not generally placed in batteries, the trenches affording sufficient cover for them against the enemy's fire. These mortars are very annoying to the working parties of the attacking army, when fired upon them by the besieged; they will also be found very useful in the attack of intrenched posts, on account of their portability, for which reason they can be employed in situations where it would be impossible to move guns. In India, they have been found very effective in the attack of hill forts, stockades, &c.

The French and some other Continental nations use bronze for mortars of large calibre.

10. Howitzers resemble guns in form, but are much shorter and lighter in proportion to their calibre, and are, consequently, fired with smaller charges of powder; shells and case are fired from them, but not solid shot.

These pieces were originally introduced for the purpose of firing shells at low angles, and have constantly been found most useful both in the field and in siege operations during the wars of the last and present centuries. Since, however, the introduction of shell guns [5] their utility has greatly de-

[5] Light shell-guns were used in preference to heavy iron howitzers in the siege of Sebastopol, and the late Emperor Napoleon III. substituted a shell-gun for his field guns and howitzers shortly after his accession to power.

creased, for the shell gun possesses greater accuracy and range than the howitzer, these being in the present day of greater importance than small weight.

They may be divided into two classes, the heavy howitzers made of cast iron, and the lighter ones of bronze.

11. There are two natures of cast-iron howitzers,[6] viz.

10-inch of 42 cwt.
8 „ 22 „

These howitzers are mounted on travelling carriages, and have been chiefly employed for ricochet fire, but they have been also used as guns of position, in battering trains, garrisons, coast batteries, and in those situations where no great range is required. The great advantage derived from the employment of these pieces was that very large shells could be projected from pieces of small weight capable of being transported with ease; their recoil is, however, very great, and, consequently, the destructive effects upon their carriages (from the recoil), while but short ranges are obtained from them.

12. There are four natures of bronze howitzers, viz.

32-pr. of 17 cwt.
24-pr. „ 13 „
12-pr. „ 6 „
$4\frac{2}{5}$-inch „ $2\frac{1}{2}$ „

associated as already explained with the bronze guns.

13. Carronades are short pieces of ordnance, and have less thickness of metal (cast iron) than guns of the same calibre. They were first introduced by the director of the Carron Foundry, in Scotland, and were brought into the service in 1779. Very excellent practice was made from them on account of their small windage; but this superiority only lasted until the reduction of windage was effected to a certain degree in other guns, when, from their many defects, they were almost rendered obsolete.

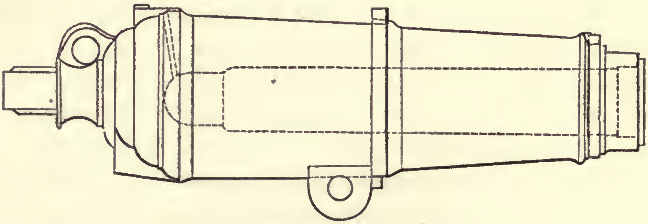
Their peculiar advantages consisted in their capability of projecting shot of large calibre with accuracy to such distances

[6] The 24-pr. or $5\frac{1}{2}$-inch cast-iron howitzer may be considered obsolete.

as vessels of war were supposed to engage at, viz. from 400 to 600 yards, with a great saving of metal, powder, and gun detachment.

These pieces have no trunnions (Fig. 32), and are cast with a loop underneath, a bolt passing through which attaches them to their carriages. They have no swell at the muzzle, but an enlargement of the bore, or cup, to facilitate the putting in of the shot, and to save the rigging and hammock nettings on board ship. They have a sight on the reinforce ring, and their chambers are cylindrical, the charge being one-twelfth the

Fig. 32.



Cast-iron SB. 68-pr. Carronade.

shot's weight. They are very unsteady in their recoil, owing to their lightness, and the position of the loop.

Carronades have been constructed of all calibres, from the 6-pr. to the 68-pr., with the exception of the 56-pr. Four natures are retained in the service, 68, 42, 32, and 24-prs.

CHAPTER IV.

RIFLED ORDNANCE.

BL. R. Ordnance: 1. Classification of BL. R. guns.—2. System of rifling in screw and wedge BL. guns.—3. Screw BL. rifled gun.—4. Different natures of screw BL. rifled guns.—5. Wedge BL. rifled guns. ML. R. Ordnance: 6. Different constructions and natures of heavy ML. R. ordnance.—7. Different natures of ML. R. 80, 64 and 40-pr. guns.—8. ML. R. 8-inch howitzer.—9. Light ML. R. guns.

Breech-loading Rifled Ordnance.

1. In the service BL. rifled guns[1] there are two different ways of closing the breech, both designed by Sir W. Armstrong; these guns must therefore be separated into two classes, viz.

Screw BL. rifled guns.
Wedge do. do.

The *calibre* of a rifled gun is measured across the *lands*.

All rifled guns of 7-in. calibre and upwards are designated by the calibre and weight, it being also stated whether they are breech-loading or muzzle-loading,[2] thus,—

7-in. ML. gun of 7 tons, R.

Rifled guns of less than 7-in. calibre are distinguished by the weight of the projectile and weight of gun, thus,—

40-pr. BL. gun of 35 cwt. R.

The screw BL. system, one of the first adopted and used in war, is very inferior to many others, both as regards strength of construction and facility of working, besides its greater complication. Krupp's single cylindrical or round-backed

[1] For the BL. guns used in other services see Appendix II.
[2] War Office Circular, Oct. 3, 1864.

wedge, described in the Appendix, would appear to be one of the best.[3]

2. Both screw and wedge BL. guns are rifled on the same *system*, which may be briefly described as follows. The projectile is coated with lead and is larger in diameter than the bore of the piece; at the lower end of the bore the diameter is enlarged to form a *shot chamber* (*b*), (Fig. 33), and behind this is a *powder chamber* (*a*) which is not rifled and has a diameter rather larger than that across the bottom of the grooves of the bore. The bore is also very slightly enlarged to within about a calibre in front of the shot chamber, the intervening portion, which has a less diameter than any other part of the bore, being termed the *grip* (*c*): the diameter of this *grip* is the *calibre* of the gun. In the bores of these BL. guns there are a great number of narrow grooves, separated by lands of rather less width. The respective widths of lands and grooves being nearly the same for all natures of these BL. guns, the number of grooves increases with the calibre.

In loading either screw or wedge guns, the projectile and cartridge are inserted through the breech into their respective chambers, and the force of the explosion drives the projectile through the bore, compressing its soft coating into the grooves, and so imparting a rotatory motion.

3. The principal parts of a screw BL. Armstrong gun are (Fig. 33):—

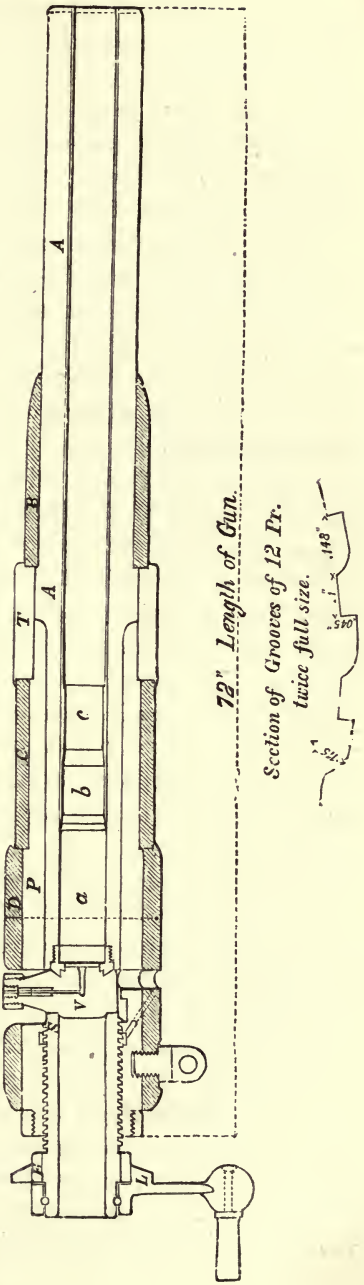
A A Barrel or inner tube.	*V* Vent-piece.
P Breech-piece.	*S* Breech-screw.
T Trunnion-ring.	*E* Tappet-ring.
B, C, D Coils.	*L* Lever-ring.

[3] Sir J. Whitworth's new BL. R. gun is described in *Naval Science*, No. 1, and an account of its performance at Southport, in Oct., 1872, was inserted in the *Times* of the 10th Oct. The method of closing the breech is peculiar; a breech-block works at a small inclination in straight-lined threads cut across the projecting breech, and the block is drawn out, to allow of loading, by a rack and pinion with handle behind the breech; the powder chamber is enlarged to hold a high charge ($\frac{1}{4}$), and the windage is only ·01 inch. The gun weighs $8\frac{3}{4}$ cwt., and the projectile 9 lbs.; the calibre is 3 inches, and the charge $2\frac{1}{4}$ lbs. The practice was, as might have been anticipated, very good, and long ranges were obtained, the greatest being 10,320 yards at 40° of elevation, with a $2\frac{3}{4}$-lbs. charge. The strain

In the larger guns there are two or more layers of coils, shrunk one over the other, outside the breech-piece and inner tube.[4]

In the *barrel* are the bore, with the *grip*, the *shot-chamber*, and the *powder chamber;* at the end of the powder-chamber in all guns, except in the 7-inch, is screwed a copper ring (termed the *breech-bouch-copper*), against the outer edge of which the copper facing of the

Fig. 33.
Screw Breech-loading 12-pr.



must have been very great upon the gun, which is made of the Whitworth compressed steel; the small windage would necessitate very great accuracy in manufacture, and much care in the service of the gun.

[4] A *coil* is made by heating a long bar of iron and twisting it round a mandrel; the rough cylinder thus formed is welded, turned, and bored. The length and diameter of a coil, as well as the dimensions of the section of the bar of which it is made, depend upon the nature of gun for which the coil is intended, and on the position of the coil on the gun. The fibre of the metal is disposed by coiling so as to withstand the tangential strain, and therefore to support the barrel all round and prevent its fracture by the force exerted on the interior surface of the bore when the gun is fired.

vent-piece fits and so closes the bottom of the bore. In the 7-inch guns the ring in the powder chamber is of wrought iron.

The barrel has generally been made of wrought-iron coils, but a solid cylinder of steel, which is cast, hammered, turned, bored out, and tempered in oil, has been latterly used for the inner tube of some of the shortened 12-prs. and other natures.

The *breech-piece* is a solid forging of wrought iron; it is bored, turned, and shrunk on to one end of the barrel. The breech-piece of the larger natures is welded to the coil in front of it. A slot or opening is drilled through it and the coil above to admit the vent-piece, and behind the slot a screw is cut in the interior surface of the breech-piece into which the breech-screw fits.

It may be seen from the drawing that the vent-piece is kept against the end of the barrel by the breech-screw, which is supported by the breech-piece, and the latter has therefore to withstand a longitudinal strain, viz. that exerted by the gas against the vent-piece tending to force it backwards. It is for this reason that the breech-piece is not made of coiled iron, but is a solid forging with the fibre of the metal disposed so as to resist longitudinal strain.

The *trunnion-ring* is a solid wrought-iron forging which is turned, bored, and shrunk on to the gun: the fibre of the metal is in the contrary direction to that of the breech-piece.

The *vent-piece* is a small piece of iron or steel (tempered in oil), which, when dropped through the vent slot or opening in the top of the gun to its position, and pressed by the breech-screw tightly against the end of the powder chamber, effectually closes the bottom of the bore.

All the vent-pieces, except that of the 7-inch, are fitted with a copper ring which has an angular face to correspond with that of the copper ring at the end of the powder chamber; the closing of the bore, and therefore the safety of the gun, depends upon the exact fitting together of these two pieces.

The vent-piece contains the vent, which descends vertically until it reaches the prolongation of the axis of the bore, when it turns at right angles and leads into the bore. The upper portion of the vent is bouched with copper in one plain length, with a screwed-in piece about 1 inch in depth at the top of the bouch to secure it.

The vent-piece of the 7-inch guns has no copper facing, and, as there is no copper ring at the bottom of the bore, it is necessary, in order to prevent the escape of gas, to fire this gun with a tin cup placed behind the cartridge. The vent-pieces of the 7-inch guns and 40-prs. have two shackles (handles), those of the 20-prs. and lower natures but one shackle; the shackles are attached to a cross-head which is screwed on to the neck of the vent-piece.

The *breech-screw* is made of steel for 20-prs. and lower natures of gun, of wrought iron or steel for 40-prs., and of wrought iron faced with steel for the 7-inch guns. The breech-screw fits into the thread cut in the breech-piece, and is worked forwards or backwards by the lever and tappet so as to press home or release the vent-piece. It is bored hollow to allow of the charge being passed through in loading the gun; the diameter of the hollow is rather larger than that of the powder chamber. The breech-screw is allowed a certain amount of play in the gun, for if made to fit very accurately it would be liable to become clogged with dirt.

The *tappet-ring* is made of wrought iron, and fits on to the octagonal part of the breech-screw. It has projections called *cams*, against which the lever acts and thus moves the breech-screw backwards or forwards; the 7-inch and 40-pr. tappet-rings have two *cams*, and the other natures but one.

The *lever-ring* is also made of wrought iron, and fits on to the circular part of the breech-screw. It is kept in its place by two split keep pins which work in a groove round the breech-screw. When required, the motion of the lever can be suddenly arrested by the *cams* on the tappet, and thus considerable power obtained to tighten up or release the vent-piece.

The 7-inch guns have a double lever with two handles, the 40-pr. a double lever with one handle, the 20-pr. and lower natures a single lever with a handle.

Indicator rings are fitted to all 7-inch and 40-pr. BL. screw guns; indication is given by plain raised lines of brass.

4. There are six different natures of screw BL. rifled guns, viz. 7-inch, 40, 20, 12, 9, and 6-prs.

7-inch guns. There are two 7-inch guns,—

Heavy 7-inch of 82 cwt.[5]
Light do. 72 „

The first is used for both land and sea service, the second for land service only; they can be used in garrisons, or even as siege guns when adequate transport could be procured, for as their shells contain such large bursting charges they are well adapted for firing at earthworks or masonry. These guns can only be fired with comparatively small charges, and therefore their projectiles would do no injury to ironclad vessels, but their shells would no doubt be most destructive to wooden ships.

40-prs. There are two 40-prs.—

40-pr. G pattern of 35 cwt.
do. old pattern 32 „

These pieces are intended either for land or sea service.[6] For the former they are mounted on travelling carriages, and would be employed either as siege or position guns; they may also be used in fortresses, iron garrison carriages having been constructed for them.

20-prs. There are three guns of this calibre, viz.:—

20-pr. LS. of 16 cwt.
do. SS. „ 15 „
do. SS. „ 13 „

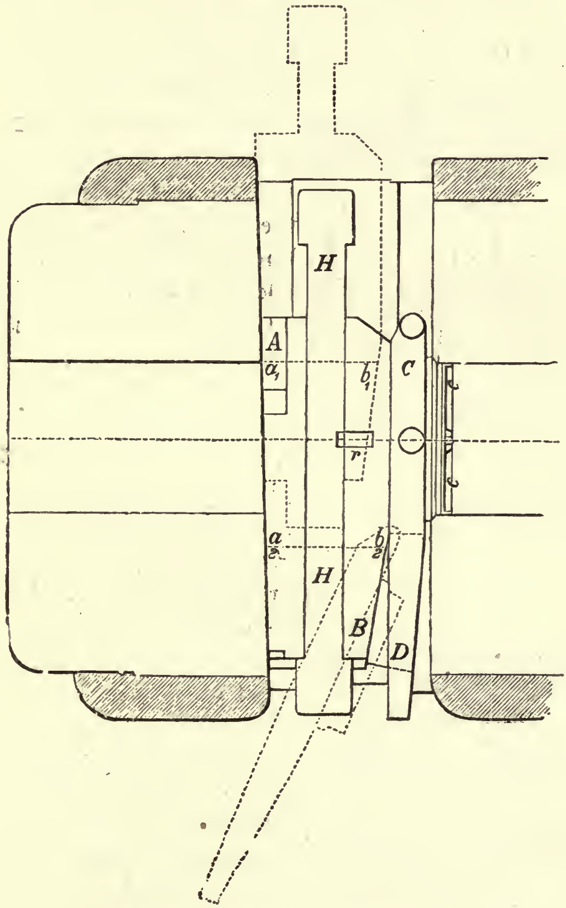
The first is mounted on a block trail carriage, and would be employed for heavy field batteries. The 15-cwt. gun is

[5] Nominal weight.

[6] For naval service the larger BL. rifled guns are provided with locks for firing cross-headed tubes, and all natures with crutches and guide plates for firing the quill friction tubes. The 12-prs. and lower natures when required for sea service are fitted with a *patch* under the breech for the head of the elevating screw, which is not attached to the piece, to rest upon.

intended for the broadside of vessels of the sloop class, and the 13-cwt. gun (pinnace gun) for boat service.

Fig. 34. PLAN.

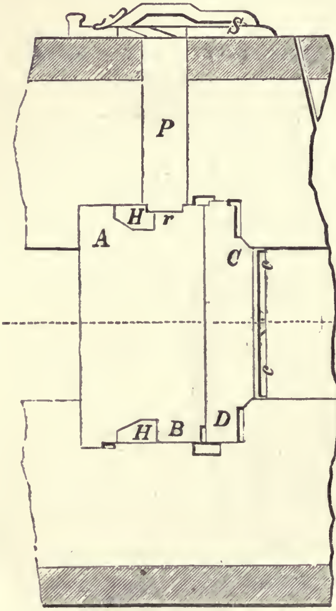


Wedge Breech-Loading 64-pr. Gun.

12-pr. There is one 12-pr. of 8 cwt. with which all field batteries, except those in India, were armed; this gun is supplied to the navy mounted on a SS. travelling carriage to accompany land expeditions. It is prepared for both LS. and SS. fittings.

9-pr. The 9-pr. of 6 cwt., which has the same calibre as the 12-pr., but fires a shorter projectile, was introduced for horse artillery batteries, as the 12-pr. with its ammunition was considered too heavy for that service. It is also used as a naval gun.

Fig. 35. SECTION.



A B. Wedge. C D. Stopper.
H H. Hammer. P. Locking pin.
S. Slide Plate. c c. Tin cup.

6-pr. The 6-pr. of 3 cwt. is intended for colonial service.[7]

5. The *wedge* BL. R. pieces are similar in general construction to the BL. rifled guns before described, and they are rifled on the same principle so as to fire a lead-coated shot, but the method of closing the breech is altogether different from that of the screw and vent-piece gun.

In the *wedge* and *stopper* gun a slot passes through the breech from side to side, and the parts which close the bore are therefore inserted or withdrawn at the side of the piece instead of at the top; by this arrangement the gun can be loaded more rapidly and with much less labour, and the detachment are less exposed than with the screw and vent-piece.

The *stopper*, C D (Figs. 34, 35), which is made of iron or steel, has a projecting face to fit into the bottom of the bore, and upon this face a tin cup is placed to prevent escape of gas at the breech. The stopper has studs on the top and bottom which travel in guiding grooves cut in the slot, and it cannot be detached from the gun until a little stop-pin is raised.

The *wedge* A B is made of iron, and has a taper of $\frac{1}{2}$ inch in its whole length to correspond with a similar taper at the back of the slot; a piece of iron, H H, formed into a handle at each end

[7] The 6-pr. BL. rifled gun was intended for mountain service, but is too heavy and too long for transport on the back of a mule.

fits loosely across the wedge with a play of about 4 inches, so that it can be used like a *hammer* to tighten or release the wedge.

On the top of the breech is a *slide plate*, S, the motion of which backwards or forwards raises and lowers a *locking pin* passing through the metal of the gun into the slot; on the upper surface of the wedge is a small recess (r) of about 1 inch in depth, and in such a position that when the wedge is in its place for firing, the end of the *locking pin*, P, drops down into it, and thus prevents any lateral motion of the wedge; until this happens the *slide plate* covers the vent, and therefore the gun cannot be fired.

The *hammer* must also be returned into the slot, as part of the recess for the *locking pin* is cut in its upper surface; conversely until the vent is again covered with the *slide plate*, the *wedge* and *stopper* are immovable, as the end of the *locking pin* can only be raised out of the recess (in the top of wedge and hammer) by the *plate* being pressed forward over the vent.

To load,—cover the vent with the *slide plate*, by which the *locking pin* is raised up out of the recess in *wedge* and *hammer*; loosen and push wedge out by the hammer; force back the handle of *stopper* to withdraw the face from the bore, and then pull the *stopper* out to the side; the shot and cartridge can now be inserted, and the tin cup placed on the pin in the centre of the face of the *stopper*, before the latter is replaced; the wedge is not pushed aside clear of the bore, for its end is hollowed out so that the shot can be loaded through it; the line a_1, b_1 (Fig. 34) shows where the hollow commences when loading, and a_2b_2 the same when firing. After the wedge has been replaced, tighten it by a smart blow with the *hammer*, return the latter into the slot, and draw the *slide plate* from the vent.

There are two natures of wedge BL. guns in the service, the 64-pr. and the 40-pr., both intended for siege guns.

Muzzle-loading Rifled Ordnance.

6. The heavy rifled ordnance, from 7- to 12-inch, are made of wrought-iron coils over a steel tube with a solid end, which is supported by a cascable screwed up against it through the breech. Some are built up on the Armstrong, others on the Fraser, or the modified Fraser, method of construction. With regard to these constructions, it may be remarked that they differ essentially in the number, arrangement, and cost [8] of the portions shrunk round the inner tube, in the diameter of the cascable, and in the thickness of the steel tube, which has been decreased as the construction has been modified. In the Armstrong method there is a breech-piece forged solid, and a large number of smaller coils shrunk on and hooked together to prevent longitudinal separation; [9] in the Fraser there is no breech-piece, but over the tube and cascable is a breech coil, composed of treble and double coils welded to the trunnion to form a mass which is shrunk on in one operation, the muzzle being strengthened by a short tube formed of two coils united; in the modified Fraser method there is a coiled breech-piece under the breech coil, which is therefore reduced in thickness (Fig. 36).

The guns are,—

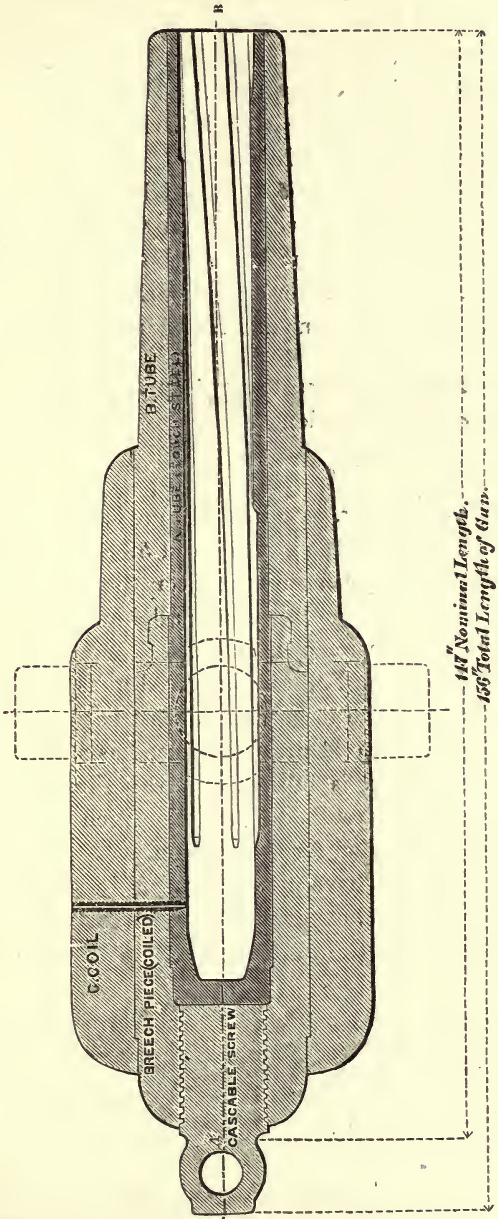
The	12-inch	of	35 tons,	throwing	a projectile	of	700 lbs.	For Coast Batteries and Naval Service.
,,	12	,,	25 / 23	,,	,,	,,	600 ,,	
,,	11	,,	25	,,	,,	,,	530 ,,	
,,	10	,,	18	,,	,,	,,	400 ,,	
,,	9	,,	12	,,	,,	,,	250 ,,	
,,	8	,,	9	,,	,,	,,	180 ,,	
,,	7	,,	7	,,	,,	,,	115 ,,	For Land Service.
,,	7	,,	6½	,,	,,	,,	115 ,,	For Naval Service.
,,	7	,,	4½	,,	,,	,,	115 ,,	

They are all rifled on the Woolwich system, the twist of the grooves being *uniform* in the 7-inch, but *increasing* in the

[8] The outer coils in the Armstrong constructions were made of a much more expensive iron than those in the Fraser constructions.

[9] The plan of hooking together, by means of projections or shoulders with corresponding recesses, was introduced by Dr. J. Anderson, C.E., F.R.S.E.

Fig. 36.



Built-up 9-inch ML. R. Gun. (Modified Fraser Construction.)

higher calibres; the projectiles have gun-metal studs, all of equal size on the 7-inch projectiles, but the top being smaller than the bottom studs on the projectiles for the guns having grooves with an *increasing* twist.[1] The *loading* side of the grooves of 10-inch and heavier ML. R. guns is cut away at the muzzle to facilitate loading.

7. The ML. R. 80-pr. of 5 tons, which is of the same calibre as the 64-pr., has been converted from the 68-pr. SB. cast-iron gun by *lining* with wrought iron on the Palliser method.

The 64-pr. ML. R. gun is exceptional, both in construction and rifling. There are four different constructions:—

(1) Converted[2] BL. Armstrong 70-pr.	Of 64 cwt., built up and having wrought-iron tubes.[3]
(2) Fraser B construction	
(3) do. D do.	

(4) 8-inch and 32-pr. cast-iron SB. guns, *lined* with wrought iron on the Palliser method, of 71 and 58 cwt. respectively.

The three built-up guns are rifled on the *shunt system*,[4] the lined guns on the *Woolwich system*; all, however, fire the same projectiles, which have copper studs.

These 80 and 64-pr. Palliser converted guns take the place of the heavy SB. ordnance in garrisons, coast batteries, and for sea service. The built-up 64-pr. will be used as a siege gun.

The ML. R. 40-pr. is built-up on the Fraser construction, rifled with uniform twist on the Woolwich system, weighs 35 cwt., and is intended for a siege gun.

8. Rifled mortars have not yet been introduced into our service, but very good experimental results have been obtained with an 8-inch ML. R. howitzer, built up like the heavy guns

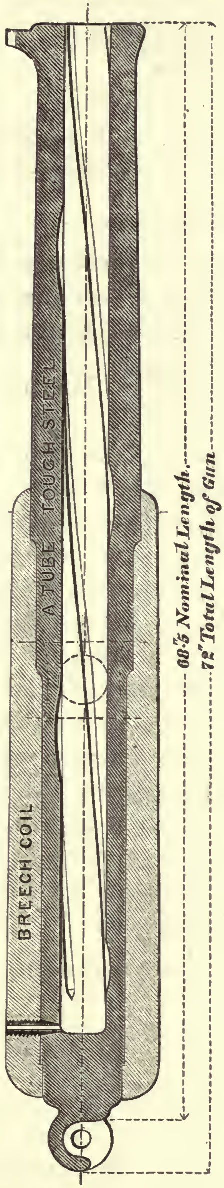
[1] There are two 13-inch ML. R. guns of 23 tons, having forged breech-pieces and inner steel tubes with loose ends. Figs. 36, 37, are taken from the small lithographs drawn in the Royal Gun Factories.

[2] The tube of this gun being of coiled iron, and therefore open, it is closed at the bottom by a copper cup, supported by a cascable screwed in at the breech.

[3] Guns of future manufacture to have solid-ended steel tubes.—*List of Changes*, § 2084.

[4] All 64-prs. of future manufacture, and those requiring to be re-tubed, to be rifled on the Woolwich system, so that the shunt may gradually become obsolete. —*List of Changes*, § 1996.

Fig. 37.



9-pr. ML. R. Gun. (8 cwt.)

of wrought iron with steel tube, and rifled on the Woolwich system. It is intended for a siege piece.

Weight of howitzer, 46 cwt.
Charge, $1\frac{1}{2}$ to 10 lbs.
No. of grooves, 4.
Twist of do., 1 turn in 16 calibres, uniform.
Weight of shell = (167 lbs. + 13 lbs. burster) 180 lbs.

9. The light ML. R. guns are,—

16-pr. of 12 cwt., iron field gun (heavy).
9-pr. of $8\frac{1}{4}$ cwt., iron field gun.
9-pr. of 8 cwt., bronze field gun (for Indian service).
7-pr. of 2 cwt., bronze } Mountain service.
7-pr. of 150 lbs., steel }

The iron 9-pr. (Fig. 37) consists of a steel tube having a wrought-iron breech-coil with trunnions shrunk over it; it has no screwed-in cascable, as the tube projects beyond the coil at the breech, the end being shaped to receive the head of the elevating screw. Like the bronze 9-pr., it has no ornaments, but a tulip with a projection on the top for a muzzle sight. Both bronze and iron 9-prs. have the same rifling, are vented and sighted alike, fit the same carriage, and take the same ammunition.[5] The 16-pr. is of similar construction to the iron 9-pr., but it has no projection for a muzzle sight.

The grooves of the 16- and 9-prs. are, as before pointed out, of nearly the same form as the French, adapted to *centre* the projectiles; those of the other two guns have straight sides, but are not intended for *centering*; the studs of the projectiles for all three guns are made of zinc.

[5] A 9-pr. of 6 cwt. will probably be introduced as a horse artillery gun.

CHAPTER V.

CONSTRUCTION OF ARTILLERY CARRIAGES.

GENERAL PRINCIPLES OF CONSTRUCTION: 1. General principles to be observed in the construction of artillery carriages.—2. Points to be considered with regard to the draught of the carriage. DRAUGHT OF ARTILLERY CARRIAGES: 3. Number of horses required for artillery carriages.—4. Mode of draught. EFFECT OF DISCHARGE OF GUN: 5. Recoil of a gun.—6. Effect of recoil upon carriage when axis of trunnion passes through that of piece.—7. Effect upon the carriage from the axis of trunnions being below that of the piece.—8. How the impulse on the elevating screw is influenced by the position of the trunnions.—9. Principles to be observed in order to lessen the destructive effect upon a gun-carriage.

General Principles of Construction of Artillery Carriages.

1. BEFORE describing the different classes of carriages and the special purposes for which they are intended, it is necessary to consider the general principles of construction common to all artillery carriages (whether gun-carriages or for draught), and also the effect of the discharge of a piece upon its carriage. An artillery carriage should be of simple construction, so as to be capable of being easily repaired; it should have sufficient mobility for its peculiar service; and its centre of gravity should be so placed that it may not be liable to upset on passing over rough or uneven ground.

There should be as few varieties of carriages as possible, and the several parts of the same description of carriage should correspond, and be made of exactly the same pattern. Moreover, it is desirable, as far as possible, to assimilate the general constructions, modes of draught, size of wheels, &c., of those carriages which are intended to act together—as, for instance, those of a field battery; the parts also designed to perform the same offices in carriages of different constructions should have the same form and dimensions when possible. By attention to these points the manufacture will be more rapid and correct, the equipment of stores will be simplified, and the different carriages can be readily repaired by exchange of parts, which will be found very important on service.

2. The following points must be attended to, in order to decrease, as far as possible, the work necessary for the draught of the carriage :—

(1) The wheels must have all the height they can be allowed.

(2) The mean diameter of the axletree arms must be reduced to a minimum, consistent with the necessary strength.

(3) The axletree arms and boxes of the wheels must be made of materials between which there will be but slight friction.

(4) The angle of traction must be that most favourable to the motive power.

With regard to the first point, it is generally considered that the height of wheel for carriages intended to move with rapidity or for general purposes should not exceed 5 feet, as the weight of the wheel would be increased by greater dimensions, and the load would be raised to a height that would render the carriage liable to upset, unless its width was increased, or its construction otherwise altered. A diameter of 5 feet is consequently adopted for the wheels of all carriages in our field artillery, as well as for the greater number of those for siege carriages. With carriages that are required to move but slowly, and over very rough ground, a greater diameter may sometimes be employed with advantage, as with the hind wheels of sling wagons (which are 7 feet), the extra height being also necessary with these carriages, in order to raise the gun or mortar conveyed underneath sufficiently above the surface of the ground.

The axletree, being of forged iron, a strong material, can be made with a small diameter, and thus the friction of the arm against the pipe-box will act with a very small lever arm, compared to the radius of the wheel, and the size of the nave is diminished, as well as the weight of the wheel.[1]

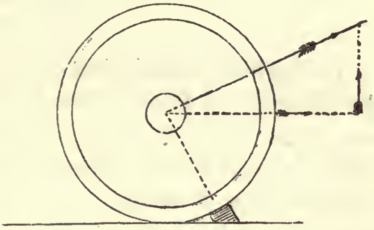
The axletree arms for wheels with wood naves have a portion

[1] When a cylinder rolls on a plane, if both are perfectly hard, they would touch merely in a line; in fact, they touch in a surface, the breadth of which depends on the compressibility of the materials in contact. There will arise a *resistance to rolling* depending upon the compressibility and elasticity of the materials; and a further resistance, termed *friction*, will arise from the roughness of the surfaces in contact.

of steel let into them underneath, at those parts bearing upon the pipe-box (about 3 inches from each end of the box), which is made of cast iron; the wheels of the new iron field carriages have gun-metal boxes, and the axletree arms are not *steeled.* We, therefore, have cast iron working on steel, or gun-metal on wrought iron, between which there is but slight friction, particularly when the proper unguents are employed.

If the plane upon which a carriage had to run was a perfectly smooth surface, the most advantageous direction for traction would doubtless be parallel to the plane; but as artillery carriages may have to travel on the worst description of roads, or over very rough ground, where there are stones, ruts, and other obstacles to be constantly overcome, the angle of traction must be slightly inclined upwards, as the vertical

Fig. 38.



Experiments made by Morin showed that the resistance to rolling was nearly

1. Proportional to pressure.
2. Inversely proportional to the diameter of wheel.
3. Greater as breadth of zone (width of tire) diminished.

As regards the effect of the wheel in diminishing friction. If A be radius of wheel, and *a* that of axle, the friction is diminished in the ratio of A : *a*, or as diameter of axle for the same wheel is less. As the axle and bearings are made of hard polished materials, and well greased, the coefficient of friction between them is much less than between the circumference of the wheel, if fixed, and the ground; the pressure upon the axle is also less than the sum of the pressures upon the circumference, if it were fixed.

The following are the *coefficients of friction* of axle ends, in motion in their bearings, from Morin's experiments:—

Cast-iron ends on cast-iron bearings
Wrought-iron ,, ,, ,,
,, ,, brass ,,
} Coated with oil, lard, tallow, &c.

	Coefficient.
When greased from time to time, like cart wheels, at end of journey	·07 to ·08.
When kept continuously greased, as wheels with patent boxes	·054.
Only slightly greasy, surfaces beginning to abrade	·25.

[These remarks are abridged from those given in the *Course of Mathematics for R. M. Academy*, vol. iii. Part I. 'Mechanics,' by J. F. Heather, Esq., M.A., pp. 75, 77, 83.]

component of the pull will then assist the wheels to surmount such obstacles; the weight being transferred to the shoulders of the horse, increasing the pressure of his feet upon the ground, thus giving him a firmer hold, and enabling him to exert with ease a stronger pull, while the resistance against which he contends is at the same time diminished (Fig. 38).

In the third volume of the 'Mathematical Course,' p. 237, it is stated, 'That to produce the best effect, the tangent of the inclination of the traces should be equal to the ratio of the traction to the load,[2] or

$$\tan a = \frac{T}{W} \text{ nearly.'}$$

In Begbie's translation of an 'Essay upon Gun Carriages,' by Miguet and Bergery, we find 12° given as 'the angle which combines every advantage,' and 'if by adopting it we do not obtain to the letter the maximum of effect, we may at least be certain that it is not very far from it.' This angle was deduced from some experiments carried on at Metz, in 1816, by General Berge. As, however, different animals exert their strength most advantageously in different directions, practice alone can determine the proper position for the traces, which, however, should always be arranged so that they may be slightly inclined upwards, when attached to the collar of a horse of the average size employed. This angle in our service is about 6½°.

Draught of Artillery Carriages.

3. In order to determine the number of horses that will be required for the draught of any carriage, it is necessary to ascertain the *force of traction* which a horse of average strength is capable of exerting. It is not the momentary, but the continued effort, which it is necessary to know, the latter being of course much less than the former. This effort will depend upon the *rate* or speed of travelling, the *time* for which the force must be exerted, and the *nature of the ground* over which the carriage will have to travel.

[2] Capt. W. H. Wardell, R.A., in his *Problems on Artillery Machines*, p. 20, makes $\frac{T}{W} = \sin a$. The difference would, however, be inappreciable.

It is generally considered that a horse moving at a rate of about 3 miles an hour can exert a force of 125 lbs. for 8 or 10 hours; if the rate be 7 miles an hour, the draught should be reduced to about 90 lbs., and be continued for a shorter time, viz. 5 or 6 hours; and should greater speed be required, the horse ought not to have to draw with a force exceeding 50 or 60 lbs., and for a period of from 1 to 3 hours, depending upon the speed.

If a team of horses be harnessed to a carriage, the effective power exerted by the whole team will not be increased in the same ratio as the number of horses, but as this number is increased, so will the effective power of each horse be decreased; this arises from the great difficulty of making all the horses of the team exert their proper amount of force at the same instant.

It is considered by the French [3] that no more than six horses should be employed for the draught of any carriage that may be required to move with rapidity, and to traverse every description of country. For carriages of the greatest weight in our service (the 64-pr. siege gun), it is found advisable not to employ more than 12 horses.[4]

Artillery carriages, having no springs, and being usually obliged to travel over very rough ground, require a greater number of horses than would be necessary for ordinary carriages of similar weights; and this is the more needful, in consequence of their being liable to lose some of the number in action, or from the hardships to which horses are always exposed in a campaign.

As the force of traction is diminished by rapidity of movement, it has been considered desirable to divide the teams of artillery horses into—

(1) Those of the horse artillery.
(2) „ „ field batteries.
(3) „ „ heavy ordnance.

Horse artillery, having generally to act with cavalry, are

[3] Miguet's and Bergery's *Essay upon Gun Carriages*, translated by Begbie.

[4] This remark applies only to organised teams; a sling wagon with a heavy gun is drawn by a number of pairs of horses, frequently more than six pairs.

frequently obliged to move with great rapidity, or at a gallop. Field batteries usually acting in concert with infantry, their rate of movement would not often exceed an ordinary trot. Heavy ordnance are never required to manœuvre with troops, and from their great weights, the rate of travelling is confined to a walk.

The load which each horse should be required to draw is given by Decker thus:

For horse artillery, 500 lbs.
„ foot „ 650 „
„ siege „ 750 „

These, however, he adds, are less than what would actually be the case on service.

In Miguet's and Bergery's 'Essay upon Gun Carriages,' the following is given:—

For teams of light field batteries, 743·281 lbs.
„ „ field parks „ 878·425 „
„ „ siege train „ 1013·576 „

The following table will show the load that each horse had to draw in heavy and light teams with BL. R. guns in our service:—

Nature of carriage	Total weight of gun, carriage, limber, ammunition, &c.	Number of horses	Weight each horse has to draw
	cwt.		cwt.
40-pr. Armstrong gun-carriage .	81¼	12	6·77
20-pr. „ „ „ .	48½	8	6·06
12-pr. „ „ „ .	37	8	4·62
9-pr. „ „ „ .	31¼	6	5·2
12-pr. ammunition wagon .	43¼	6	7·2
9-pr. „ „ .	40¼	6	6·7

From this table it appears that each horse had to draw a heavier load in a horse artillery than in a field battery team,[5] viz.:—

In a team for horse artillery, about 5¼ cwt.
„ „ field batteries „ 4½ „

[5] Independently of the weight which each horse has to draw, one half of the horses will have in addition the weight of their drivers to carry.

For the ammunition wagon the draught is however much heavier, each horse with the 12-pr. ammunition wagon being required to draw about 7¼ cwt., a greater weight than that given to a horse in a 40-pr. team; with the 9-pr. wagon the load for one horse was about 6¾ cwt. These figures clearly show the necessity of properly arranging the respective weights to be drawn by horses of artillery teams intended for different purposes.

In an experiment at Metz, in 1825, with a light field gun-carriage, it was found that at a walk over fine turf the ratio of the traction to the load was one-twentieth, and over recently ploughed land one-tenth. Applying these values to the 12-pr. Armstrong field carriage, each horse would have to exert a force of only 25¾ lbs. on turf, but a force of 51¾ lbs. on ploughed land.

With the ML. R. 16-pr. gun carriage the total weight is about 41½ cwt., so that each of the 8 horses would have a load of 5·2 cwt. to draw; with the ML. R. 9-pr. carriage the total weight being 35 cwt., each of the 6 horses would have a load of 5·8 cwt.; each horse in either 16 or 9-pr. wagon has a load of about 6·7 cwt.[6]

4. Shafts are employed in the British service, in preference to the pole, for the draught of artillery carriages.

For field carriages, and those for light guns of position, double draught is employed, the off-horse being placed in the shafts; for siege carriages, and those of heavy guns of position, four horses are harnessed abreast, there being two pairs of shafts, one for each of the inside horses; shafts for single draught are supplied to mountain and colonial service artillery carriages.

The chief advantage obtained by the use of shafts, instead of a pole, for field carriages is, that the carriage is more under control for manœuvring or turning. They have the following disadvantage, viz. that in stopping the carriage, or in going

[6] The French and Austrian batteries armed with canon de 4 have only 4 horses to a gun. Baron Berge, Lieut.-Col. in the French Artillery, recommends 6 horses for the horse artillery batteries, as the weight for each horse is now greater in a horse artillery than in a reserve battery, the over-weight accounting for the rapidity with which their artillery horses are ruined in a campaign. (*Rapport sur le Canon de Campagne Anglais*, p. 48.)

down steep hills, the shaft-horse will have to bear the greater part of the weight of the carriage, and very powerful horses will therefore be required. The pole is generally employed on the Continent, as the draught is supposed to be more equally distributed between the horses, the harness is simpler, and very powerful horses are not required ; should it however be requisite to cross a ditch or depression in the ground, the pole may sometimes bear down upon the horses, when they are attempting to rise on the opposite side. The method of attaching the shafts will be explained in the next Chapter.

Effect of the Discharge of a Gun upon its Carriage.

5. When a gun is discharged, as the elastic gas exerts an equal pressure in every direction, a force will be applied at the bottom of the bore, and in the direction of the axis, equal to that which acts upon the projectile,[7] and the gun, if free to move, would be forced backwards in a direction opposite to that in which the projectile is thrown. If the gun be placed upon a carriage, its momentum, acting upon the carriage, causes the recoil always observed when a piece is discharged, and also certain destructive shocks or strains upon the carriage.

The momentum of the gun and carriage is equal to that of the projectile, both being acted upon by equal forces, and the velocity of recoil of the former may be roughly found as follows :—

If G=weight of gun,
C= „ carriage,
w= „ shot,
v=initial velocity of shot,
V= „ „ gun and carriage,

$$wv=(G+C)V,$$

$$V=\frac{wv}{G+C},$$

v must be determined by experiment or from the formula for finding the initial velocity of shot.

[7] Not strictly correct, for the force of the gas acts in most cases for a longer time upon the gun than upon the projectile ; and when there is windage, the force exerted upon the base of the shot is less than that upon the bottom of the bore of the piece.

The velocity of recoil thus found would only be a rough approximation; if an accurate calculation be required, the angle of elevation of the gun, the rotation of the system, and the friction must be taken into account. It is however sometimes useful to ascertain the velocity of recoil of the gun alone, so as to be able to form an estimate of the probable effect of the discharge of the piece upon its carriage.

If V' = initial velocity of recoil of gun,

$$V' = \frac{wv}{G},$$

and the work done upon the carriage may then be found by the formula

$$PS = \frac{WV^2}{2.g},$$

where W = weight of gun
V = velocity of „
g = force of gravity.

If two guns have bores of the same calibre, but the weight of one gun is greater than that of the other, their respective velocities of recoil, and also the strains exerted upon their carriages, when fired with equal charges and similar projectiles, will be inversely as their weights.

If v = velocity of shot,
w = weight of „
W = weight of the 1st gun,
W' = „ 2nd „
V = velocity of the 1st „
V' = „ 2nd „

the momentum of each gun will be equal to vw.

$$\text{But } V = \frac{vw}{W},$$

$$\text{and } V' = \frac{vw}{W'},$$

or the velocities of recoil are inversely as the weights.

The work done by the guns in their recoil, and consequently the strains upon the carriages, will be as

$$WV^2 : W'V'^2,$$

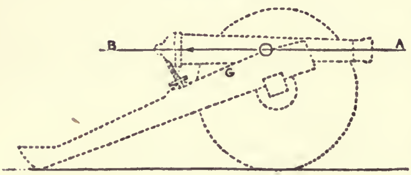
or, by substituting the values of V and V', as

$$\frac{v^2w^2}{W} : \frac{v^2w^2}{W'},$$

or the strains are inversely as the weights.

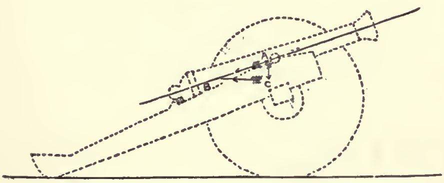
6. Should the carriage rest upon a horizontal plane, and the gun be laid point blank, the axis of the trunnions not being below that of the piece (Fig. 39), then the momentum of the gun will be expended in forcing the carriage to the rear in the direction of the axis of the piece, and strains will, consequently, be exerted upon the trunnion holes, and from them be transferred to the axletree arms; also, since the centre of gravity, G, of the system (gun and carriage) is below the axis of the piece, in which direction the force of the powder acts, the whole will have a tendency to rotate round the axletree, which, being checked by the point of the trail touching the ground, will cause the system to rotate round this point, forcing it into the ground, the wheels being at the same time lifted up.

Fig. 39.



Should, however, the gun be fired at a considerable angle of elevation, the momentum communicated to it will give a shock vertically down upon the carriage, causing destructive effects upon various parts of it, as well as a backward shock of somewhat less amount than in the former case. This destructive effect increases with the angle of elevation.

Fig. 40.



In Fig. 40, if A B be taken to represent the force of the gas, acting at the bottom of the bore, A C will represent the destructive effect exerted normally upon the carriage, and C B that which urges the carriage to the rear.

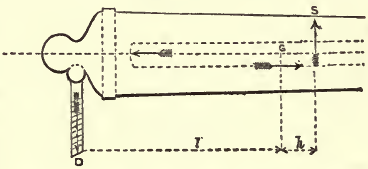
If A C or the angle of elevation be considerable, the wheels and trail will both be forced into the ground, and divide the shock acting vertically upon the carriage between them.

In each of the above cases, the gun and carriage not being rigidly connected together, when a resistance is suddenly offered to the trail by the ground, the gun will continue to rotate round the fixed axis of the trunnions, until stopped by the head of the elevating screw, upon which, consequently, a considerable blow will be given.

It is also evident, that should the gun-carriage be standing upon a plane, inclined upwards to the rear, destructive effects will be exerted upon the carriage, and ground or platform, according to the inclination of the plane.

7. In our service, the axis of the trunnions of a smooth-bored gun is below that of the piece, and two parallel forces may therefore be considered to be acting upon the gun, one of which is the pressure of the elastic gas, applied at the *centre point of the bottom of the bore*, and in the direction of the axis; the other, the *reaction of the trunnion holes* in the opposite direction (arrow below G); there will, consequently, arise a tendency to rotation about G, the centre of gravity of the gun, which will cause impulses to be exerted on the head of the *elevating screw*, and on the *capsquares*. In Fig. 41 the gun is supposed to be resting on its carriage, on a horizontal plane, and laid point blank, or with its axis parallel to the plane.

Fig. 41.



Let P = impulse on elevating screw,

S = " capsquares,

h = horizontal distance of axis of trunnions from centre of gravity of gun,

l = horizontal distance of elevating screw from centre of gravity of gun.

The centre of gravity of the piece being in rear of the trunnions, the force exerted at S will be in the opposite direction to that at P. When the two forces first mentioned act upon the gun, the direction and position of the forces being represented by the *horizontal* arrows, there will be a tendency to rotate round the point G; and this tendency will cause certain impulses to be given on the top of the *elevating screw*, and on the *capsquares* the direction and position of which are represented by the vertical arrows.

Since the effect produced upon the centre of gravity will be the same as if they were applied directly at this centre, then, in the case in which the centre of gravity has no vertical motion, these impulses will be equal, or $P=S$.

These impulses are, in fact, the effect of pressures, and the time for which these pressures act being equal, these pressures themselves are also equal; but their *destructive effects* will be measured by the products of the pressures, and the space through which the points, where they act, are moved; these spaces are proportional to their distance from the centre of gravity, and the *destructive effects* will likewise be in the same proportion, or as l to h.

Should the resistance to motion be greater at the elevating screw than at the trunnions, which would probably be the case on hard ground, or on a platform, the impulse on the elevating screw will be greater than that on the capsquares; in this case, the system (gun and carriage) will have a tendency to rotate round the *point of the trail* from this cause, in addition to that arising from the general rotation of the whole system round its centre of gravity.

If the ground be very soft, the system would have a tendency to rotate round the *axletree*, and the pressure on the elevating screw would therefore be diminished, and that on the capsquares increased.

These remarks will show in what way the resistance of the plane, upon which the gun-carriage is resting, to the rotation of the trail, will influence the effect upon the carriage.

If the plane be very hard, or should it have a considerable upward inclination to the rear, then will the destructive effect be very great on the axletree,[8] as well as on that part of the

[8] As in the case of the axletrees of the 16-pr. carriages, which gave way just below the brackets.

trail to which the elevating screw is attached, especially if the gun be fired with a large charge. The carriages first made for the BL. R. 12-pr. guns were found liable to give way just above where the elevating screw passes through the trail; they were then strengthened by bolting an iron plate underneath the trail, but in the carriages afterwards made the depth of wood was increased in front of the elevating screw (between it and the trunnion holes).[9]

8. The manner in which the position of the trunnions of a piece of ordnance will influence the impulse on the elevating screw may be shown as follows (Fig. 42):—

Let P = force of gas,
R = reaction of elevating screw,
a = distance from the centre of trunnions to axis of bore,
b = distance from centre of trunnions to elevating screw.

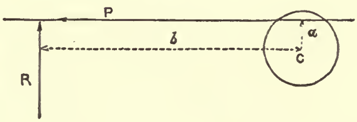
Taking moments about C,

$$P \times a = R \times b,$$

$$R = \frac{a.P}{b}.$$

Consequently, 'The impulse on the elevating screw increases directly as (a), or distance from centre of trunnions to axis of bore, and inversely as (b), or distance from centre of trunnions to elevating screw.'

Fig. 42.



9. In order to lessen as much as possible the destructive effect upon a gun-carriage from the discharge of the piece, the following principles should be observed.

(1) The *weight of the piece* must be at a *maximum*, with due regard to mobility, as the velocity of recoil of the gun which acts upon the carriage will thus be diminished.

(2) The *weight of the carriage* must be at a *minimum*, consistent with the requisite strength, as its inertia will then be more readily overcome; and, consequently, a less amount of the force of recoil will be expended upon it.

[9] Circular 835, Sep. 5, 1863, § 765.

(3) The *centre of gravity* of the system (gun and carriage) must be *as near* to the *axis of the bore* of the piece, and as far as possible from the *point of support of the trail,* in order to decrease the tendency to rotation.

(4) The *wheels* must be as *light* as is consistent with strength, in order [for the same reason as in (2)] to save the axletree and breast of the carriage.

CHAPTER VI.

ARTILLERY TRAVELLING CARRIAGES.

1. Classification of carriages. FIELD CARRIAGES: 2. Different carriages of field batteries.—3. Gun-carriages.—4. Wooden gun-carriage.—5. Ammunition wagon. —6. Iron field artillery carriages.—7. Rocket wagon.—8. The additional carriages.—9. Sleighs.—10. Mountain service carriages. SIEGE CARRIAGES: 11. Requisite conditions in the construction of siege carriages, and different siege carriages employed.—12. Gun-carriages.—13. Mortar carriages.—14. Wrought-iron siege carriages.—15. Platform wagon.—16. General service wagon.—17. Siege wagon, store wagon, and hand cart.—18. Sling wagon.—19. Trench cart. WHEELS AND AXLETREES: 20. Wheels.—21. Axletrees.

1. THE artillery carriages used for land service are of two kinds—

Travelling, for field and siege service.
Standing, for garrisons and coast batteries.

A *travelling* carriage, provided like an ordinary carriage with wheels, generally consists of two parts—a *body* and a *limber*: the former carries the whole or greater part of the load;[1] and the latter, which carries or supports a portion of the load, serves as a means whereby motion is communicated in travelling to the first, and forms with it a four-wheeled carriage, suitable for the requisite purposes of transport or manœuvring; the fore-part of the body hooks up to a *pintail* placed at the back of the limber.

When the weight is very great, as in siege carriages, it must be distributed in travelling throughout the whole length of the body (trail); for should the load be placed too far back over the rear axletree, it would, in going up steep inclines and over rough ground, cause the point of the trail to be jerked upwards with violence, the gun tending to fall over to the rear.

[1] The body in our service carries about two-thirds, and the limber one-third, of the load.

A *standing* carriage has no wheels, but trucks suitable only for movement upon a platform.

Artillery carriages (LS.) may be classed into—

(1) Field carriages (including those for position pieces).
(2) Siege carriages.
(3) Garrison carriages.

Field Carriages.

2. This class embraces all carriages for the transport and service of guns, and the conveyance of ammunition, stores, &c., belonging to the various kinds of batteries for field or mountain service.

The construction of a gun-carriage differs according to the nature of the piece for which it is intended; but all the other carriages of a battery, such as the ammunition wagon, forge, &c., whether for field batteries or horse artillery, are similar in general construction, the only difference being in the interior arrangement of the boxes which contain the ammunition or stores.

The gun-carriage and ammunition wagon are the two most important carriages in a battery; for although in our service the latter is not supposed to accompany the gun in action, but must be kept as much as possible out of the range of projectiles by remaining at some distance from the guns, or taking advantage of cover, &c., yet the effective fire of the battery for any length of time will depend upon the wagons being sufficiently near to make use of their ammunition when required, and the construction of the wagon must therefore allow of its passing over any ground accessible to the gun-carriage. These two carriages will be considered in the first instance.

The following remarks will be confined to a brief explanation of the carriages attached to batteries of rifled pieces.

3. The gun-carriages of a battery being *required to accompany the troops*, either infantry or cavalry according to the nature of battery, in all their principal movements, it is necessary that they should possess great mobility, and have a much

stronger construction than the other carriages, which merely convey the ammunition, stores, &c., in consequence of the strains exerted upon them by the discharge of the piece, or when moving rapidly over rough ground, and also from their being constantly exposed to the fire of the enemy.

The construction of a field gun-carriage will depend upon the calibre and charge as well as on the nature and weight of the piece, both with regard to its peculiar action when fired, and its requisite mobility. The general principles to be carried out in the construction of a gun-carriage, with regard to the injurious action of the gun upon it when discharged, have been already noticed; the following conditions must also be fulfilled in its construction, in order to ensure the efficient service of the piece in the field:—

(1) The construction of the carriage, and the manner in which it is attached to the limber, should allow of its moving with rapidity, of its turning readily, and of its being easily unlimbered or limbered up.

(2) The height of the carriage should be such as to admit of the gun being loaded with ease.

(3) It must have a simple and strong elevating screw or other means of giving elevation or depression to the piece; also, it must be provided with a traversing handspike which can be attached to, or detached from the trail without difficulty.

(4) The limber boxes must contain such a quantity of ammunition that the gun may not be too dependent upon the ammunition wagon.

The BL. guns have wooden carriages, and the ML. iron carriages.

4. The different parts of a *wooden field gun carriage* (Fig. 43) are the *trail*, two small brackets (one attached to each side of the trail and projecting slightly above it), a wooden *axletree bed* with an iron axletree passing through it, two small *axletree boxes*, an *elevating screw*, and two *wheels*. The trunnion holes are cut in these brackets; there is only one set, or pair, in the carriage for field service, as it is necessary that the piece should occupy the same position both in travelling and firing, in order

that it may be rapidly brought into action. The trunnion holes are placed far back on the carriage, over the rear of the axletree, this position having been found most advantageous with regard to the least amount of strain upon the carriage from the action of the piece when fired; the point of the trail is also rendered very light by thus placing them, so that it can be lifted without difficulty in limbering up or unlimbering.[2]

The inclination of the trail to the ground has a tendency to check the recoil, but the less so as the angle it makes with the ground becomes more acute; the decrease of this angle must, however, have its limits, as a great length of trail would render the carriage heavy and unmanageable. The trail of a field gun-carriage usually stands at an angle of about 21° with the ground.

The introduction of the block trail[3] lessened the weight of the (field gun) carriage, and also gave greater facility for manœuvring, the wheels being enabled to lock very close. A bracket trail, similar to those of the old pattern siege carriages, was used previously for field gun-carriages.

The wooden carriages of the 20, 12, 9, and 6-pr. BL. R. guns have all the same general construction, but the weight increases with that of the piece for which the carriage is intended. The 20 and 12-pr. carriages have a traversing arrangement capable of giving 3° of deflection to the gun, $1\cdot\frac{1}{2}°$ on either side, and consisting of a gun-metal *saddle* with trunnion holes working in dovetailed slots in the brackets (Fig. 43); the saddle is worked right or left by a *lever* pivoted on the trail, one end resting in a slot in the saddle, the other connected to a screw passing across the trail and turned by a *hand-wheel* outside the bracket. All the carriages are provided with the *ball and socket* elevating screw, which allows the breech to move freely in any direction.[4] The top of the elevating screw is

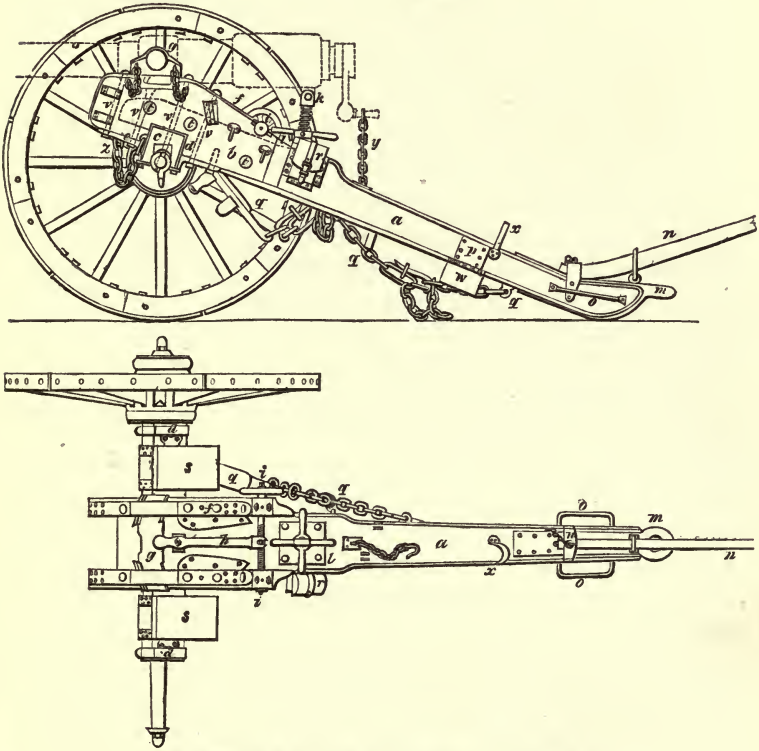
[2] The method of securing the brackets, axletree bed, &c., is described in the *Notes on the Manufacture of Carriages.* The names of the different parts of the carriage are given under Fig. 43.

[3] The block trail, proposed by Sir W. Congreve, was introduced for field guns about 1792; it was adopted for 18-prs. shortly after the Crimean war, and for siege guns in 1860.—*Equipment of Artillery,* compiled by Major Miller, V.C., p. 90.

[4] The gun being supported at the trunnions, the breech must move in an arc.

attached to the gun, and the screw works in the thread inside of the ball, which rests in a gun-metal socket bolted to the trail; the ball is turned by four handles to raise or lower the

Fig. 43.



Wooden Field Gun Carriage (12-pr. BL. R.).

a. Trail. *b.* Brackets. *c.* Axletree and bed.
d. Yoke hoops. *e.* Axletree bands. *f.* Trunnion plates.
g. Saddle traversing. *h.* Lever for saddle. *i.* Screw and hand wheel for saddle.
k. Elevating screw (attached). *l.* Pan and oscillating nut.
m. Trail eye. *n.* Traversing handspike and shoe.
o. Trail handles. *p.* Locking plate.
q. Eye bolt, skid chain, and pan. *r.* Leather pocket for spare vent.
s. Axletree boxes. *t.* Horizontal bracket bolts. *v.* Trunnion plate bolts.
w. Leather pocket for sponge. *x.* Sponge loop.
y. Chain for securing breech. *z.* Advance chain.

screw. The axletree boxes are attached to the bed on the right and left of the trail; each carries two rounds of case shot and some small stores.

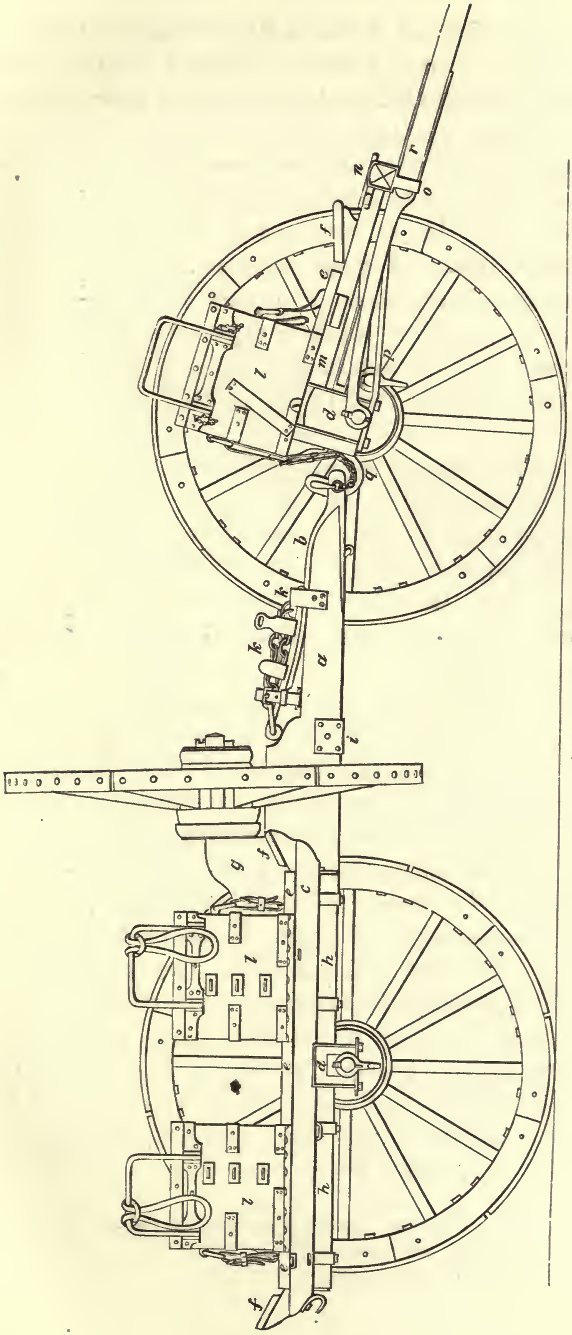
The limber (like that of wagon, see Fig. 44) consists merely of a framework of wood, placed upon wheels of equal height with those of the gun-carriage, and carrying two boxes for the ammunition, &c., to be conveyed with the gun; the frame consists of the *axletree bed* and *block* (attached behind it) connected with the *splinter bar* by three *futchells*, and in front of the boxes are the *platform board* and *footboard*. The trail of the gun-carriage hooks up to a *crooked pintail* at the back of the limber, and when the two (gun-carriage and limber) are thus attached or *limbered up*, as it is called, they form a four-wheeled carriage, suitable for travelling; when unlimbered, the gun-carriage rests upon three points, viz. the trail and two wheels, which ensures its steadiness, and enables the piece to be readily laid. The limber has a splinter bar to which the traces of the horses are attached, and the shafts can be arranged for single, double, or treble draught.[5]

The limber carries two large boxes for projectiles and cartridges, the former packed round the latter to protect them, and a narrow centre box between the others for fuzes and tubes. For BL. R. guns it conveys thirty rounds; three case shot, three common shell, and nine segment in each box. The boxes are covered with canvas, provided with folding guard irons, and are attached to the limber by nib plates and leather straps.

5. *The ammunition wagon* (Fig. 44) consists of a body and limber, the latter, being identical with that of the gun, can be substituted for it if necessary. The body of the wagon is composed of a framework of wood, having a *perch* passing

[5] For *double* draught, the near shaft passes through the splinter bar band, the end fitting into a mortise, a bolt passes through the platform board and shaft, and is keyed underneath to prevent the shaft moving; the off shaft passes through the splinter bar band, the end of the shaft iron fittting on to the axletree arm, where it serves as a washer. In *single* draught, the near shaft passes through the splinter bar band, and the end fits into a stump of iron fixed underneath the near side futchell, a bolt passing through the footboard secures the shaft as before; the off shaft passes through the splinter bar band, and the end fits on to an iron crutch attached to the axletree-bed; this crutch usually carries a linchpin and washer to supply the place of the shaft on the axletree arm when arranged for single draught. By means of *swingletrees* and the shafts placed for single draught, three horses can be harnessed abreast; the swingletrees must be attached to the trace loops at each extremity of the splinter bar.

Fig. 44.



AMMUNITION WAGON.

a. Perch. b. Trail eye. c. Sides. d. Axletree and bed. e. Platform boards. f. Footboards.
g. Wheel block. h. Horse-shoe box. i. Locking plate. k. Skid chain, pan and shoe. l. Ammunition boxes. m. Futchells.
n. Splinter bar. o. Shaft iron. p. Crutch hook. q. Limber hook and key. r. Brandling shaft.

G

down the middle, the end of which, like that of the trail of the gun-carriage, hooks up to a crooked pintail behind the limber. Upon the body are carried four large boxes for ammunition and small stores, similar to those on the limber, and two centre boxes; there are platform and footboards both in front and rear, so that a man can be seated on each box.

The boxes must be so constructed that the ammunition within shall be preserved from moisture of any kind; that it shall not suffer derangement in passing over rough ground, as otherwise it might be liable to explode or become unserviceable; and, that the ammunition may be packed in such a manner in the boxes that it can be easily taken out when required.

All ammunition wagons carry a spare wheel, which is placed on an axletree attached to the perch: the French carry it behind the carriage, so that it can be removed without unlimbering the wagon. There is only one description of ammunition wagon [6] for the different batteries, but the interior arrangement of the boxes differs according to the nature and bulk of the ammunition.

6. The ML. R. field guns have iron carriages. *A wrought-iron field gun-carriage* (Fig. 45) is made chiefly of wrought iron; the trail consists of two brackets of plate iron riveted to an angle-iron frame, connected by transoms and bolts, and meeting at the trail eye. The wheels have wooden spokes and felloes, but gun-metal naves; the axletree has a wooden bed, but the arms are not *steeled*, the pipe box being of soft metal. The axletree boxes carry two rounds of case shot each, and are fitted as seats with guard irons and steps. The handspike of carriages for the bronze 9-pr. for Indian service is made of iron with a T handle, and is hinged to the trail so as to fold back, but the iron carriages for general service (for 9 and 16-prs.) have the removable wooden handspike. The elevating screw [7] works in a metal nut enclosed in an iron box between the brackets, and the nut is turned by a pinion connected by a shaft with a

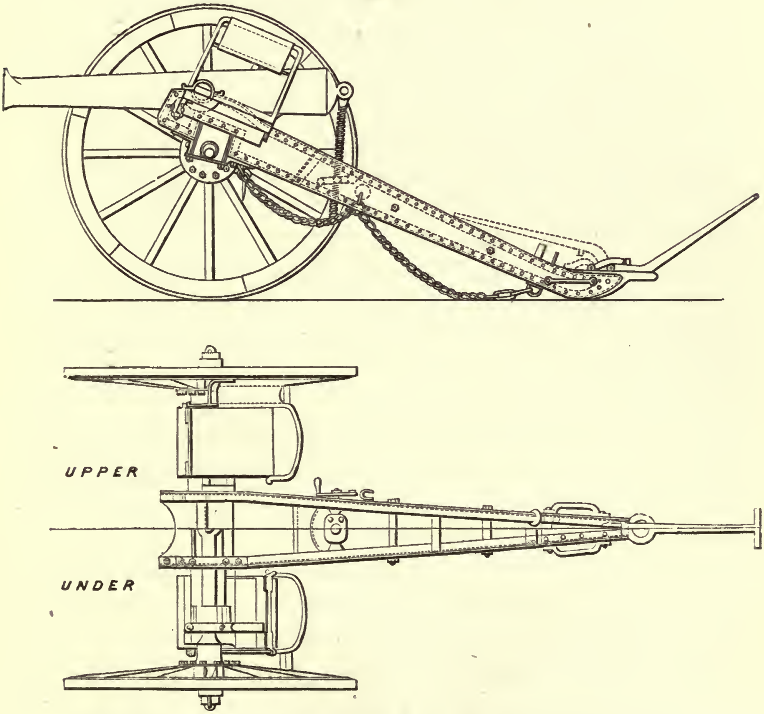
[6] There is, however, a special ammunition wagon for the BL. R. 6-pr. Armstrong Gun when equipped for colonial service.

[7] Designed by Sir J. Whitworth, Bart.

handle outside the bracket. A brass plate giving the ranges and elevations is attached to the top of the right bracket.

In the *limbers*, *ammunition*, and other *wagons*, iron is used for futchells, perches, and frames, iron filled in with wood for splinter bars, wood for platform and footboards, the wheels and axletrees with beds being similar to those of the gun-carriage.

Fig. 45.



Wrought-Iron Field Gun Carriage (9-pr. ML. R. Indian Service).[8]

For the ML. R. 9-pr. each limber or wagon box holds 18 rounds, viz. 6 common and 12 shrapnel shell; for the ML. R. 16-pr. each limber or wagon box holds 12 rounds, either 5 common and 7 shrapnel, or 7 common and 5 shrapnel, or 12

[8] The removable wood handspike for the iron carriages is similar to that of the wood carriages (see Fig. 43). Thus Figs. 43 and 45 show the different kinds of trail handspike. The present pattern of iron gun-carriage will probably be modified, and the wood axletree bed be replaced by iron.

shrapnel shell. The limbers have centre boxes for fuzes and tubes, but the wagons have no centre boxes.

7. *The rocket wagon* only differs from the ordinary field ammunition wagon in the boxes being made deep enough to receive 25 Hale's rockets, resting vertically in each box, and in having no centre boxes. It carries the same stores as the ammunition wagon, excepting the spare wheel and tents. It is fitted with three blocks of wood—one on the perch, one on the centre, and one on the rear of the wagon for the conveyance of the rocket trough. It is also fitted with box staples and pins to take the gun ammunition boxes, so that it may be used as an ordinary ammunition wagon if required.

The limber is also the ordinary field limber, fitted with two boxes like those on the wagon, each to carry 25 rockets, and one centre box to carry portfires, slowmatch, tubes, &c.

The wagon with four boxes and limber with two boxes carry together 150 rockets; it answers for either 9 or 12-pr. Hale's rockets, the dimensions of the boxes being the only point of difference.

8. Besides the carriages described above, there are a number of others to carry the stores, tools, &c., requisite to keep the battery in a state of efficiency; these carriages would, if possible, be kept entirely out of action, but, as they might be required under peculiar circumstances (for instance, in rejoining their batteries) to move with rapidity, and for the sake of simplicity in the *matériel*, their general construction has been assimilated as much as possible to those of the gun-carriage and ammunition wagon. All these carriages have wheels of equal height, viz. 5 feet, and take the same axletrees as the gun-carriages of the battery to which they belong.

The *forge wagon* consists of the body of an ammunition wagon, carrying a movable frame for the bellows, hearth, anvil, &c., and the limber, in which the necessary tools are conveyed.

The *store wagon* consists of a body and limber, and is employed to carry the various stores of a field battery, such as the collar-makers', wheelers', farriers' stores, &c.

The *store cart* carries the company's books, officers' stores, &c.

The *spare gun carriage* is merely an ordinary gun-carriage, fitted up so as to carry four axletrees, the ironwork for a spare gun-carriage, a pair of shafts, two sponges, one wadhook, and other spare articles for the battery.

The forge and store wagons and the store carts are, however, to be replaced by G. S. wagons, which as they hold more stores, will not be required in such numbers. The spare gun carriages will be attached to the reserve columns.

9. Sleighs have been employed in Canada, to convey guns and ammunition during the winter; one sleigh carries the gun, and two others the boxes of the limber and wagon.

10. Artillery for mountain service, with ammunition, stores, &c., are usually conveyed on the backs of mules: the only carriages therefore that are required for such a battery are those for the guns; these carriages are made on similar principles to those of ordinary field artillery, but are not provided with limbers, as they are not required to travel, the gun carriages being themselves conveyed on mules; the carriages are, however, furnished with a pair of shafts for single draught, which can be attached to the trail. The carriage for the 7-pr. is of wrought iron entirely, or of wrought iron with steel brackets; it can be made, by removing the elevating screw and lowering the breech of the gun into a hollow between the brackets, to give 34° of elevation to the piece if required.

Siege Carriages.

11. The second class of carriages are those intended for heavy guns and howitzers, employed in the attack of fortresses. These carriages do not require the same mobility as field carriages, or those for guns of position, but must be capable of travelling over rough roads and ground presenting considerable obstacles, at a slow pace. These carriages require great strength, as the pieces mounted upon them are generally fired with large charges of powder.

The following principles must be carried out in the construction of a siege carriage, in order that the working of the piece may be effectively performed:—

(1) There should be only one description of carriage, both

for firing and transport; this is very important, for it is desirable to have as few kinds of carriages as possible in a siege train, and great inconvenience would be caused by having to shift the piece from one carriage to another under fire.

(2) It is generally considered that an elevation or depression of 12° should be allowed to the gun by the construction of the carriage.

(3) The carriage must raise the piece, as high as is consistent with its effective service, in order that the sill of the embrasure may be of corresponding height, by which the parapet will be strengthened, and more cover obtained.

The Prussian siege carriages are adapted to raise the gun sufficiently high to fire over a parapet, by bolting on to the trail two small open wrought-iron brackets, with trunnion holes and capsquares; the breech of the piece is supported by a gun-metal block secured between the arms of an iron stool-bed, and the elevating screw below the block is turned by a hand wheel. This arrangement is evidently suited only to a BL. gun, which could be readily served when the carriage had been run up under cover, no embrasure being required in firing with a comparatively low charge and high elevation.[9]

The following pieces[1] are mounted on siege travelling carriages:—

Rifled BL. or ML. { 40-pr.
64-pr.

ML. R. 8-in. howitzer.

SB. Mortars. { 13-in.
10-in.
8-in.

The carriages employed with a siege train are—

Gun-carriage.	General service wagon.	Sling wagon.
Mortar carriage.	Siege wagon.	Hand cart.
Platform wagon.	Store wagon.	Trench cart.

[9] A drawing of this arrangement is given in the *Report of a Professional Tour of Officers of the Royal Artillery in* 1865, p. 71.

[1] The SB. siege guns, viz. 8-inch (54 cwt.), 32-pr. (50 cwt.), and 24-pr. (50 cwt.), the 10- and 8-inch howitzers, and SB. 18-pr. (38 cwt.) position gun, were mounted on travelling carriages.

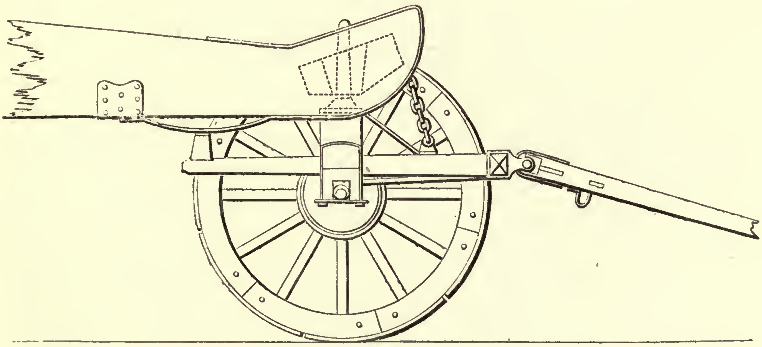
12. The *travelling carriages* for *siege guns* had *bracket trails*,[2] but block trails were introduced a few years ago in order to obtain the following advantages.

(1) That the limber, which is nearly similar to that of a field carriage, carries a small quantity of ammunition, none being carried by the old limber. (2) That the carriage can lock round much closer, and does not therefore require much space for turning, the old limber having low wheels (3 ft. 10 in.) to effect this purpose. (3) The wheels of the carriage (gun carriage and limber) are of one height, viz. 5 ft., those of the gun-carriage being, however, of greater strength and weight than the limber wheels, which are similar to the heavy wheel for field guns.

[2] The body of the *bracket-trail* carriage consisted of two brackets, connected together by three transoms, the trail thus formed being termed a *bracket trail;* the brackets were of the same form and dimensions for the SB. pieces—8-inch 32-pr., and 24-pr.; but the length of the transoms which regulate the width of the carriage varied according to the nature of the gun; there were two sets of trunnion holes.

The limber consisted of a framework, which carried no ammunition boxes, as the straight pintail upon which the trail rested was placed upon the top of the axletree bed (Fig. 46). A part of the weight of the brackets was taken by a sweep bar, which also served to keep the limber framework horizontal. The limber wheels were made lower than those of the body of the carriage, in order

Fig. 46.

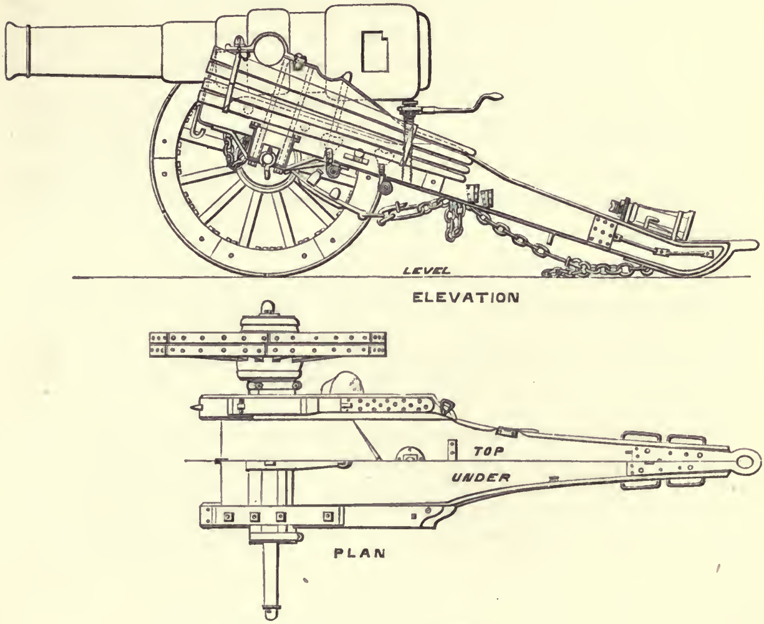


Limber for Bracket-Trail Siege Carriage.

that the carriage might be able to reverse in a small space. The draught of the carriage was not taken by the pintail eye, but by a draught chain, which connected the axletree of the gun with that of the limber.

The siege carriages for the 64- and 40-prs. are in general construction like a field carriage, but they have two sets of trunnion holes, viz. the *firing* and *travelling holes* (Fig. 47);

Fig. 47.



64-pr. Siege Carriage (Wood).

the piece rests in the former when in action, but is removed into the latter if required to travel any distance, the weight of the gun being thus more equally distributed between the wheels, and the end of the trail kept down upon the pintail in going up hill or over obstacles. These carriages have no axle-tree boxes. The elevating screw has a ratchet head turned by a removable lever handle; it works in a gun-metal nut let into the trail, and it is not attached to the gun. The siege carriages of the 64- and 40-pr. rifled guns,[3] being merely converted carriages of the smooth-bored siege pieces, have no traversing

[3] The 64-pr. travelling carriage will take either BL. or ML. gun.

saddles ; but the carriages of the 40-prs., as *position guns*, being specially made for them, have traversing saddles.

The limber for these carriages has a straight pintail bolted to a short block of wood in rear of the axletree-bed. It has two pairs of shafts, one similar to that of a field limber, and the other a pair of frame shafts fitting on to a long bolt attached to the splinter bar; at each end of the splinter bar is an iron *outrigger* which has a loop for a swingletree, and another for an iron stay to connect it with the drag washer (of shaft iron) on the axletree. By means of the shafts and outriggers, four horses can be harnessed abreast; the outriggers can be turned back when not in use.

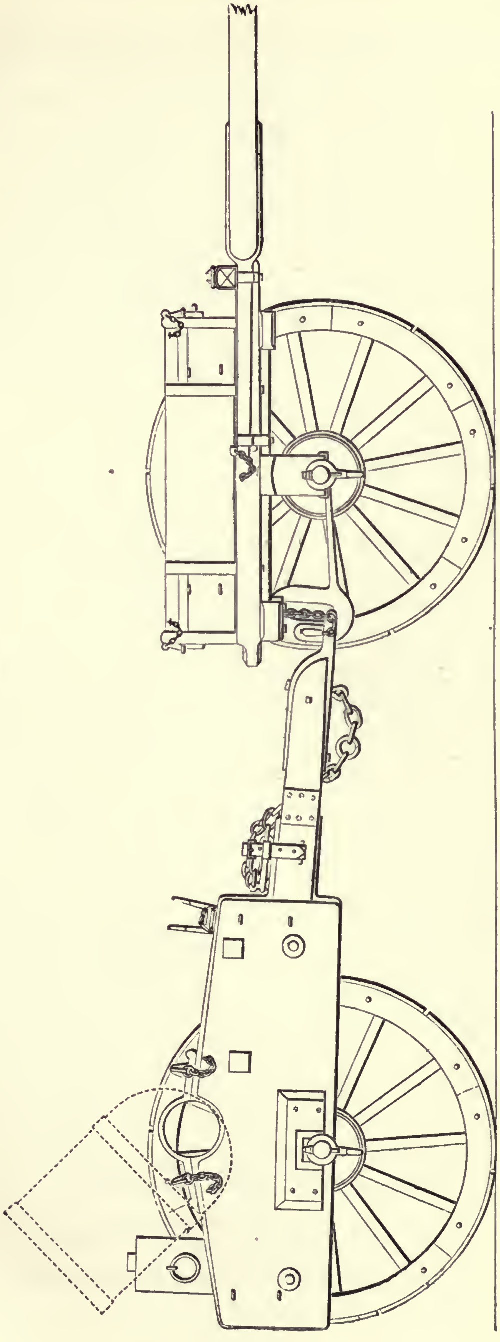
13. The body of the *travelling carriage for a mortar* consists of a bed, having an axletree let in underneath, and a perch in front which hooks up to the pintail of the limber ; the bed for each nature has running-up bolts, and that for the 13-in. has in addition movable traversing bolts in front and horns behind ; on each side of the bed is an iron plate which protects the ends and top, and forms a trunnion plate : the beds are supplied with ordinary capsquares (Fig. 48). When in battery the wheels are removed, and the bed rests as usual on a platform.

The carriages of the 8-in. and 10-in. mortars have *shell cart limbers*, in which a number of shells can be conveyed; this limber is a kind of trench cart having movable sides, a crooked pintail behind, and a number of battens or cleats of wood upon which the shells rest; the battens have iron pins underneath near each end, and by placing them along the bottom of the limber at different distances, the limbers can be adapted for the transport of shells of various sizes. By thus arranging the battens, this limber can carry

Six . .	13-in. shells,
or Twelve .	10 „ „
Twenty .	8 „ „
Thirty-five	32-pr. „
Seventy-two	24 „ (or $5\frac{1}{2}$-in. mortar).

The limber is provided with two single reversible shafts, and two outriggers like those of the ordinary siege limber.

Fig. 48.



Travelling Mortar Carriage (10-inch).

The 13-in. carriage takes the same limber as the block trail siege gun-carriages.

14. The siege carriages just described are of wood, but wrought-iron travelling carriages have been made for the ML. R. siege guns, and will, no doubt, shortly be adopted for general service. The ML. R. 8-in. howitzer is mounted on a wrought-iron travelling carriage, which serves as a bed when the wheels are removed, and allows of angles of elevation up to 40°.

15. The *platform wagon* is a wagon having no sides, and fitted up by means of wooden brackets, either for guns, mortars or their beds, and gyns. This carriage is capable of carrying one 10-in. mortar and its bed, or two 8-in. mortars and their beds, or a gun and its carriage (placed over the gun).

16. *The general service wagon* is of ordinary construction, having a long body covered with waterproof canvas; it is fitted for double draught, and has wheels and axletrees of the third class. It will carry a weight of $1\frac{1}{2}$ ton, or take 20 powder cases.

17. The siege wagon is merely a general service wagon fitted with movable trays for shot and shell; it has second-class wheels and axletrees. The *store wagon*, by removing its internal fittings, will carry 16 powder cases. The *hand cart* will take a load of 15 cwt.

18. The ordinary *sling wagon* consists of a wooden frame and perch, the eye of which hooks on to a straight pintail on the limber, thus forming a four-wheel carriage; it has a *windlass* over the axletree worked by levers for raising the gun or mortar, the trunnions of which are supported by iron *thimbles* and a *sling* of 6-in. rope. The wheels are 7 ft. in diameter, and the gun is slung below the wagon with its muzzle to the rear, the breech being lashed up to the perch; besides the gun, its carriage is also carried over the perch. This is a most useful carriage for conveying ordnance considerable distances, and as the wheels are of large diameter, over very rough or uneven ground. There are two heavier sling wagons, one of wrought iron with 8-ft. wheels to transport guns of from 6 to 12 tons, and the other of wood with 11-ft. wheels for ordnance of from 12 to 25 tons weight.

19. The *trench cart* is merely a small cart with shafts for single draught. 10-in. and 8-in. mortars and their beds, as also the small brass mortars, can be transported in trench carts, although they are used for a variety of other purposes.

Wheels and Axletrees.

20. The travelling carriages having been described, it is necessary to give a brief account of their different wheels and axletrees.

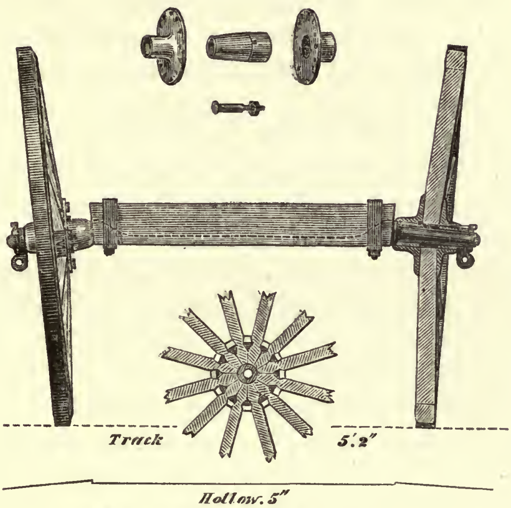
A wooden wheel of ordinary construction has a stock or *nave* of elm, 12 *spokes* of oak, and 6 *felloes* of ash. A cast-iron *pipe-box* is fitted into the nave, and, as before pointed out, the hollow passing through it is enlarged in the middle to hold grease, so that the bearing surfaces extend only to 3 inches from each end; the nave is strengthened by two *nave hoops*.

Wheels are made with a *dish* or inclination of the spokes outwards, to enable them to withstand the lateral thrust that they may be subjected to in passing over uneven ground, when one wheel is often much higher than the other, in which case a pressure is exerted on the nave of the lower wheel tending to force it outwards; the dish is usually about ½ in. for 1 ft. in length of spoke.

The tire of the wheel of the wooden artillery carriage now in the service is composed of 6 short pieces of iron called *streaks*, each of which is placed over the junction of 2 felloes, and secured with 4 bolts and 2 nails; by using a *streak* instead of a *ring* tire a wheel can be repaired in the field, for as the streaks are of small size, they can be transported with a battery, and heated in the ordinary field forge.

The wheels of all carriages liable to come under fire are, however, to have gun-metal naves (Fig. 49) and ring tires. The nave consists of three separate pieces—two flanges and a pipe-box, the latter being prevented from turning by a projecting feather, fitting into a slot cut in the inner flange; the flanges are connected by 12 boss-headed triangular iron bolts, passing between the spokes, and secured by nuts on the outside of the inner flange.[4] The spokes are of oak and the felloes of ash.

Fig. 49.



Wheel with Gun-metal Nave.

In the *field* wheel, the ring tire is 3″ wide, and $\frac{5}{8}$″ thick, and is secured by six bolts, with nuts and collars, one bolt passing through the middle of each felloe. In the *siege* wheel the tire is formed of two rings of the same size as that on the field wheel, shrunk on side by side, and each ring is secured to the felloes by six bolts, the bolts being placed diagonally across the felloes.

The wheels of carriages for all services, not exceeding 3″ in breadth across the sole of the felloe, will in future manufacture be shod with ring instead of streak tires.

The *track* of wheels is the distance from the outside of one to the outside of the other; it is 5 ft. 2 in. for the wheels of field carriages.

Wheels are divided into four classes, termed *siege*, *field*, *general service*, and *naval* wheels; there are several wheels in

[4] The pipe-box, if it has to run upon an old *steeled* arm, is bouched with steel at both ends, to prevent wear of the bearing surfaces from the friction on the arm.

each class differing in weight and diameter, but all in a class have the same *pipe-box*, and will therefore fit on the same axletree arm.

21. Wooden and iron travelling carriages hitherto made for our service have wrought-iron axletrees let into wooden beds; the axletree-bed is fitted underneath the brackets and trail by *housings*, and is attached to the carriage by two axletree-bands, having bolts passing through them and the brackets. The axletree is also secured at each end of the bed by a *yoke-hoop* and *coupling plate*; the hoop can be tightened by screwing up the coupling plate, in case the wood shrinks. The axletree-arms have a slight inclination downwards termed the *hollow* of the arm (see Fig. 49), so that the lowest spoke of each wheel may be vertical; if a wheel has no *dish* the *hollow* of the arm is not required. The arm has also a very slight inclination forwards called the *lead;* the hollow and lead together are termed the *set* of the arm. The bearing surfaces of the arms of axletrees for wheels having cast-iron pipe-boxes are *steeled*, to prevent wear.

Axletrees are, like wheels, divided into four classes, named respectively *siege*, *field*, *general service*, and *naval* service axletrees; each class contains several natures of axletree, but all those in a class have *arms of the same size* and only differ in the amount of metal between the arms; the similarity in the arms allows of an interchange of wheels when required.

CHAPTER VII.

STANDING AND SLIDING CARRIAGES, BEDS, AND PLATFORMS.

Garrison Carriages: 1. Construction and different kinds of garrison carriages.—2. Common standing carriage (wood).—3. Rear chock carriages (wood).—4. Sliding carriage (wood).—5. Casemate sliding carriage.—6. Wrought-iron standing carriage.—7. Wrought-iron carriages for heavy R. guns.—8. Single-plate carriage.—9. Double-plate carriage.—10. Plate compressors.—11. Hydraulic buffer.—12. Moncrieff carriage.—13. Mortar beds. Platforms: 14. Object of a platform.—15. Ground platform.—16. Clerk's platform.—17. Traversing platforms (wood).—18. Traversing platforms (wrought-iron).

Garrison Carriages (including those for Coast Defences).

1. The carriages for garrison ordnance have no wheels, and are not therefore adapted to the transport of the guns, for which a separate class of carriages, including sling and platform wagons, &c., is employed. There are three descriptions of garrison carriages, viz.—

Common standing, Rear chock, Sliding.

The first and last are made both of wood and wrought iron, the rear chock of wood.

The following principles should be observed in the construction of a garrison carriage:—

(1) The height of the carriage must depend upon the efficient working of the gun.

(2) The carriage must be so constructed that it may be easily run up or back, traversed, or moved from one embrasure to another near it.

(3) The carriage should occupy as little space as possible, for it may be exposed to enfilade or ricochet fire; and, moreover, it is desirable to have all the available space that can be obtained within the battery and under cover for the con-

veyance of ordnance, stores, &c., from one part of the works to another.

(4) The material of which the carriage is composed must be capable of withstanding the exposure to the various changes of the atmosphere for a considerable period, as, except when in casemates, the carriages are not under cover.

With guns of over 4 tons, the slope of the platform is not alone sufficient to limit the recoil, and it has been found necessary to check the motion of the carriage by means of a *compressor*, which by acting against the platform causes the resistance requisite to absorb the recoil. As will be seen, there are various patterns of compressors.

2. The *common standing carriages* when made of wood are composed of two *brackets*, connected together by a *transom*, two *bolts*, one passing through the transom, and two *wooden axletrees;* they are not mounted on wheels, but on four small iron *trucks*, the two front being of larger diameter than the two rear trucks; elevation is given to the gun by means of *quoins* and *elevating screw*, the latter supporting the *stool-bed* upon which the quoins and breech of gun rest; the front of the stool-beds fits on to the rear bolt. These carriages have no capsquares, as the guns mounted on them are very heavy, and consequently have not such violent action when discharged as lighter pieces[1] (Fig. 50).

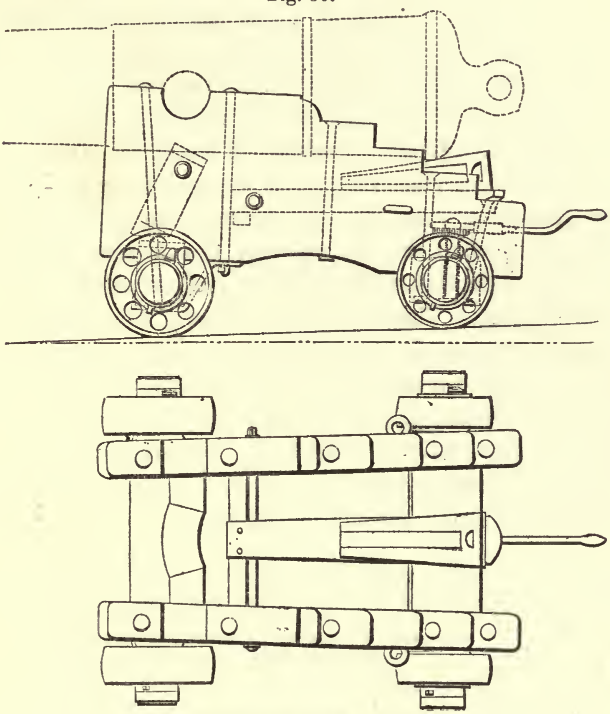
In consequence of the rapid decay of wood in some climates, especially in the tropics, a certain number of carriages are made of cast iron with open brackets, but these have the following disadvantages, viz. that they weigh two-thirds heavier than wooden ones, that if struck by a shot they would be easily damaged, the splinters from them would be very destructive, and if fractured they are difficult to repair.[2]

[1] Besides the common standing, there is a depression carriage for guns mounted, as in Gibraltar, at great height above the plane; also a converted Armstrong non-recoil carriage.

[2] It is not intended that these cast-iron carriages should be used in war time, and an old order directs that a wooden carriage should be supplied with every iron carriage, so that it may be substituted for the latter on the breaking out of hostilities. Wrought iron is a good material for gun carriages, as it does not break up if struck by a shot like cast-iron, and is more durable than wood; at

3. A *rear chock carriage* is similar in construction to a garrison standing carriage, except that it has only the two front

Fig. 50.



Garrison Standing Carriage (Wood).

trucks, and, instead of a rear axletree, it has a block of wood which rests upon the platform.

The *howitzer* (*rear chock*) *carriages* are of similar general construction to the gun carriages, but are strengthened with iron to a greater extent.

4. *Sliding carriages* are mounted on traversing platforms, and are used in coast batteries where rapidity of traversing is required, the objects fired at from such batteries being seldom stationary. A sliding carriage for a dwarf traversing platform is similar in construction to the garrison standing carriage,

the same time it is more expensive and probably more difficult to repair than the latter.

but instead of axletrees it has two blocks upon which it rests on the platform, the part of the block between the cheeks being deeper, and passing between them so as to keep the carriage in its place (Fig. 57). A pair of *cheek plates* are attached to the front of each bracket, in which works a gun-metal truck that comes into play when the rear of the carriage is hoisted up by the *truck levers*. It recoils on the blocks, but can be easily run up after loading by using the truck levers, which raise the carriage on to four trucks; its forward motion can be checked at any time by means of the *preventor rope*, which is attached to the rear block of the carriage, and, being twisted round the *bollard* of the platform, is held by one of the gun detachment. The carriage is run back at drill by means of tackle, the levers also being used to raise the carriage off the blocks; a wood *compressor*, worked by an iron handle, fits in between the blocks, and also between the side pieces of the platform, against which it presses in checking the recoil.

5. The *casemate sliding* is similar to the dwarf sliding carriage, except that it has lower brackets.[3]

[3] The following angles of elevation and depression can be given to guns mounted on garrison standing carriages with a ground platform, viz.—

About 11° elevation (with stool-bed and elevating screw).
„ 23° „ (without stool-bed and elevating screw).
„ $5\frac{1}{2}$° depression.

With a rear chock carriage rather more elevation can be given, but about the same angle of depression.

With a dwarf platform and sliding carriage the angles are—

	Elevation: With bed and screw	Elevation: Without bed and screw	Depression
	°	°	°
To a 7-in. gun, R.	16	$26\frac{1}{2}$	6
„ 68-pr. 95 cwt. SB.	10	$19\frac{1}{2}$	5
„ 10-in. gun, SB.	11	20	5

With a casemate platform and sliding carriage—

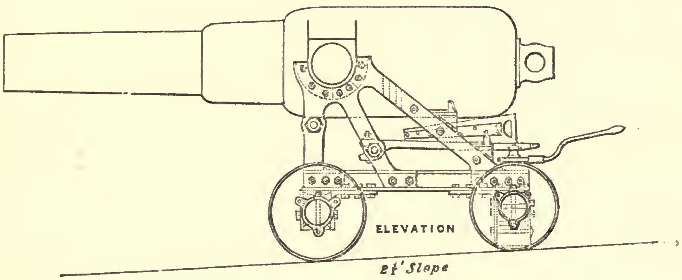
	Elevation: With bed and screw	Elevation: Without bed and screw	Depression
	°	°	°
To a 7-in. gun, R.	6	13	6
„ 68-pr. SB.	3	10	6
„ 10-in. gun, SB.	$2\frac{1}{2}$	10	5

6 Two patterns of wrought-iron *garrison standing carriages* have been approved for service in climates where wood is liable to rapid decay. They are of similar construction, but the brackets of (2) are four inches closer together than those of (1).

The carriages are constructed of open or *skeleton brackets*, each bracket consisting of three *stays* of double plate iron $\frac{3}{4}''$ thick, bolted to a *tie beam* of T iron at the lower ends at such intervals as to afford the greatest strength to the carriage (Fig. 51).

The axletrees are made of 7″ girder iron (I), and two blocks of sabicu are screwed underneath the rear axletree, to enable

Fig. 51.



Wrought-Iron Garrison Standing Carriage.

it to be used as a rear chock carriage by removing the rear trucks.

The trucks are of elm, bouched with gun-metal, and shod with iron ring tires; each carriage has an iron stool bed, ratchet-headed elevating screw, and two quoins. When not in use the carriage is to be mounted on cast-iron trucks, and the wooden ones placed in store.

No. 1 *carriage* takes the 64-pr. BL. or ML. R. gun without fittings, and the 8-inch (65 or 54 cwt.) either as SB. or as

The height of a garrison carriage is such as to allow of the gun being fired over a 2 ft. 7 in. *genouillère*.

The height of *genouillère* for a gun mounted on a

	ft.	in.
Dwarf platform and dwarf sliding carriage is	4	3
,, ,, casemate ,,	3	2
Casemate platform and ,, ,,	2	7

Palliser converted ML. R. 64-pr. gun with a trunnion plate in each trunnion hole.

No. 2 *carriage* mounts the 32-pr. of 58 cwt. either as SB. or as Palliser converted ML. R. 64-pr. gun, with a trunnion plate in each trunnion hole, and the 32-pr. of 56 cwt. with a collar on each trunnion, in addition to the plate in trunnion hole. For the 40-pr. BL. R. gun there are special trunnion plates.

Weight of carriage, 17 cwt. 1 qr.

7. Carriages for guns weighing 6 tons or more are made of wrought iron. These carriages for different natures of guns are similar in construction, but differ in dimensions and in the substance of the iron employed.[4]

A wrought-iron gun carriage consists of the following parts, viz.—

2 Brackets.	4 Gun-metal trucks.
1 Transom.	Elevating gear.
1 Bottom plate.	Compressor.

There are two constructions of these carriages, the *single-plate* and *double-plate*, and there are several patterns of each construction.

8. The bracket of a *single-plate* carriage is made of *plate iron* riveted to a frame of *angle iron* and strengthened with a centre stay of T iron, riveted diagonally across the plate from the rear of the trunnion hole to the bottom of the frame. Four holes are cut through the bracket:—

(1) For the breeching.

(2) „ compressor screw.

(3) and (4) For the spindles of elevating gear and friction roller.

[4] Wrought-iron carriages of various special patterns designed by Capt. R. A. E. Scott, R.N., to suit different ships and gunboats, are used for the ML. R. 9- and 10-in. guns. They have low brackets (with cast-iron frames) which reach nearly to the lower edges of the slide, the essential feature of the design being a very low carriage and high slide with the usual height for the gun. The carriages for the ships have training and running in-and-out gear; in the gunboats they have no such gear, and are pivoted at the centre of gravity of the whole system. (*List of Changes*, § 2023–24.)

These and the trunnion holes are lined with gun-metal, the centre of the latter being $\frac{1}{2}$ in. below the top of the bracket in all but the 9-in. dwarf and the 12-in. gun carriages, in which the sink is 1 in.

The transom is made of plate iron riveted to angle iron.

The bottom is of plate iron, to the under surface of which are riveted 2 *guides* of angle iron, intended to fit in between the sides of the platform or slide, and keep the carriage from running off; the distance between the outside edges of these guides is the same in all carriages except the 12-in. An aperture is cut in the bottom for the plates and levers of the compressor, and a stay of angle iron is riveted across the bottom in rear of the aperture, to strengthen the plate and prevent its buckling.

A stay of T iron is bolted to the inside of the rear of the bracket, and to the bottom on each side, to secure rigidity in the carriage.

The trucks work in iron *flanged feet*, bolted to the brackets; the rear trucks have eccentric axles.

The *elevating gear* may be thus described:—The breech of the gun is fitted with a *segmental arc* on each side (Fig. 52), and elevation is given by an iron spindle working through each bracket, and having an iron *pinion-wheel* inside the bracket, the teeth of which work into those of the segmental arc. On each spindle outside the bracket is an iron *drum*, having a number of holes in its circumference to receive the point of the lever used to work it; the drum can move laterally on the spindle, but is prevented from turning round it by a projection on the axis of the drum, fitting into a slot in the spindle. The elevation given by turning the drum can be preserved by a *screw-lever clamp* outside each drum, the clamp, when turned, pressing the drum and pinion tightly against the bracket between them. A *friction roller*, attached to the inside of each bracket in front of the pinion, keeps the teeth of the arc, which is not rigidly attached to the gun, in gear with those of the pinion.

9. The *double-plate* (Figs. 52, 53) differ from the single-plate carriages in the following respects, viz.—

The brackets are made of two plates with a frame of *flat iron* between them, the whole riveted together, instead of a single plate riveted to an angle-iron frame. The plates extend beyond the frame at the bottom in the front and rear, so as to form flanges for the trucks, and there are movable strengthening plates at the bottom in rear.

Instead of sockets for the rear trucks a *connecting bar* joins the axles of the trucks, and has a socket hole at each end for the point of the shod levers; the trucks must therefore always move together.

The *elevating gear* of the carriages for the 9-in. gun and under is the same as described above, but for 10-in. and heavier guns the arrangement is somewhat different. Instead of capstan and levers, a *worm-wheel* and *worm* are used for elevating, the worm being on a shaft attached to the inside of the bracket, but projecting beyond so as to be worked by a hand-wheel on the end of the shaft in rear of the carriage.

To the front of the transom of the carriages is bolted a cleat of wood, which, when the carriage is run up, comes into contact with four gutta-percha buffers on the inside of the front of the platform or slide, so as to lessen the shock in running up. There is also a buffer on each side of the platform or slide inside the girder, to receive the rear of the carriage in the recoil.

10. There are two patterns of *plate compressors* attached to the iron *sliding carriages* for heavy R. ordnance, one to the single and the other to the double-plate carriages, the latter being merely a modification of the former.[5]

The compressor of the single-plate carriage consists of a number of iron plates suspended through the bottom of the carriage, between which are others attached to the platform or slide; these plates, being jammed together, check the recoil of the carriage. The compressor plates of the carriage hang through the aperture in the bottom plate, being suspended by slots cut on each side, fitting on to the angle iron of the transom, and to a bar bolted to the bottom plate.

On each side of the plates is a *rocking lever* pivoted on a

[5] The principle of the American compressor has been adopted in the plate compressors.

Fig. 52.

Double-plate Wrought-iron Carriage.

a. Segmental arc. *b.* Drum. *c.* Friction roller. *d.* Screw-lever-clamp. *e.* Compressor plate. *f.* Adjusting handle. *g.* Adjusting arc.

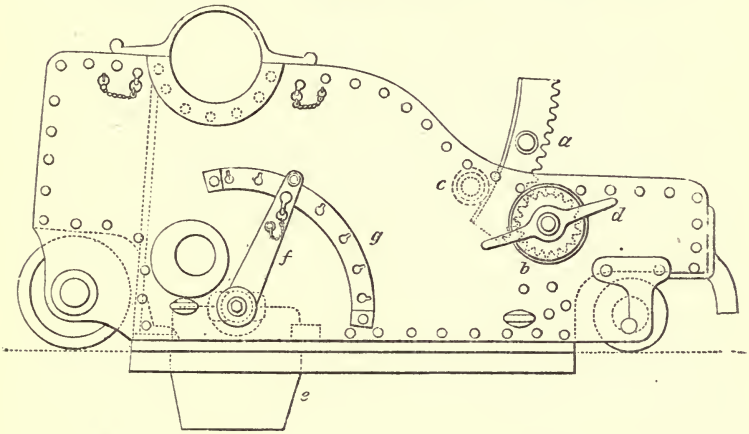
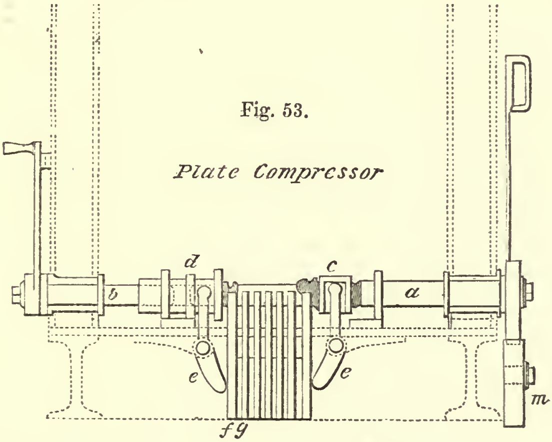


Fig. 53.



a. Compressor shaft.
c. *d.* } Nuts working levers.
f. Compressor plate on carriage.
b. Plain shaft.
e. Rocking levers.
g. Compressor plate on platform.
m. Tripper.

stay bolted to the bottom plate; the lower arms of these levers bear respectively against the outer plates of the carriage, and on the upper arms of the levers are *slotted screw nuts* to receive the screw shafts, which, passing through the brackets are worked by two *lever handles.* By pressing down the handle on either side, the lower arm of the rocking lever connected with it presses the plates towards the opposite lever arm. The screw on the shaft on the left side is only half the pitch of the other, and is termed the *adjusting screw;* the other is called the *compressor screw.*

The *compressor shaft* of the double-plate carriage (Figs. 52, 53), extends beyond the plates, and has two threads upon it, one for each rocking lever; the threads run in opposite directions, but are of the same pitch, viz. $1\frac{1}{8}$ inch. The end of the *compressor screw* shaft fits into a nut on the end of the short plain shaft of the *adjusting handle.* The arms of the rocking levers are lengthened.

The advantages of this compressor over the former pattern are, that the strain of compression is taken by the *shaft,* and not by the brackets, and that the screws are not so liable to run down.

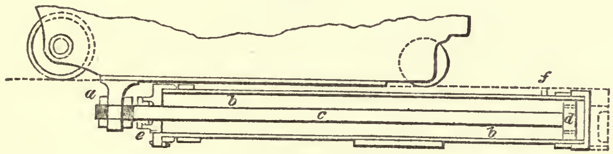
The compressor is thus made to act. The lever handle of the *adjusting screw* is forced through an arc corresponding to the amount of compression required, and then secured by a keep-pin passing through the handle, and into one of the holes in a metal arc attached to the bracket. The handle of the *compressor screw* is always pressed down through the whole arc, so that the plates are jammed towards the rocking lever of the *adjusting screw.* It is obvious that, by securing the lever handle of the *adjusting* screw at the different distances on the arc, the amount of compression may be varied.

Should the gun detachment omit to press down the handle of the compressor screw, a metal *tripper* attached to the platform or slide will catch the short arm of the handle and force it down through the whole arc.

11. The *hydraulic buffer,* intended to replace the compressor, is simple in construction and entirely self-acting (Fig. 54). It consists of an iron cylinder with rod and piston, the latter, which is 8·04 inches in diameter, having four holes to allow of the passage of the fluid in the cylinder from one side of the piston to the other when moving. The cylinder is attached to

the platform or slide by two bands, and has a filling hole at the top in rear, and an emptying cock at the bottom in front. The piston rod is connected to a bracket attached to the carriage above, and the carriage is provided with *clips*, to prevent its

Fig. 54.



Hydraulic Buffer

a. Bracket. *b.* Cylinder. *c.* Rod of piston.
d. Piston. *e.* Emptying tube. *f.* Filling tube.

rising on recoil. The buffer is adapted to use with all the heavy ML. R. gun carriages, the only difference being in the size of the holes.

For 7-in. gun-carriage,	diameter of hole	is	1·25 in.
„ 8 „	do.	do.	
„ 9 „	do.	do.	1·00
„ 10 „	do.	do.	·80
„ 11 or 12-in.[6]	do.	do.	·90

The cylinder can be filled with water,[7] or Field's oil, which is non-freezing. The cylinder holds 12 gallons of water, or about ·1 more of oil. When the gun recoils, the piston, being forced rapidly back, is resisted by the fluid, which can only pass through the holes at a certain rate, depending upon their diameter. The buffer does not interfere with the running up of the gun, for, the velocity being then low, the fluid can easily pass through the holes from one side of the piston to the other.

12. The principal parts of the *Moncrieff carriage* are, the

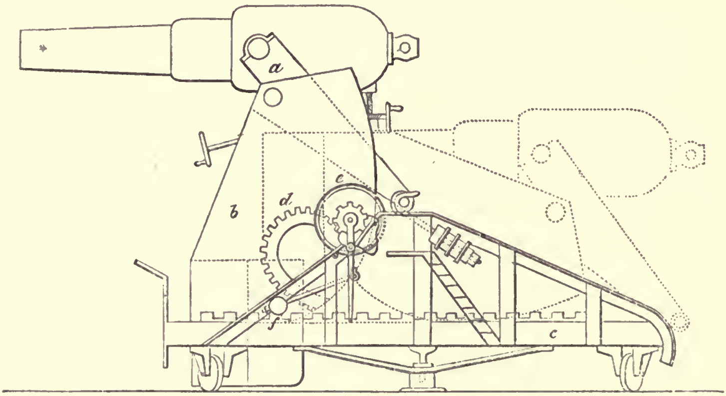
[6] Of 25 tons.

[7] The carriage is run back to the stops, and the cylinder is filled with 12 gallons 7 pints of water, the carriage being then run up and 7 pints removed, thus allowing a small space for air. A graduated gallon measure, of tin, with a metal cock, is supplied for filling the cylinder.

carriage, the *elevators*, and the *platform*. The *carriage* (*a*), consisting of iron brackets with stool bed and elevating screw, is supported between the elevators on a strong bolt or shaft passing through them from side to side; each bracket has a truck in rear to run upon the inclined frame of the platform (Fig. 55).

The *elevators* (*b*) are merely two very large iron brackets, with a box between them to hold the *counterweight*, which is rather heavier than the gun; they are curved in rear and pro-

Fig. 55.



Moncrieff Carriage.

vided with teeth to run in rolling back upon the horizontal side-pieces of the platform, which have corresponding teeth.

The *platform* (*c*), consisting of iron side-pieces and frame above, traverses round a central pivot by means of four trucks running on racers. A self-acting break wheel (*e*), with a pinion inside working into a *cycloidal arc* (*d*) on the elevator, is attached to the platform, to hold the elevators down and to check them in rising when necessary.

In later constructions (for the 7-in. guns) the carriage has been dispensed with, the trunnions are held by the elevators, and the breech of the gun is supported and can be elevated or depressed by the following arrangement. An upright rod attached to the breech pivots between two levers below on a bolt passing through them; these levers fork to the front and work on centres inside the elevators, one to each; the other ends of the levers are connected by a roller, which works in a slotted *guide* pivoted in rear to a transom of the platform. The front of the guide has a *toothed arc* below worked by a pinion to give elevation, the pinion being turned by a drum on the same axis, but outside the platform. The elevation is preserved by a *break* with lever arm and weight at the end. To check or raise the gun, a *connecting rod* is attached at one end to the elevator, and at the other to a *movable rack*, worked by toothed gearing, but which can be kept at rest (when the gun is in loading position) by a *break* with lever and weight. Should the gun have not recoiled sufficiently, it can be brought down by an iron-shod lever, working a pinion connected with the gearing, which is provided on both sides. For the 9-in. gun the arrangement is the same in principle, but there are two upright rods and two guides, one on each side; as much width as the trunnions will allow is given between the elevators; and, as the force of recoil is greater with the use of heavy charges of pebble powder, the counterweight is increased.

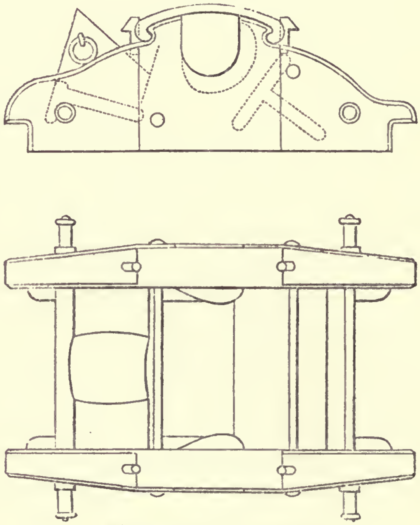
The purpose of the carriage is to protect the gun from direct fire, and to obtain security for the gunners when loading. Its working is as follows:—When the gun is fired, the recoil of the carriage forces the elevators to roll backwards upon the platform, the gun therefore descending and the counterweight rising. The weight of the latter gradually checks the motion, and brings the gun to rest when below the parapet; the break preventing the gun being again raised by the fall of the counterweight, the piece can be loaded under cover of the parapet, but, by releasing the break, it can be quickly raised for firing. With this carriage it is obvious that no embrasure is required.

13. Mortars are not, like guns and howitzers, mounted upon carriages, for, being fired at very high angles of elevation, a carriage having wheels or trucks would not be capable of withstanding the shock of the discharge, the vertical strain from which is so very great. *Beds* of wood or iron of simple construction are therefore employed, the whole length of the bed

resting on and being supported by the platform.[8] A mortar bed is provided with a quoin, upon which the piece rests, usually at an angle of 45°, and also with bolts on each side, both in front and rear, for the convenience of running the mortar up or back (Fig. 56).

In mortar vessels the mortar rests upon its wooden bed, which traverses on a central pivot over a large table of wood,

Fig. 56.



Mortar Bed (10-inch SB.).

called an *octagon deck*, having a gun-metal racer for the bed to turn on; this deck is supported on circular pieces of india-rubber, about $2\frac{1}{2}$in. thick, which take the shock of the discharge of the mortar, and by their reaction prevent injury to the vessel.

The beds for

Sea service mortars		(13 and 10-in.)	are of wood.
Land	do.	(13, 10, and 8-in)	„ iron.
do.	do.	($5\frac{1}{2}$ and $4\frac{2}{5}$-in.)	„ wood.

[8] This is also the case with the travelling mortar carriages, which are merely beds provided with wheels for transport; the wheels, as before stated, are removed for firing.

When the SS. mortars are used for land service, they are mounted in a similar way with an octagon deck, and india-rubber rings between it and a platform consisting of four longitudinal sleepers 12″ × 10″ in section, upon which are laid crosswise three double beams, 2′ 2″ × 12″, the whole being secured by five carlings and twenty metal bolts.

Platforms.

14. It is only in the field that the gun-carriage is placed upon the ground; in every other instance it has a platform of some description on which to stand and recoil. The platform is necessary with a heavy piece of ordnance, which remains in a fixed position for a considerable time, as the carriage would otherwise sink into the ground, when it would be difficult, if not impossible, to manœuvre the piece; the recoil would be too suddenly checked, causing the destruction of the carriage, and the firing would be inaccurate. The length of a platform is regulated by the distance through which the gun recoils; the recoil is, however, checked to a certain extent by giving the platform a slight inclination to the rear, so that the gun, when loaded, may have to be run up through as small a space as possible. This inclination of the platform, if too great, would cause the piece to act injuriously upon both carriage and platform.

15. A ground platform for a siege gun is made of wood, and has a slope of 1 in 24; there are two sizes, one 18′ × 10′ for large guns, and the other 15′ × 10′ for smaller pieces. For a mortar which recoils only to a short distance, the platform is 7′ 6″ × 6′ 6″ and has no slope. Ground platforms for guns mounted in permanent works are made of stone (9″ granite blocks have been recommended); they are 21′ long, 8′ broad in front, and 16′ in rear, and have a slope of 1 in 15.

16. Clerk's platform[9] is of very simple construction, consisting of two *inclined planes*, having a slope of 3° for the wheels of the carriage to run upon, two *transoms*, two *sleepers*, and a *trail plank* for the trail to rest on; the front transom and trail planks have spikes underneath to secure them to the ground;

[9] Proposed by Col. Clerk, R.A., late Superintendent Royal Carriage Department.

the different parts are cut out of a log of fir $17' \times 20'' \times 16''$, and they can be packed into the original shape for travelling. The transoms and sleepers are buried flush with the surface of the ground, and the inclined planes and trail plank are placed on them, the latter being between the inclined planes and projecting further to the rear. It can be used for either siege or garrison guns, the inclined planes being brought nearer together for the latter.

17. Traversing platforms are of three kinds, viz., *common*, *dwarf*, and *casemate*.

Common traversing platforms are employed to raise guns sufficiently high to enable them to fire over a parapet, and they are made of either wood or iron. The wooden platforms consist of two long side pieces placed upon four legs, having trucks, which run upon circular racers let into the ground, and on the top of each side-piece is a plank for the trucks of the carriage to run upon; there is also a riband of wood inside each side-piece to keep the trucks from running off. These platforms can be made to traverse either in front, centre, or rear, the central pivot being only employed when guns are mounted on circular towers; they have a slope of 1 in 12, to check the recoil, and facilitate the running up of the gun. The ordinary garrison carriage is used with this platform, the hind trucks being removed, and a block of wood substituted for them.

The advantages obtained by the use of these platforms are, (1) that the gun can traverse through a much greater angle than an embrasure will admit of; (2) that the parapet is much strengthened; and (3) that there is more cover for the interior of the work. There are, however, the following disadvantages, viz. (1) that guns mounted on them could be easily dismounted by ricochet or cross fire, in consequence of the large object they present above the parapet; (2) their great height above the ground renders the mounting guns upon them a comparatively difficult operation; (3) also the men working the guns are very much exposed.

Wooden *dwarf traversing platforms* have almost entirely superseded the common traversing platforms, to which they are similar in general construction, and guns mounted upon them can fire through embrasures. The chief parts of this platform (Fig. 57) are—

Two side-pieces.
One head block.
Two transoms (middle and rear).
One cross block under rear transom.
Two footboards outside of side-pieces.
Four battens between side-pieces and transoms.
Four cast-iron flanges.
Four wrought-iron hollow soled trucks.

Along the top of each side-piece is a wrought-iron plate for the truck of the carriage to run upon, and two flanges with their trucks are bolted to each side-piece underneath, one in front and the other under the cross block.

A *bollard* is attached to the left side-piece for the *preventer rope*, and at the end of each side-piece is a *stop iron* to prevent the carriage running off the platform. The carriage can be transported by two wheels and a *dilly*, as shown in Fig. 57, the axletree for the former passing through two bands bolted under the side-pieces just behind the middle transom.

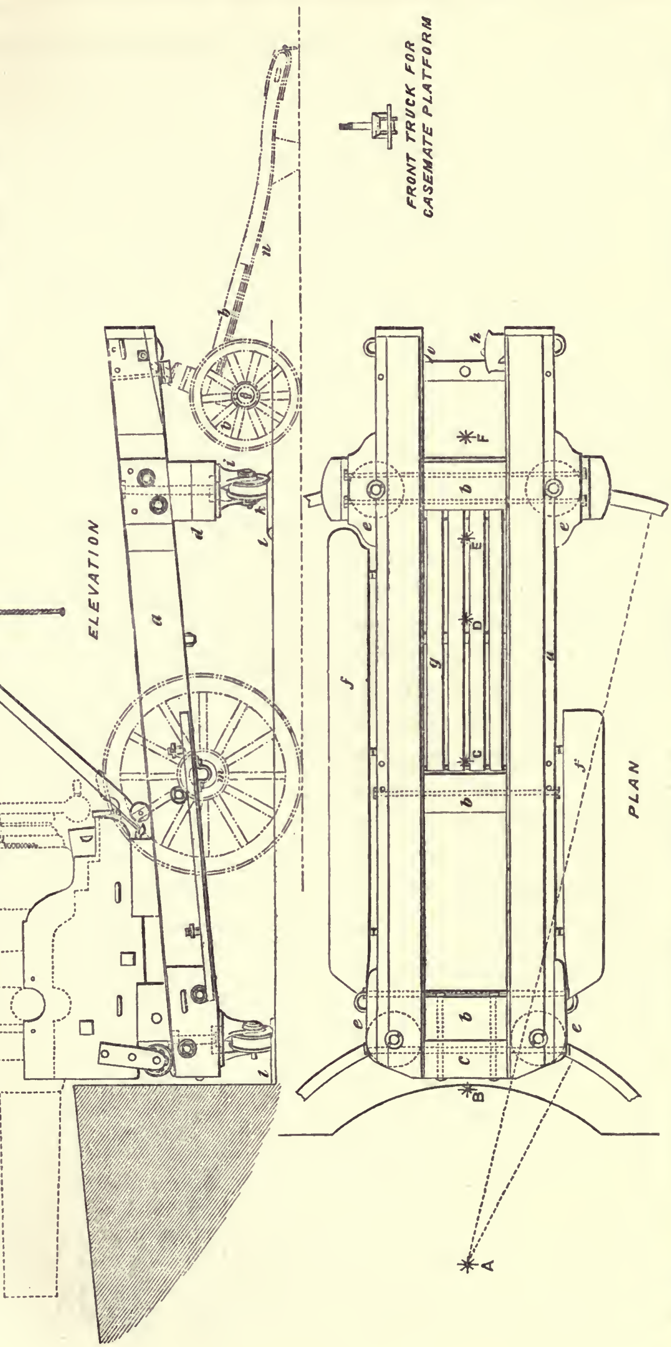
There is only one nature of wood dwarf platform, which is suitable for all the heavy SB. cast-iron guns and BL. rifled ordnance; the platform has a slope of 5°, the distance between the side-pieces is 21″, and it weighs $33\frac{3}{4}$ cwt. Both these and the casemate platforms used to traverse on a pivot fixed in the ground, but the pivot was liable to fracture or displacement from the strain of the recoil, which is now distributed over the lengths of the two curved racers upon which the *hollow soled* trucks run. By varying the positions of the racers,[1] the gun

[1] *Table of Radii.*

			′	″	
1.	Imaginary pivot	Front	5	0	A
		Rear	16	6	
2.	Radii of racers the same as with old pattern front pivot . . .	Front	1	10	B
		Rear	12	10	
3.	Radii of racers the same as with centre pivot	Front, Rear	6	1	C
4.	Radii of racers the same as with intermediate pivot . . .	Front	9	0	D
		Rear	3	$4\frac{1}{4}$	
5.	Radii of racers the same as pivot rear before chock . . .	Front	10	$8\frac{1}{4}$	E
		Rear	2	2	

Fig. 57.

Wooden Dwarf Traversing Platform.



a. Sides. *b*. Transom. *c*. Stop block. *d*. Rear block. *e*. Cheeks. *f*. Stops. *g*. Slats. *h*. Bollard. *i*. Flange foot.
k. Truck. *l*. Racers. *m*. Transporting loop, axletree, and wheels. *n*. Transporting dilley. *o*. Stops.

can be made to traverse round several different centres as required: when arranged for *muzzle pivoting* the (imaginary) centre from which the curves of the racers are described, and round which the gun moves in traversing, being at the muzzle, only a small embrasure is required [2] (Fig. 57).

The *casemate* is the same platform as the dwarf, only lowered by substituting the front flanges and trucks for the rear ones, which are removed, and supplying the place of the front trucks with two very small trucks or rollers in flanges let into the side pieces. The weight of this platform is 27 cwt.

18. Wrought-iron platforms are made for the heavy ML. R. ordnance, from 7 to 12-inch calibre. The first, made for the 7 and 9-inch single-plate carriages, had the same width between the sides, and were suited to either carriage; but the platforms for double-plate carriages differ in width according to the nature of gun mounted on them.

An iron platform [3] consists of—

Two sides.
Two transoms, front and rear.
Head plate.
Bottom plates.
Diagonal stay.
Four flanged feet.
Four trucks.

6. Radii of racers as with pivot rear behind chock . . . { Front 12 10 } F
{ Rear 2 2 }

No. 1. Applies to both casemate and dwarf platforms, the rest to dwarf platforms only.

[2] *Muzzle-pivoting* carriages, to enable the gun to be elevated or depressed without movement of the muzzle, so as, combined with the *imaginary pivot* for traversing, to require but a very small port or embrasure, have been proposed by Mr. R. Mallet, C.E., Capt. Heathorn, R.A., Col. Shaw, R.A., Col. Inglis, R.E., and others. The two latter have been tried with success at Shoeburyness.

[3] *Notes on Manufactures of the Royal Carriage Department*, by Captain C. Le Mesurier, p. 61.

TABLE OF WROUGHT-IRON CARRIAGES FOR ML. R. GUNS.

Nature	Weight	Maximum Elevation	Maximum Depression
	cwt.	°	°
12-in. (25 tons) .	68·5	15	5
10-in.	51·25	10	7
9-in.	44·5	14	5
8-in.	41·5	15	5
7-in.	30·75	20	5

and is fitted with—

- Compressor bars.
- Tripper.
- Loops for Tackle.
- Axletree bands.
- Eye-plate for limber.
- Front buffer.
- Rear stops, with buffer.
- Bollard.
- Foot planks.

The platforms provided with hydraulic buffers have no compressor bars. Those for guns of 10-in. and over are of the built-up (fish-belly) girder pattern. The dwarf and casemate are of the same construction, but the former has higher trucks and a loading stage hinged to the front.[4] All platforms for guns of 9-in. and over are to be provided with *traversing gear*, which gives greater facility and rapidity in training than tackle and ringbolts. The racer is smooth, a rack racer being objectionable for land service; the rear trucks have toothed wheels fixed to them, so that they can be driven by the gearing.

[4] See *List of Changes*, § 1937.

CHAPTER VIII.

AMMUNITION FOR SMOOTH-BORED GUNS.

1. Division of subject.—2. Classification of Projectiles.—3. Shot.—4. Shells of the common class.—5. Shells of the shrapnel class.—6. Carcass, light ball, and smoke ball. SB. AMMUNITION: 7. Solid shot.—8. Grape shot.—9. Case shot.—10. Mortar shells.—11. Common shells.—12. Diaphragm shell.—13. Carcasses.—14. Ground light balls.—15. Parachute light balls.—16. Smoke balls.—17. Wooden bottoms or sabots.—18. Time fuzes for shells of SB. ordnance.—19. Common fuze.—20. Diaphragm fuze.—21. Large mortar fuze.—22. Small mortar fuze.—23. Percussion and concussion fuzes.—24. Pettman percussion fuze (LS.).—25. Charges LS.—26. Cartridges.—27. Powder cases and barrels.—28. Wads.

1. THE term *ammunition* is applied not only to the charges of powder for ordnance and small arms, but it also includes all kinds of projectiles used in the service, the various appliances for igniting the charges, &c.

The following remarks will only refer to the ammunition used with (land service) ordnance, and to rockets; and the order followed will be—

(1) Ammunition for SB. Ordnance: Projectiles. Sabots. Fuzes. Charges. Wads.

(2) Ammunition for R. Ordnance.: Projectiles. Fuzes. Charges. Lubricators. Wads.

(3) Means for firing Ordnance. Rockets.: Tubes. Primer. Portfires. Match. Rockets.

2. Before entering upon the first part of the subject, it may be as well to explain briefly the general principle and object of each of the various classes of projectiles required for the effective service of artillery under different circumstances. Projectiles fired from ordnance—rifled or smooth-bored—may be thus classed:—

Shot		Solid and hollow. Grape. Common case or canister.
Shells	Common Class	Mortar. Common.
	Shrapnel Class	Diaphragm. Shrapnel for R. Ordnance. Segment.
Incendiary Projectiles		Carcass. Light balls (ground & parachute). Smoke ball.

3. *Shot* are cast either solid or hollow, the interior of the latter not being filled with powder or composition; or, as with grape and case shot, they are made up of a number of small balls attached or packed together. Shot have been employed to destroy, fracture, or penetrate an object by the mere force of impact; for instance, to dismount ordnance, breach revetments, penetrate and shake iron defences, or to injure troops in masses, grape and case being especially suited to this last purpose when the range is short.

4. A *shell of the common class* is a hollow projectile filled with gunpowder, which is ignited by a fuze at the required moment, the bursting of the shell causing destruction by its explosive force, and by the fragments,[1] and if the object be combustible, by setting it on fire.

[1] Formerly the bursting charge only filled a certain portion of the interior of the shell, for it was considered that the smaller charge would cause the shell to break into larger fragments; this is however of less importance than the increased effect from the explosion of large charges of powder; besides which, the filled shell will probably be less eccentric than one partially loaded, and consequently be more accurate in flight than the latter. All shells except those for field and

The thickness of metal in these shells must be such that the shell may contain as large a bursting charge as possible, but that it be strong enough to withstand the shock of the discharge within the bore of the gun. The thickness of metal in a spherical shell of this class is about *one-sixth* of the diameter,[2] and the weight of the shell (empty) is about *two-thirds* of that of a solid shot of equal diameter. The shell of a rifled gun being elongated is, usually, by giving it a greater length than the shot, brought up to the same weight as the latter. Mortar shells are fired from mortars at high angles, the large shells being intended to fall upon and set fire to buildings, vessels, or other combustible constructions, to destroy earthworks, or, by their great penetration before bursting, to explode magazines protected from other projectiles; the small mortar shells, or rather the 24-pr. and 12-pr. common shells fired from the small $5\frac{1}{2}$ and $4\frac{2}{5}$ inch mortars, are used to annoy troops posted behind parapets or cover at short ranges.

Common shells are fired from guns and howitzers against troops in line or masses, especially when posted behind cover; also to destroy buildings, earthworks, or vessels.

5. A shell of the *shrapnel class* is filled with bullets, and has a small bursting charge; the latter, being ignited by a time fuze, should be merely sufficient to open the shell at the required moment and release the bullets, which will then proceed onwards in nearly the same direction, and with the same velocity that the shell had on bursting. The conditions to be fulfilled in a shell of the shrapnel class are therefore—

(1) That the thickness of the metal should be such that it will resist the explosion of the charge within the bore of the gun, but open readily with a small bursting charge.

siege service, and diaphragm shells for any service, are filled from loose powder, the charge being as much as the shell will hold; in mortar or common shells, however, space must be left for the fuze. Bursters holding charges which approximately fill the shells are issued for field and siege services; but should a burster not fill the shell, another burster must be opened to supply the deficiency. Diaphragm shells require fixed bursting charges which are merely sufficient to open them, and are issued in calico bursters.

[2] Except in the 10″ common shell, and in the hand grenades, which have about $\frac{1}{7}$.

(2) That the bursting charge should be merely sufficient to open the shell without affecting the flight of the bullets.

If the bursting charge be too great, or not placed in the right position within the shell, the penetration of many of the bullets will be decreased, and the scattering, or what is termed the *cone of spread*, will be too great. A shell of this class is, in fact, simply a case shot adapted to long range.

A spherical shell of this class has a less thickness of metal than a common shell, viz. about *one-tenth* of its diameter, and its weight (empty) is about half of that of a solid shot of similar diameter. The shell and shot for rifled guns are, as before explained, of almost the same weight.

Shrapnel shells are employed against skirmishers, troops especially in line, column, or masses of any kind, when uncovered, and at considerable ranges. They are of little use against troops posted behind cover.

6. *Incendiary projectiles* are hollow and filled with composition suited to the purpose required. The interior of a *carcass* is filled with a highly inflammatory composition, which being ignited by the discharge of the piece issues in a powerful flame from the vents for the space of three to twelve minutes (according to the nature), and upon the shell falling into a building, or among combustible material of any kind, the flames will produce conflagration; the nature of the composition is such that it will burn under water, and cannot be extinguished without the greatest difficulty.

Carcasses are chiefly employed in bombarding towns and shipping. They can be fired from mortars, howitzers, or guns, but when used with howitzers or guns have wooden bottoms attached with a single rivet; the 13″ and 10″ have *lugs* or *lewis holes*.

Light balls are filled with composition, which burns with a bright flame for from ten to twenty minutes.

Light balls are generally fired with reduced charges from mortars by the garrison of a besieged place to discover at night the working parties of the enemy; they may also be thrown into the ditch to ascertain the strength and disposition of assaulting columns.

The composition in a *smoke ball* when ignited evolves a large volume of smoke. These balls are fired from mortars with very small charges. They are employed for throwing into mines or other confined situations to suffocate or expel the working parties, &c.; also, to conceal your own position from an enemy.

Ammunition for Smooth-bored Ordnance.[3]

To simplify this portion of the subject, it will be divided into three sections:—

A. Projectiles.
B. Sabots and Fuzes.
C. Charges and Wads.

SECTION A.

7. *Solid shot*[4] are spheres of iron or steel; there are eleven natures, varying from the 3-pr. to the 150-pr. *Sand shot* are merely small cast-iron balls, of which there are fifteen different natures, varying between $1\frac{1}{2}$ oz. and 4 lbs. in weight; the larger natures of solid shot used to be cast in iron moulds, and these in sand, hence they were called *sand shot*, but solid shot of all sizes are now cast in sand moulds. Besides being used for

[3] For an exhaustive account of the ammunition used with SB. ordnance, including the numerous modifications and improvements made since their introduction for war purposes, see *Ammunition for SB. Ordnance*, by Capt. (now Major) V. D. Majendie, R.A. This work has been continued by Capt. C. O. Browne, R.A., in a work entitled *Ammunition for Rifled Ordnance.*

[4] If the centre of gravity of a shot does not coincide with the geometrical centre of its figure, the shot is termed *eccentric*. Almost every shot that is cast is slightly *eccentric*, for, from the contraction of the metal on cooling, a cavity is formed in some part of the interior (rarely in the centre), and irregularities will be found on the exterior surface. The effect of this eccentricity upon the flight of the projectile will be explained hereafter, and it is only necessary to state here, that if the shot be placed in the bore with its centre of gravity *above*, and in the same vertical plane with the centre of the figure, the range of the shot will be increased. In order to take advantage of this circumstance, the Prussians, and some other nations, have used shot made purposely eccentric; but such projectiles were considered objectionable in our service, the increase in range thus obtained being variable, and therefore not to be depended on, great care being required in the loading, and should they happen to rotate on a vertical axis, the lateral deviations would be far greater than with ordinary shot.

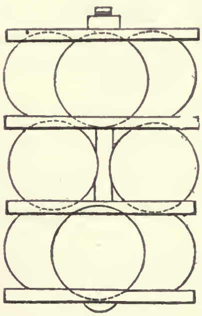
grape and case, a number of them are sometimes piled loose on a hemispherical bottom and fired as *pound shot charges* from a mortar; 100 from a 13″ or 10″, and 50 from an 8″.

8. All iron SB. guns are supplied with Caffin's *grape shot* except the 10″, the 100-pr., 150-pr., 3-pr., and all carronades; the grape for the 10″, 100-pr., and 150-pr. are a kind of case shot, the cylinder and ends being made of iron, and the shot provided with iron handles.

The grape for the 3-pr. and carronades is like the case except that the balls are heavier and the projectile is longer. Grape shot are not fired from bronze pieces, as they would injure their bores.

Caffin's *grape shot*, which has been substituted in the service for *quilted grape*,[5] consists of a number of cast-iron balls, arranged in three tiers by means of three cast-iron circular plates, and a bottom-plate of wrought-iron; the whole is secured firmly together by means of a wrought-iron bolt which passes through the centre of the plates, and has a head on the lower end and a screw on the top to receive a nut (Fig. 58). The number of shot in each tier varies from three to five, according to the nature of the gun for which the grape shot is intended.

Fig. 58.



These grape shot are exceedingly destructive if the range does not exceed 300 yds., and can be employed with considerable effect up to 600 yds., unless the ground be very uneven or much broken by obstacles, such as banks, hedges, &c.

9. *Case shot* made for all SB. guns, howitzers, and carronades consist of cylinders filled with sand shot, the number and size of which vary with the nature of case, and the interstices between the balls are packed with

[5] The quilted grape consists of a number of iron balls placed in a canvas bag round an iron spindle, which is attached to an iron tampion or bottom; the top of the bag is drawn tightly in underneath the top of the spindle, and the whole secured firmly together by means of the quilting line or cord. The number and weight of the balls differ, according to the nature of the grape shot.

shavings and sawdust (Fig. 59). They may be divided into three classes, viz.—

(1) Of sheet iron, wrought-iron ends, and an iron handle for 32-pr., 68-pr., or 8-inch, 10-inch, and 100-pr.

(2) Of tin with one iron end, and a rope handle, for 18, 24, and 42-prs.

(3) Of tin with wood bottom[6] for 3, 6, 9, and 12-prs.

The case for a howitzer or carronade has smaller shot and is lighter than that for a gun of the same calibre, as the gun will bear a greater strain than either of the other pieces.

This kind of projectile is very effective at short ranges, up to 300 yards, when the enemy's front is considerable, especially

Fig. 59.

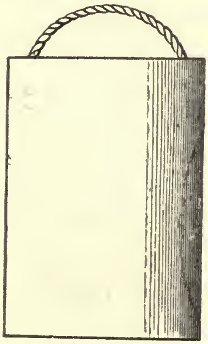
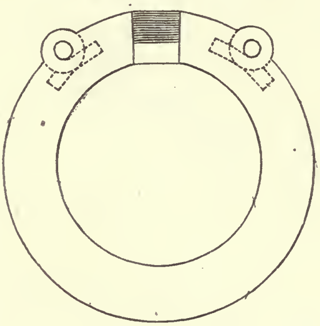


Fig. 60.



if the ground be hard and free from obstacles, and will be found most useful when artillery is attacked in the field, or in the defence of works. Beyond 300 yds. the dispersion of the shot (the case being broken by the shock of the discharge) is so great, and the velocity of the balls so low, that they have but little effect.

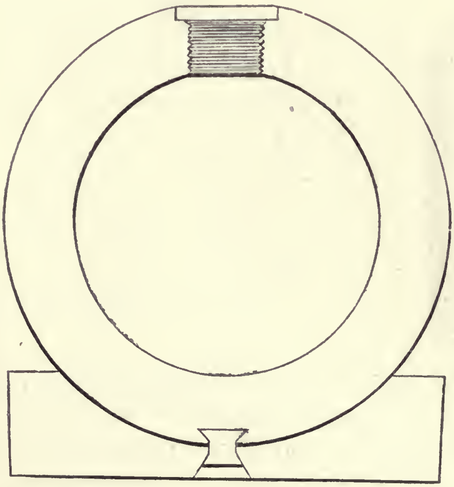
10. There are three natures of *mortar shells*—viz., 13″, 10″ and 8″ (Fig. 60)—which are all fired without sabots, and therefore have no rivet holes; the two higher natures have either

[6] The wooden bottom is conical for all gomer chambered ordnance and unchambered ordnance of corresponding calibre, cylindrical for all others, except those with cylindrical chambers (the obsolete $5\frac{1}{2}''$ and $4\frac{2}{5}''$ howitzers), the bottoms for which are hemispherical.

lugs[7] or *lewis holes*, in order that they may be lifted for loading by means of *shell hooks* or *tongs*. The fuze holes of mortar shells are larger in diameter than those of other common shells; they are *tapped* to give the fuze a firm hold, but they are not countersunk; the fuze hole of the 8″ is smaller than those of the 10″ and 13″, for the internal diameter of the former shell is too small to allow the long mortar fuze to be set home, and the diameter of the hole must therefore be reduced to fit the part of the fuze passing through it when driven in. The fuze holes of mortar shells are not closed with screw plugs, but with corks or bungs beeswaxed.[8]

11. There are seven natures of *common* shell, from the 12-pr. to the 10″ inclusive; they have no lugs, but are provided with wooden bottoms or sabots, attached by means of a rivet to the shell opposite the fuze hole (Fig. 61); these bottoms are necessary in order that the fuze may be kept in the axis of the bore when loading, and no doubt serve to decrease the rebounding of the shell within the bore, the gas acting more uniformly upon the bottom than upon the surface of a shell without one. The fuze holes of all natures are slightly conical in form, have the same diameter, to take the Boxer common shell fuze, and are *tapped* to receive the LS. Pettman

Fig. 61.



[7] The lugs are objectionable for two reasons—1st, shells having them cannot be cleaned in a mill; and 2ndly, the lugs are liable to be knocked off in transport or piling. All mortar shells now manufactured have lewis holes, not lugs.

[8] The fuze holes of mortar shells issued loaded for naval service are secured with a bung and kit plaster.

fuze, and a gun-metal screw plug required to close the shell when in store or not loaded; the fuze hole of the 12-pr. shell is bouched with gun-metal, and the bouch extends into the shell to confine the explosion, and thus prevent the fuze blowing out without firing the bursting charge. The fuze holes of all common shell are *countersunk*, so that the plug may not project.[9]

12. There are ten different natures of *diaphragm shell*—eight, from the 6-pr. up to the 8″,[1] for cast-iron guns; and two, the 100-pr. and 150-pr., for built-up ordnance.

The *diaphragm shell*, invented by Lieut.-Col. Boxer, R.A., has a wrought-iron partition or *diaphragm*, which, dividing the shell into two chambers, the upper termed the *powder chamber* and the lower the *bullet chamber*, separates the bursting charge from the bullets (Fig. 62); four flanges or projections on the circumference of the diaphragm are cast into the metal of the shell, and thus support the diaphragm. The bursting charge in this shell is also much reduced, and the interior of the shell is coated with marine glue, in order to ensure complete separation between the powder of the bursting charge and the coal dust with which the interstices between the bullets are filled up, instead of the rosin as in the *improved shrapnel*.

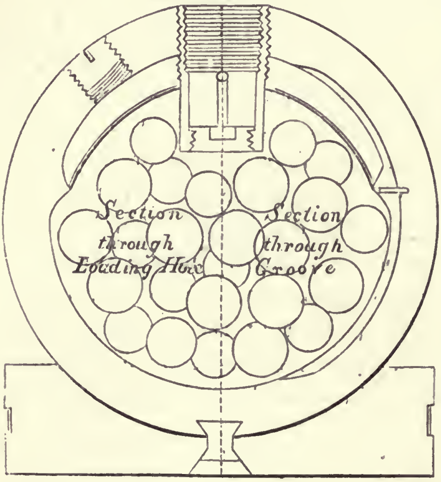
[9] There are five natures of *naval shells*, which differ from common shells in the following respects. They have larger fuze holes to receive the GS. bouch, and are fitted with elm tops attached by four rivets, and having rope beckets; the shells have four rivet holes at top and two at bottom, and the 100 and 150-pr. shells are lacquered inside, to prevent the liability of premature explosion.

There are two natures of *hand grenade* (also of the common class)—viz., the LS. or 3-pr., and the SS. or 6-pr. They are merely small shells, differing from common shells in having a less thickness of metal, $\frac{1}{7}$th the diameter, a smaller fuze hole to receive a special fuze, and in the absence of rivet holes. The thickness of metal can be reduced, and the shell thus made to contain more powder, as they are usually thrown by hand, and are not therefore, like other shells, subjected to a violent shock on discharge. Hand grenades are used for close combat, in the assault of works, &c., and can be thrown by hand to from 20 to 30 yds. distance; a number of them are however sometimes fired from a mortar, which for such a purpose should have an elevation of about 30°, so that the grenades may not sink into the ground.

[1] A few experimental diaphragm have been fired from the 10″ shell gun, but with such heavy projectiles it will only bear a reduced charge; as the velocity of the shell is low, but little penetration can be obtained with the bullets, and a 10″ diaphragm shell has not therefore been adopted.

The opening of the shell by the bursting charge is facilitated by four grooves formed in its interior surface, extending from the fuze hole to points near the bottom of the shell, forming so many lines of *least resistance.* In the improved shrapnel, the bursting charge, being in the middle of the shell, must in opening it cause dispersion of the bullets, but in the diaphragm it is intended that the charge shall fracture the shell along the grooves, and so release the bullets without scattering them.

Fig. 62.



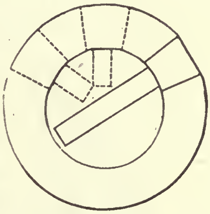
The fuze hole is fitted with a gun-metal socket, which passes through the diaphragm, and is *tapped* to receive a gun-metal screw plug with a serge-covered wooden plug attached below it to fill up the socket; a slot leads up from the bottom of the socket inside to a fire hole, which passes through the metal and into the powder chamber. The sockets of the shells from 6-pr. to 8″ (or 68-pr.) take the diaphragm fuze, but the 100-pr. and 150-pr. shells have sockets to receive the common fuze, which contains 2″ instead of 1″ of composition. The bullets are made of hard metal, viz. lead and antimony, in order that they may retain their correct form, and they are inserted through the socket, which is afterwards closed by a screw plug; the bursting charge is poured into the powder chamber through a small *loading hole* passing through the metal of the shell a little below the fuze hole, and closed by a gun-metal screw plug.[2] Diaphragm shells are fired with bottoms attached with a single rivet, and

[2] There are two sizes of plugs—large, for diaphragm shell from 24-pr. to 8″ inclusive; and small, for those from 6-pr. to 18-pr.

when filled they weigh about $\frac{7}{8}$ths as much as solid shot of the same nature.[3]

13. There are nine different natures of *carcasses*, from the 12-pr. to the 13″ inclusive. A carcass for a SB. piece is a cast-iron spherical shell having three vents or fire holes in the upper hemisphere, but no fuze hole; the thickness of metal is greater than in a common shell, being about $\frac{1}{5}$th of the diameter; this is necessary, in order that the shell may be capable of resisting the explosion of the charge with which it is fired, the three vents weakening the shell very considerably, and also that it may not be fractured by the pressure of the gas generated from the ignited composition inside (Fig. 63). The composition with which the shell is filled is composed of—

Fig. 63.



	lbs.	oz.
Saltpetre (ground) . .	6	4
Sulphur	2	8
Rosin (pounded) . . .	1	14
Sulphide of antimony . .	0	10
Tallow (Russian) . . .	0	10
Turpentine (Venice) . .	0	10

Three holes, one longer than the other two, are made into the composition at each vent, and they are driven with fuze

[3] In the shells originally introduced by General Shrapnel, the bursting charge was poured loosely among the bullets inside the shell previous to fixing the fuze; experiments have shown that by this arrangement premature explosions frequently resulted (especially when full-service charges were used), in consequence, in most cases, of the friction of the balls against each other and the interior surface of the shell.

The *improved shrapnel shell* was proposed by Lieut.-Col. Boxer, R.A., to obviate the defect of premature explosion; in this shell the bursting charge is entirely separated from the balls, by being placed in a metal cylinder extending from the fuze hole down the centre of the shell, and the interstices between the balls are filled with melted rosin, to prevent the balls from being disfigured by the concussion of the discharge, or from breaking into the powder cylinder. In consequence of the complete separation of the bursting charge, a smaller quantity of powder was required to burst the shell, and these shells could be fired with full-service charges without danger of premature explosion, which was of great importance, the velocity and penetration of the bullets being thereby greatly increased. A modification of this shell was used by the Americans, and several Continental Powers.

composition and matched; the vents are plugged with brown paper and covered with kit plaster, which has to be removed from one of them before loading. Carcasses are fired with service charges, except the 13″ and 10″, which are fired with 16 and 9 lbs. respectively.

14. The *ground light ball* consists of a cylindrical wrought-iron skeleton, 1½ calibres in length, with hemispherical ends; the higher natures have an iron cup at top and bottom, but the lower natures have a cup at the bottom only; this skeleton is covered with canvas, the cylindrical part woolded with twine, and the frame filled with the following composition;—

	lbs.	oz.
Saltpetre (ground) . .	6	4
Sulphur	2	8
Rosin (powdered) . .	1	14
Oil (linseed boiled) . .	0	7½

which, when ignited, burns for a considerable time (from ten to twenty minutes), with a red flame, there being holes cut through the canvas to serve as vents; the higher natures have lugs and five vents, but the lower natures have no lugs and four vents. These lights are of four different natures, viz. 10, 8, 5½, and 4⅖″; they are fired from mortars with reduced charges.

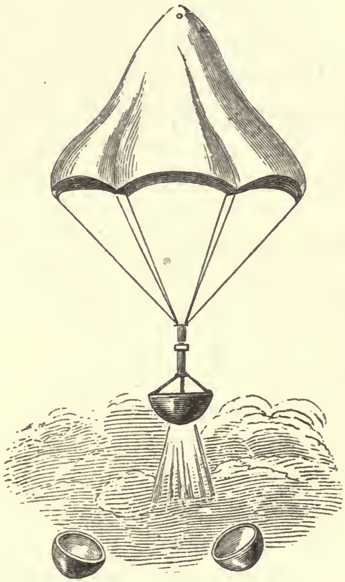
15. The *parachute light ball* (Fig. 64) consists of a thin iron shell formed by two hemispheres riveted together, inside of which are two other iron hemispheres, the lower one filled with composition, and the upper one with the calico parachute packed tightly in and attached to the case by a cord; this last hemisphere is attached to the one outside it by two chains. The parachute is connected to the lower hemisphere, which holds the composition, by ropes attached to three chains hooking into the hemisphere. The upper outer hemisphere has a socket for a fuze and two leaders of quickmatch pass round from the latter to the vent in the bottom of the hemisphere containing the light composition, which is primed with ordinary fuze composition. The composition is nearly the same as that used for signal lights,[4] and consists of—

[4] Signal light composition is the same as that formerly used for blue lights, and is sometimes termed *blue light composition*; the parachute light composition differs only in the proportions of the ingredients.

		lbs.	oz.
Saltpetre (ground)	. .	7	0
Sulphur (sublimed)	. .	1	12
Sulphide of arsenic[5]	. .	0	8

These balls are fired from mortars with low charges. The fuze is bored, so that when the light has reached the highest point of the trajectory, it ignites the quickmatch and priming of the light, sufficient force being thus obtained to separate the halves of the outer shell and release the parachute, which, expanding, and with the hemisphere holding the composition burning brightly from the vent hanging from it, is supported by the air, and descends very slowly.[6]

Fig. 64.



16. *Smoke balls* consist of a paper shell (the thickness of the paper depending upon the nature of the shell), having one vent, and filled with a composition that, upon ignition, evolves a large volume of smoke; the composition is—

		lbs.	oz.
Powder (LG. bruised).	. .	5	0
Saltpetre (pulverised)	. .	1	0
Sea coal (pounded)	. .	1	8
Pitch (Swedish)	. . .	2	0
Tallow	. . . . .	0	8

[5] Realgar or red orpiment.

[6] The suspended light was proposed by Lieut.-Col. Boxer, R.A., the ground light possessing the following defects, to which the former would not be subject:—(1) That the ground light can be smothered by shovelling earth over it; (2) That if the ground upon which it falls be soft, or should it lodge in a ditch or hollow, the light would be in a great measure obscured; (3) That if it be projected short of

When driving this composition a small portion of sulphur and coal is put into the shell, three times in the large natures, and twice in the smaller; a quantity of gas is generated from these substances which blows out any accumulation of slag at the vent and prevents its becoming clogged.

Section B.

17. Shells for guns and howitzers and all projectiles for field and position pieces are provided with *wooden bottoms* or *sabots*, made of elm or of alder if the former be not procurable; teak is however used for bottoms for tropical climates. There are two classes of bottoms, termed respectively *plank* and *end bottoms*, the grain of the wood running across the bottom in the former, and lengthways in the latter. Common and diaphragm shells for heavy iron ordnance, except the 18-pr., are supplied with *plank* bottoms; diaphragm shells for field service have *end* bottoms in order that they may break up easily and not fly in large pieces, which would annoy skirmishers; these bottoms are carried half-way up the projectile, and are strengthened by a tin strap to prevent their splitting in transport. For howitzers and shell guns the bottoms are conical, being sloped off to fit into the chamber, and the bottoms of shot and shell for all guns of a corresponding calibre with howitzers are also conical; this leaves only three natures of shell, viz. 6, 9, and 18-prs., which are furnished with cylindrical bottoms. Bottoms are always made at their highest diameter equal to the low gauge of the shot or shell to which they belong.

Bottoms were formerly attached to the projectile by tin strapping, but now, except for naval shells, in the following manner:—

A small hole in the form of the frustum of a cone is drilled to the depth of one-tenth of an inch into the shell opposite the

the object, the light would have a contrary effect to that intended; and (4) that its discovering power is very low, not exceeding 20 yards round the light. The suspended light, from its elevation and great brilliancy, illuminates a very considerable extent of ground, but it is difficult to give it the desired direction.

fuze hole, the base of the cone inwards; a gun-metal rivet, which passes through the centre of the bottom, is placed in this conical hole, and with a few blows of a hammer the top of the rivet, which is hollow, expands into the interior of the hole, and is thus retained in the shell. The rivet has a small head to prevent the sabot from slipping off it, but this head is bevelled off, in order that it may not hold on any portion of the sabot after the projectile has received the blow from the discharge of the piece.[7]

18. Fuzes are used with shells, the object for which they are employed being to ignite the bursting charge at the required moment. There are a great many varieties of fuzes, but those at present in our service may be divided into two classes—*Time* fuzes and *Percussion* fuzes.

The *time* fuzes,[8] for the shells of SB. ordnance are[9]—

Common fuze.	Mortar fuze (Large).
Diaphragm „	Mortar „ (Small).

These were proposed by Major-General Boxer, R.A., and are usually termed Boxer fuzes.[1]

These *time* fuzes consist of a case of wood, into which is pressed[2] the following composition, called *fuze composition*:—

	lbs.	oz.
Saltpetre (ground) . . .	3	4
Sulphur (sublimed) . . .	1	0
Powder (pit mealed) . .	2	12.

This composition burns progressively and regularly, at the rate of one inch in five seconds, so that any length may be given

[7] The tops of naval shells are attached by four long inclined gun-metal rivets. The tops of the 100 and 150-pr. shells are hollowed out in the middle and provided with two rope handles.

[8] The cases of the wooden fuzes of this class are all made to the same cone.

[9] Besides those given in the Text, there are special fuzes for hand grenades and parachute light balls.

[1] The fuzes before the adoption of Boxer fuzes were similar to them in general features, but were rude in construction; the case was of beech wood and filled with *fuze composition*, and the fuze was prepared by filing it down to fit the fuze hole of the shell, and sawing off the end of the case so as to leave the required length of composition; however, for shrapnel firing, fuzes cut to different lengths were issued, the above tedious method of preparation requiring too much time for such practice.

[2] By hydraulic pressure.

to it, to correspond with the time of flight of the shell, by boring a small hole through the case into this composition, thus making a communication for the flame into the bursting charge within the shell; these fuzes are ignited by the flame from the discharge of the piece which (in SB. ordnance having

Fig. 65.

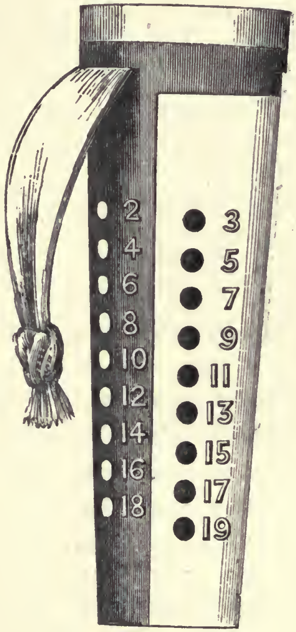
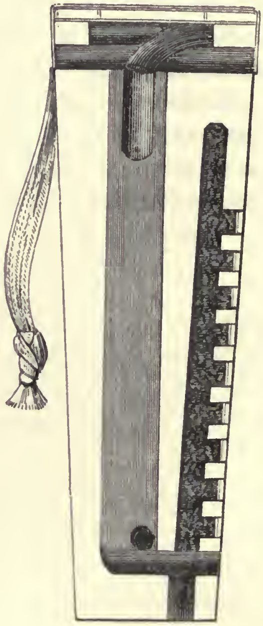


Fig. 66.



windage) envelops the shell, the top of the fuze composition being primed to render its ignition more certain.

The conditions to be fulfilled in time fuzes are—

(1) That they should ignite with certainty.

(2) That they should burn regularly.

(3) That, when ignited, they should not be liable to extinction on striking earth, water, or wood.[3]

19. The case of the *common fuze* is a truncated cone of

[3] This is rarely fulfilled.

beech wood about 3″ long (Figs. 65, 66), having a composition bore made eccentric with regard to the exterior, and two powder channels bored parallel to the composition, on that side in which there is the greatest thickness of wood; the top of the composition bore is enlarged for the quickmatch and priming, and this bore does not pass through the case at the bottom, but to within a short distance of the latter, a small thickness of wood being left to support the composition; the powder channels are bored through to the bottom, so as to conduct the flame into the shell. Side holes, ·2 in. apart, are made into the powder channels, those into one powder channel indicating the even, and those into the other channel the odd tenths of fuze composition; the bottom hole of each row is continued into the axis of the composition bore, in order to ensure the eventual bursting of the shell, should the boring of the required hole previous to firing not have been properly executed; the powder channels are filled with rifle powder, and the side holes have the same powder and then a little clay pressed into them, the clay outside; the last side holes in each row and the portions of the powder channels below these holes are filled with quickmatch; the bottoms of the channels are closed with putty. A hole is bored through the priming and to a depth of ·4 in. into the composition,[4] in order to ensure the ignition of the fuze, a greater surface of the composition being thus exposed to the flame; three pieces of quickmatch are placed in the cup, the ends of two passing through four holes in the side, and the third is bent under one of the others; the priming of the cup is powder damped with distilled water. There are 2″ of solid composition from the bottom of the priming hole to the highest of the two lowest side holes, neither of which are numbered. The side holes and bottom of the fuze are protected by paper pasted over them, and when the fuze is painted the holes are marked and figured, so that the different tenths of composition with their corresponding side holes may be readily distinguished.

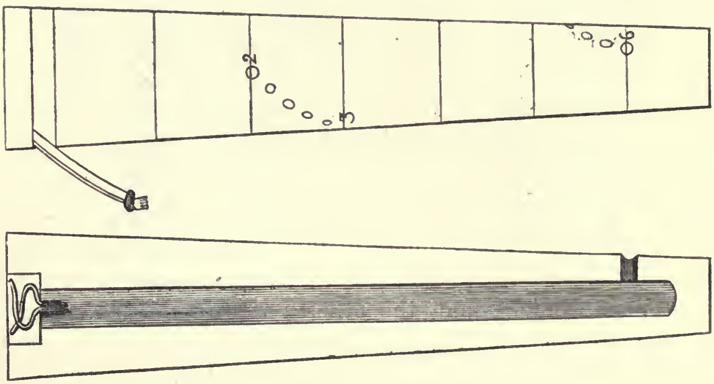
In order to prepare the fuze for any given range, an auger is

[4] The top side hole of one row is ·2 in., and the top hole of the other ·3 in. below the bottom of the priming hole, which is the zero point of the fuze.

inserted into the side hole marked with the number of tenths corresponding to the time of flight, and the bit is forced into the composition; a communication is thus made for the flame into the powder channel, and the fine powder with which the latter is filled conducts it instantaneously into the shell. These fuzes have a metallic cap to preserve the priming, inside of which is a disc of cardboard, having a piece of tape attached to it; when the shell is inserted into the bore of the piece, the cap is readily removed by pulling the tape upwards.

20. The *diaphragm* is similar to the *common fuze*, except that it is shorter, and contains only 1″ of solid composition; also in this fuze the powder channels are connected by a groove filled with quickmatch, so that both are fired together; this is necessary in consequence of the fuze being in a socket and the flame having to make its way through the fire-hole in it to the

Fig. 67.



powder in the shell. A long fuze is not required, for spherical shells lose their velocity so quickly that at a long range the bullets of a diaphragm shell would have little penetration.

21. In the *large mortar fuze* (Fig. 67) the axis of the composition bore is identical with that of the fuze, and there are no powder channels; the latter are not required, as any hole at which the fuze may be bored will always fall within the

interior of the shell, the times of flight, and consequently the lengths of fuze composition, being greater for mortar shells than for shells fired at low angles. These fuzes, the composition in which is 6 in. long, have one set of side holes, which are placed spirally round the fuze, in order to prevent the wood from splitting when it is being bored; the side holes are ·2″ apart, the top one being 2″ and the lowest 6″ from the bottom of the priming hole, and the lowest side hole is bored through into the composition, but has no quickmatch. This fuze has only one long piece of quickmatch at the top, but is primed and capped like a common fuze.

22. The *small mortar fuze* is used with 12-pr. and 24-pr. common shells when fired from the small brass mortars at ranges having times of flight exceeding 10 seconds; it is similar to the large mortar fuze already described, except that it is shorter and smaller in diameter, has only 3″ of composition, and the top side hole is 1″ below the bottom of the priming hole.

23. Percussion and concussion fuzes were intended and generally employed for naval service, but they have also been used both in field and siege operations. The distinction between a percussion and concussion fuze has been thus defined:—'A percussion fuze is one which is prepared to act by the shock of discharge, but put in action by the second shock on striking the object; a concussion fuze is one which is put in action by the shock of discharge, but the effect of that action is restrained until it strikes the object.'[5]

The essential requirements of a good *percussion fuze* are—

[5] *War Office Circular* 822, *Art.* 725. This definition is not very satisfactory, but as there is no concussion fuze now in the service, the following description of Freeburn's fuze is given in order to illustrate the distinction drawn:—

Freeburn's concussion fuze is simply an ordinary wooden case with a composition bore down the centre, which is rather more than half-filled with fuze composition; three small wedges of gun-metal are fitted into the wood round the upper part of the composition, the larger end of the wedges being towards the composition. When the shell is fired, the wedges, being supported by the composition, are not displaced by the shock of the discharge; but on the shell striking the object at a considerable range, the composition will have been consumed to some distance below the wedges, thus leaving them unsupported, and they will therefore fall into the composition bore, the flame at the same time making its way through the empty spaces into the shell.

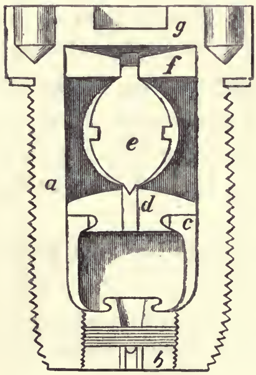
(1) That it shall not be ignited by the shock of discharge; (2) that it shall be ignited on the impact of the shell against the object, and, if for field service, on graze; (3) that it may not be liable to explode during transport; and (4), *for naval service*, that it shall not explode on striking water.

24. The different parts of the *LS. Pettman fuze* are (Fig. 68)—

a. Body.	*d*. Cone plug.	*f*. Steady plug.
b. Screw plug.	*e*. Ball.	*g*. Top plug.
c. Cup.		

The *body* of the fuze is made of a kind of gun-metal; it is slightly conical in form except at the top, which is cylindrical, and a screw is cut in the conical portion to fit the fuze hole of a common shell; the top, or head, has four wrench holes. The body is closed at the bottom by the *screw plug*, having a fire hole through it, and a cross hole to contain quickmatch. Above the *screw plug* is the lead *cup*, and over it the *cone plug*, also with a fire hole bored through it. On this last plug rests the *ball*, having a small cone point at the bottom of it, to rest in the fire hole of the cone plug; a cylindrical projection at the top of the ball fits into a hole in the centre of the *steady plug*; the ball is serrated, a groove passes round it, and it is covered with detonating composition,[6] with which the groove is also filled; the ball is covered with gut and fine silk to protect the composition. The ball is made of harder alloy than the body of the fuze, in order that the retaining points may not be liable to flatten.

Fig. 68.



The action of the fuze is as follows:—When the gun is fired the *cone plug*, *ball*, and *steady plug*, in consequence of their

[6] The detonating composition is the same as that used for quill friction tubes.

inertia, remain for an instant at rest after the fuze moves, and so crush the lead cup, which is carried forwards by the bottom of the fuze; the cup being thus shortened, sufficient space is given for the disengagement of the ball from the two plugs that hold it, and on the impact of the shell against a hard substance, the *ball* strikes against the side of the chamber and explodes the detonating composition, the gas passes through the fire holes of the two lower plugs, igniting the quickmatch in the cross hole, and fires the bursting charge in the shell.

This fuze is simpler in construction than the Moorsom fuze, and is more sure in its action, for, whatever part of the shell strikes the object, the *ball* must come in contact with the surface of the chamber.

Section C.

25. For land service there are certain fixed charges, termed *service charges*, for all guns and howitzers.[7] The amount of powder in the service charge of a gun should be such that it will give the greatest initial velocity to the projectile without too great strain upon the metal of the piece, or a too violent recoil of the gun, which latter would act very injuriously upon the carriage; the greater the initial velocity the less will be the angle of elevation required for any given range, and consequently the more accurate the practice.

Reduced charges are employed in firing hot shot, carcasses from the 13″ SS. mortar and 10″ gun, ground light balls, parachute lights, smoke balls; also in ricochet practice, when firing at angles of depression, or in saluting. The service, saluting, and proof charges of SB. ordnance are given in Table I., Appendix.

When carcasses are fired from the 13″ mortar the maximum charge is 16 lbs., and from the 10″ gun 8 lbs. Ground light balls are fired with charges varying between 2 lbs. and 1 oz., according to the nature and range. Parachute lights and smoke balls are fired with very small charges.

[7] The ratio of the weights of charge and projectile for different ordnance is given in the table, p. 22.

The charge for hot shot ought not to exceed $\frac{3}{4}$ the service charge, for, in consequence of the expansion of the shot and the adjacent metal of the bore, the windage is reduced, and a greater strain will be exerted upon the metal of the gun; the expansion of the gas will also very probably be increased by the heat generated within the bore; moreover, very great penetration is not required, the object to be attained being that the shot shall merely lodge in the timber.

In ricochet firing the charges are greatly reduced, those generally used being from one-twentieth to one-thirtieth the weight of shell; but no fixed charges can be laid down for this purpose, alterations having constantly to be made in them according to circumstances. The service charge may be used in firing at angles of depression as low as 15°, $\frac{1}{2}$ this charge for 15° to 30°, and $\frac{1}{4}$ for 30° to 50°.

26. In our service the charges for cannon and howitzers, after being accurately weighed out, are placed in cartridges made of serge, and secured with worsted; serge is used in preference to paper or parchment, (1) because it packs and resists the action of travelling better; (2) as it is not so liable to leave sparks in the gun.

Saluting and exercising cartridges for ML. iron guns are made of *silk cloth* instead of serge, which is more liable to leave sparks in the bore. The use of these cartridges is restricted to—

(1) Stations where the guns for firing salutes are less in number than the rounds to be fired.

(2) Garrison guns when fired at reviews.

(3) Garrison guns when fired for the dismissal of recruits.

Serge cartridges are still to be used for firing morning, noon, evening, or signal guns.[8]

Cartridges for gomer chambered ordnance are made conical in shape and out of two pieces of serge; those for other pieces are of cylindrical form and made out of one piece of serge;[9] cartridges are now made alike for both L. and S. service. The edges of the serge are, in sewing, made to overlap; the car-

[8] *Army Circular*, Nov. 1, 1869, C. 144. *List of Changes*, § 1780.

[9] There are two cartridges (not hooped), or rather bags, to contain loose powder, one holding from 10 to 15 lbs., and the other up to 10 lbs.

tridges, after filling, are choked and then hooped with worsted to keep them in shape.[1] Cannon cartridges, when not packed in metal or metal-lined cases, also when issued for field or boat service, are placed in paper bags; cartridges are sometimes packed in bags of paper, which is rendered waterproof by a solution of india-rubber with mineral naphtha.

When the cartridge is attached to the projectile, the two together are termed *fixed ammunition*; this is not now employed in our service. With fixed ammunition, simultaneous loading is more simple, and the cartridge is sure to be placed correctly in the bore, and not with the choked end first, as is sometimes the case when the projectile and cartridge are separate. Fixed ammunition has, however, the following disadvantage, viz., that in packing or stowing much greater space is required, and it is more difficult to arrange.

27. LS. cartridges are packed according to the service for which they are intended in one of the following boxes or barrels :—

Metal-lined cases, Barrels, Ammunition boxes.

A *metal-lined case* is a wooden box lined with tinned copper; it is closed with a circular metal bung and a square lid of wood, which screws firmly down, and can be opened by means of a metal key for the purpose; the bung is lutened [2] all round to exclude the air. The cases are of three sizes, viz.—

Whole, containing about	120 lbs.	(powder in serge bags).
Half ,,	60 ,,	,,
Quarter ,,	30 ,,	,,

Metal-lined cases are used in damp magazines and in siege operations.

[1] The number of hoops and rows of stitches in a cartridge are in the majority of cases the same; all cartridges above the 6-pr. gun, 12-pr. howitzer, and $5\frac{1}{2}''$ mortar have an overlap of 1″, and 3 rows of stitches; other cartridges have an overlap of $\frac{3}{4}''$, and 2 rows of stitches.

[2] Luten composition is composed of 14 lbs. of tallow and 6 lbs. of beeswax, which are melted together and allowed to cool; when cold it becomes very hard, and therefore before using it is placed on a wooden block and is well beaten until quite soft.

The barrel which is generally used for cartridges is called the *gun ammunition barrel.* It is made of oak, bound with ash and copper hoops; it has a round lid attached to the top or head of the barrel by a copper hinge, and secured by a ring bolt which screws into a gun-metal socket in the top; the cartridges can therefore be removed without unheading the barrel. There are two sizes, whole and half, and they are used in dry land magazines, the cartridges in them being placed in paper bags.

The *common powder barrel* is used to contain powder for immediate use, and sometimes, though rarely, for cartridges. There are three sizes—whole, half, and quarter;[3] the latter, when it has a leather cover, which opens and closes with a string like a bag, is called a *budge barrel*, and is employed for bringing up cartridges at mortar practice.

28. Wads are of four kinds, viz. *junk*, *grummet*, *papier-mâché*, and *coal dust*. *Junk wads* are made of oakum bound round with spun yarn, and are of similar diameter to the bore of the gun for which they are intended; their thickness, which depends upon the nature of the wad, varies from one to several inches. They are used in firing hot shot, and occasionally with bronze pieces to prevent indentation of the bore near the seat of the shot: in both cases they are placed between the charge and the projectile. They are also used in proving ordnance, one or more being placed in front of the projectile.

The *grummet wad* consists of a circle of rope, equal in diameter to the bore of the gun, and having two cross-pieces of rope tied to the circle, and crossing each other at right angles. These wads are generally rammed in after the shot, in order to prevent its rolling forwards should the bore be depressed, or if it be shaken by the running up of the gun; they are seldom used when the elevation exceeds 2°.[4]

[3] A *whole* barrel is generally used for loose powder, and contains about 100 lbs.; a *half* for blank small-arm cartridges; and a *quarter* for ball small-arm ammunition.

[4] If no wads are at hand, the shot might be kept from rolling forwards by what is called a wad-stick, which is merely a long stick passing down the bore, and jammed tightly between the ball and the bore.

Papier-mâché wads are small discs used for closing the fuze holes of filled common shells and the loading holes of diaphragm shells, and are placed below the screw plugs.

Coal dust wads are serge bags filled with coal dust, and placed inside the 5-lb. cartridges for 8″ guns, to fill up the chamber.

CHAPTER IX.

AMMUNITION FOR RIFLED ORDNANCE.

Projectiles for shells of BL. R. guns.—2. Case shot.—3. Common shell.—4. Segment shell.—5. Lead coating.—6. Boxer shrapnel for R. ordnance.—7. Projectiles ML. R. guns.—8. Caso shot.—9. Double shell.—10. Boxer shrapnel for R. ordnance.—11. Palliser projectiles.—12. Studding of projectiles for guns rifled on the Woolwich system.—13. Studding of ML. R. 64-pr.—14. Fuzes for shells of rifled ordnance.—15. Boxer's 9-seconds time fuze for BL. R. ordnance.—16. Boxer's 9-seconds fuze for ML. ordnance.—17. Boxer's 5-seconds fuzes for BL. and ML. ordnanee.—18. Boxer's 20-seconds time fuzes for BL. R. and ML. ordnance.—19. Pettman's general service fuze.—20. Royal Laboratory percussion fuze.—21. Armstrong C cap percussion fuze.—22. Charges.—23. Cartridges. —24. Lubricator.—25. Tin cups.—26. Bolton wads.

The subject will be divided into seetions as before :—

A. Projectiles for BL. R. ordnance.
B. do. ML. R. do.
C. Fuzes.
D. Charges, lubricators, wads.

Section A.

1. All the service BL. rifled ordnance, whether *screw* or *wedge*, fire lead-coated elongated projectiles, which are cylindro-conoidal in general form, the shells being slightly flattened at the apex, and varying in length from rather less than two to rather under three calibres.

Case shot (cylindrical, and not coated with lead) and segment shell are supplied to all the BL. R. guns ; common shell and shrapnel to all but the 6-pr. ; solid shot to 40-pr. and lower calibres, but only for practice to guns below the 20-pr. The Boxer shrapnel will be described in the remarks on shells for ML. R. guns ; those for BL. guns have a lead coating, and the heads of those for field service are painted red.

2. In *case shot* for large calibres the case is of sheet iron with fringed edges, and it has an iron bottom, riveted to the

lower fringe. A wrought-iron disc is placed inside the case at the bottom, and on this disc rest three sheet-iron curved plates, or segments, forming a lining. The case is filled with sand shot and coal dust, and covered with an iron top fringed down and handle soldered on.

Small calibres have a tin case with tin bottom, an iron disc inside, and the bottom riveted on outside. They have a wood top covered with tin, and rounded off to allow of easy loading. The new pattern 9 and 12-pr. case have bullets instead of sand shot, and the interstices are filled with equal parts of sand and clay. They have three studs of lead and antimony.

Both patterns have lead bands, or studs, at the base, to prevent their being rammed too far into the bore in loading.

3. The *common shell* is merely a hollow cast-iron projectile, the metal being sufficiently thick to withstand the shock of the discharge of the gun. The fuze hole of the 40-pr. and higher natures is fitted with the *general service bouch*; it is provided with a gun-metal screw plug. The screw in the bouch is right-handed, in order that the fuze may not be loosened by the rotation of the shell; and the bouch is screwed into the lower part of the fuze hole, so that the fuze may not project from the apex of the shell.

The interior surface of the shell is lacquered to render it smooth, this being considered necessary, as premature explosions were supposed to occur from the friction of the powder against the rough iron when the shell was fired.[1]

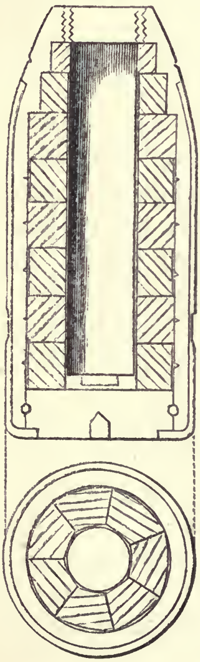
4. The *segment shell* (Fig. 69) consists of a thin cast-iron shell, inside of which are placed a number of rows of cast-iron segments round a cavity which contains the bursting charge. The lead in the operation of coating[2] is allowed to flow in between the segments, filling up the interstices, increasing the density and compactness of the shell, and forming an inside coating. The segments being arranged round the inside of the outer shell are capable of supporting the latter against very

[1] The bursting charge is *set up* by the shock of discharge, and the rapid rotatory motion of the shell causes friction and develops probably sufficient heat to produce premature explosion.

[2] Although the segment shell of the 64-pr. ML. gun was not coated, a small quantity of lead was run in between the segments.

great pressure from the outside, on the principle of the arch, but they readily yield to a slight force exerted from within; this shell consequently requires but a small bursting charge to open it. The inside of the shell is grooved, for otherwise it would be too strong and would be liable not to break up when required; there are also grooves in the head. The bottom of the shell is cast separately and pressed in after the segments have been inserted, but (in the 7″, 64-pr., and 9-pr. shells), to prevent any flame passing into the shell between the bottom and sides, a groove passes round, half in the bottom and half in the shell, into which the lead flows and thus closes the bottom securely.

Fig. 69.



The 40-pr. and larger natures of segment shells are lacquered inside like the common shells, but the 20-pr. and lower natures are not lacquered, for in these the powder chamber has a slightly less diameter than the fuze hole, and the bursting charge is contained in an iron cylinder, called a *burster*, which is inserted through the fuze hole.

The fuze holes of the 40-pr. and higher natures of segment shells are bouched like those of common shells; the fuze holes of the 20-pr. and lower natures of shells are tapped with a coarse left-handed screw to take the E time fuze (Armstrong).

The 20-pr. and lower natures of segment shells are adapted to take two fuzes at the same time, the E time fuze being screwed into the fuze hole, with the C percussion fuze below resting on the top of the iron burster, so that should the time fuze fail the shell is burst on graze by the percussion fuze.[3] The E time fuze has,

[3] A segment shell must be burst close to the object and not short of it like a shrapnel; otherwise, owing to its rapid rotatory motion and the position of the bursting charge in the middle of the shell (as with the old improved shrapnel), the dispersion of the segments is too great to be effective, and their velocity too low for penetration; the peculiar form of a segment is not adapted to flight.

however, recently been withdrawn from the service. The segment shell was intended to be used as shot, shrapnel, or case: for the first no fuze was used; for the second the time fuze was set to the required time of flight; and for the third, the time fuze being set to zero, the shell burst after leaving the bore (about 150 yds. from the muzzle). It has been thought necessary to adopt a case shot, which is not dependent for its action upon a fuze.

5. The projectiles of the BL. guns are coated with lead, attached by zinc, which has a strong affinity for both iron and lead, and the latter will therefore adhere firmly to the projectile after it has received a thin coating of zinc; a portion of antimony is mixed with the lead for the coating (5 per cent. of antimony) in order to harden it, and so prevent its being indented when the projectiles are being piled or transported.[4]

A *cannelure* (Fig. 69) is cut in the lead round the projectile near the base in order to receive any lead that may be drawn down during the passage of the projectile through the bore. The lead coating is rather thicker near the base and behind the *cannelure* than on the body of the projectile; this extra thickness near the base brings the diameter of the projectile up to the full diameter of the bore measured at the bottom of the grooves. The diameter of the projectile in front of the *cannelure* being rather less than the full diameter of the bore, the resistance and therefore the strain upon the metal of the gun is decreased, while the greater diameter near the base keeps the projectile steady, and prevents its stripping.

The parts where the coating ceases at the top and bottom of the shell are varnished, as a security against galvanic action between the iron of the shell and the lead coating.

6. The Boxer shrapnel shell will be described in the remarks on the projectiles of ML. R. Ordnance.

SECTION B.

7. All the ML. R. guns are supplied with case shot, common shell, and Boxer shrapnel shell; the 7-inch and 7-pr. with

[4] When the lead was attached mechanically by casting it into grooves cut round the outside of the projectile, the coating was liable to strip off.

double shell; and the heavy guns from 7-inch to 12-inch with Palliser cored shot and Palliser shell. All the projectiles, with the exception of the case shot, are cylindro-ogival in form, are *studded* to take the rifling of the guns, and vary in length between rather over 2 to about 3 calibres in length, except the double shell, which are about 4 calibres long; the common shell and shrapnel are the same length for the 9 and 16-pr. guns. The fuze holes of the common and shrapnel shells are fitted with the *general service bouch.* The common shell needs no particular description.

8. The *case shot* are similar to those used with BL. R. guns, but, with the exception of the 7-inch, they have no soft studs or bands at the base.[5] The 7-inch case is the same as that of the 7-inch BL. guns; the three soft studs fitting the grooves of the M.L. guns do not interfere with the loading. The case shot for the ML. R. 9 and 16-pr. guns has a tin body in three parts soldered together; the base is strengthened by a disc of zinc inside and a ring of the same outside. The inside segments are of zinc, and the top is of zinc lined with wood. The case is filled with bullets packed with sand and clay.

9. *Double shell*, made for 7″, is simply a shell of increased length (27·2″ or 4 calibres) to contain an increased charge of powder, viz. 12 lbs. 12 oz., instead of 8 lbs. 4 ozs.; to be fired with reduced charge at a short range. It has three longitudinal ribs inside to give sufficient support to the metal under the shock of discharge.

It is lacquered inside with red lacquer, and painted black on the outside except the studs.

The 7-pr. steel gun has also a double shell.

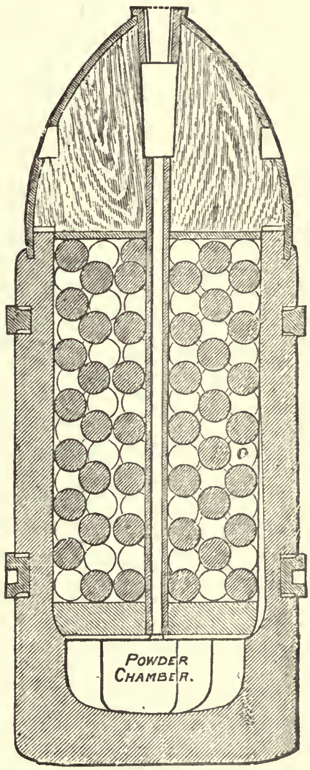
10. In the *Boxer shrapnel for R. ordnance* the essential features of a shrapnel shell are embodied. Such a shell fired from a R. gun having, previous to breaking up, a rotatory motion, considerable lateral spread is given to the bullets when released; and in the segment shell this is increased in consequence of the charge being in the middle of the shell. In the Boxer shrapnel the charge is placed in a chamber at the base,

[5] The 80-pr. and 64 pr., which are of the same calibre, take the same case shot.

so that on explosion there is no tendency to increase the lateral spread of the bullets, but rather to increase their velocity and penetration.

This shell (Fig. 70) has a cylindrical iron body, with a chamber at the bottom and four longitudinal grooves inside, but is cast without a head. A tin case for the bursting charge fits into the chamber, on the shoulder of which rests a wrought-iron disc. The shell is lined with paper and filled with balls imbedded in rosin. The balls for the smaller natures are of lead and antimony, but sand shot are used for the 7-inch and higher natures. A wrought-iron tube passes down the middle of the shell and through a hole in the centre of the iron disc, to lead the flame from the fuse to the bursting charge; the tube is tapped at the top to take a gun-metal primer.[6] A kamptulicon disc is placed over the bullets. The head is ogival in form and made of elm, covered with thin wrought iron (Bessemer's), which is riveted to the shell. This head contains a tin socket and a gun-metal bouch of GS. gauge. The bursting charge being confined in the tin case, the shell is not liable to premature explosion from pieces of iron breaking off the shoulder of the chamber by the shock of dis-

Fig. 70.



[6] The 64-pr. has a wooden cylinder round the tube to give increased length and better shooting. The tube in the ML. R. 9-pr. shrapnel is of gun metal instead of iron, to prevent the primer being fixed by oxidation. (*List of Changes*, § 2,104.)

charge. The heads of the shrapnel for field service are painted red, so that these shells may be readily distinguished.

11. The essential feature of the *Palliser projectiles* is, that, being made of carefully selected brands of iron, and *chilled* by casting in iron moulds, they possess intense hardness, the property requisite for the penetration of iron plates at high velocities. Besides, however, this hardness, they have a pointed head, which both theory and practice appear to prove to be a very favourable form for the penetration of iron masses. An additional and most important advantage is the cheapness of the manufacture of these projectiles, their cost being about one-fifth of that of similar steel projectiles.

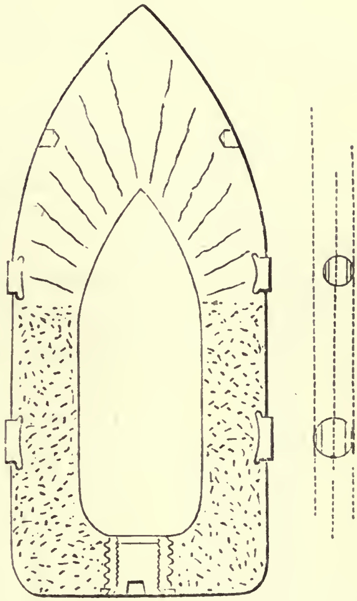
The projectiles now made differ from those of previous patterns in having bodies cast in sand, the object being to obtain a sounder casting at the base, and therefore to reduce the liability of the shells to fracture by the shock of discharge.

Palliser shot were first cast solid; then with a cylindrical hollow of small diameter, extending up from the base, but not into the head, which was solid and struck with a radius of $1\frac{1}{4}$ diameter. The shot was closed at the bottom by a conical wrought-iron plug screwed into a wrought-iron bouch cast into the base of the shot; the object of the hollow being to reduce the liability of the shot to crack or split after manufacture, which was sometimes found to occur with chilled shot cast solid.

Palliser shot are, however, now cast with a pear-shaped hollow, to ensure sounder casting, and that they may be used as shell if required, the enlarged capacity giving space for a small bursting charge. These *large capacity shot* are lacquered and closed at the base like the shell.

The Palliser shells (Fig. 71) are cast with a wrought-iron bouch in the bottom; this bouch is grooved round the outside to secure it in the casting, and it is afterwards tapped to receive a gun-metal screw-plug which closes the chamber. A thin ring of lead hammered into the base seals the junction of the bouch and the metal of the shell. The bouch is necessary, as the chilled metal is too hard to tap. The heads of these shells are struck with a radius of $1\frac{1}{2}$ diameter. Palliser shells are lacquered inside, but when they strike an iron object break up and explode without a fuze; the bursting charge in a serge bag is pressed into the shell.[7]

Fig. 71.



12. The studs are of gun-metal[8] pressed into under-cut holes in the projectiles of guns rifled on the Woolwich system (7-inch to 12-inch ML. guns).

There are only two studs in each row, the number of rows corresponding to that of the grooves in the gun; three rules are observed with respect to the position of the studs:—

(1) The two studs are equidistant from the centre of gravity of the projectile.

(2) The hind stud is at least four inches from the base of the projectile, to allow the latter to rest on the bearer in loading.

(3) The distance between the two studs is the same for all projectiles for the same bore.[9]

[7] Palliser projectiles which have been fired and recovered are not to be used again, but must be returned into store to be recast, as it has been found that they are liable to break up in the bore when fired a second time.

[8] The alloy of which they are made is—

Copper	7 parts
Tin	1 part

except for those of the 7-inch common, double, and chilled shells, and of all Boxer shrapnel, which consists of—

Copper	10 parts	Tin	1 part

on account of the weakness of these shells.

[9] The different projectiles for the same gun vary in length, as they are brought up to about the same weight; those of the 9 and 16-pr. are, however, of the same lengths and weights respectively. The distance between the centres of the two studs in a row is—

For 7-inch projectiles	4·5 inches	For 10-inch projectiles	6· inches.
„ 8 „ „	5· „	„ 12 „ „	6· „
„ 9 „ „	6· „		

For 8-inch projectiles and over, the front are of smaller diameter than the hind studs, to adapt them to the *increasing twist* of the grooves in the guns; the studs of the 64-pr. and 7-inch projectiles are all of the same diameter, the grooves in the guns having *uniform twists*. The *bearing* of the projectile should be on the studs, the body not being intended to touch the bore.

The studs of the projectiles for the 7-pr. and 9-pr. ML. R. guns are made of zinc and pressed into undercut holes, the same rules being observed as in placing those of the projectiles for the pieces rifled on the Woolwich system. The studs have all the same diameter.

13. The studs of the projectiles for the ML. 64-pr. are made of copper and pressed in; the number in a row has varied from three to five, and the studs are all of the same size.

Section C.

14. The different fuzes used for the shells of rifled ordnance are—

For Projectiles of BL. R. guns	40-pr. and higher natures	Boxer 5-seconds BL. R. O.	Time.
		do. 9 do. do.	
		do. 20 do. do.	
		Pettman's GS. Percussion.	
	20-pr. and lower natures	C cap percussion.	
		Boxer 5-seconds BL. R. O.	
For Projectiles of ML. R. guns	64-pr. and higher natures	Boxer 5-seconds ML. O.	Time.[1]
		do. 9 do. do.	
		do. 20 do. do.	
		Pettman GS. Percussion.	
	Field Service	Boxer 5-seconds (mark II.)	Time.
		do. 9 do. (mark II.)	
		RL. Percussion.	

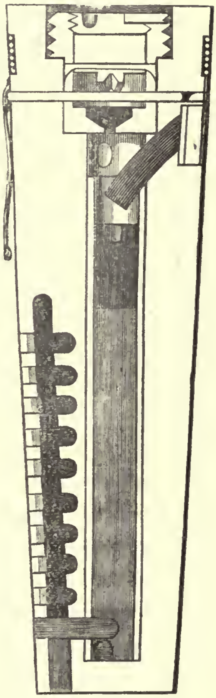
All the above *time* fuzes are on the same general principle.[2]

[1] By a recent order, the Boxer ML. O. wood time fuzes are not to be used with common shells of ML. R. guns above 64-pr., except with 7-in. common shell when fired with 14 lbs.

[2] The Armstrong E. Time fuze is not described, as it is not used for land service. It is a modification of the Breithaupt fuze, which was itself an improvement on

The Boxer 5, 9, and 20-seconds fuzes, either BL. R. O. or M.L. O., and the Pettman general service, fit the *general service bouch*, which is screwed into the shells taking these fuzes.[3] It must be remembered that shrapnel shells, as they should be burst at some distance from the object, their *cone of spread* being long, are usually fired with time fuzes ; but segment shells, having a short but very wide *cone of spread*, are most effective when burst close up to the object with a percussion fuze. Also that Palliser shells require no fuzes.

Fig. 72.



15. The *Boxer 9-seconds time fuze* for BL. R. Ordnance is a modification of Boxer's common fuze before described, with the addition of a detonating arrangement at the top, so that it may be used for the shells of rifled ordnance.

The fuze (Fig. 72) is thicker than the common fuze, and is also about 1″ longer, to give room for the detonating arrangement at the top ; the body differs from that of the common fuze in the following respects :—It has a paper lining which is not liable in dry or hot climates to shrink away from the composition ;[4] the side holes are continued beyond the powder channels, thus facilitating the boring of the fuze and rendering the operation more accurate ;[5] the side holes are plugged with rifle powder only ; above the top side hole the fuze is driven with mealed

the Bormann fuze, where the principle of driving the fuze composition into a circular channel instead of in a vertical column was first adopted. A description of these fuzes may be found in the writer's *Elementary Lectures on Artillery*, 4th Edition, pp. 105, 106.

[3] The shells of all ML. R. guns, and of 40-pr. and higher natures of BL. R. pieces are fitted with the GS. bouch. The naval shells for SB. guns are fitted with the GS. bouch, and take the Boxer ML. O. and the Pettman GS. fuzes.

[4] Should a space occur between the composition and case, the fuze will explode instead of burning slowly.

[5] The auger is guided by the continuation of the side hole beyond the channel.

powder, so that the composition[6] is not disturbed when the fuze is bored for a very short range.[7]

A hollow gun-metal cylinder, termed the *detonator*, is screwed into the top of the fuze; it is closed at the top, but has a fire hole through the bottom, and in a roughened recess above the hole is a small quantity of detonating composition consisting of—

	Parts
Potash (chlorate of)	6
Antimony (sulphide of) . . .	4
Mercury (fulminate of) . . .	4

A hammer is suspended in the upper part of the detonator by means of a copper wire, and a jagged projection at the bottom of the hammer hangs immediately over the detonating composition.

As the top of the fuze is closed by the detonator, it is necessary to provide for the escape of the gas from the burning fuze composition, and three *escape holes* are made for this purpose through the head and below the detonator; these holes are closed by a copper disc and a millboard disc, over which paper is pasted and afterwards painted. A safety pin passing through the top of the fuze and the detonator prevents the liability of accident.

When the gun is fired the suspending wire is broken, and the hammer coming in contact with the detonating composition explodes it, the flame passes through the fire hole, ignites the quickmatch, and fires the fuze composition. The fuze is bored like a common fuze. It can be employed as a *percussion fuze*, for on the impact of the shell against a hard substance the fuze is driven into and explodes the shell.[8]

16. The 9-*seconds Boxer time fuze* used with ML. guns

[6] The rate of burning is—

1″ in 4·36 seconds in 40-pr. shell
1″ „ 4·24 „ 7″ „

[7] If the top was driven with fuze composition, which burns at half the rate of mealed powder, there would be such a short distance above the upper side hole that the auger might displace the composition above this hole when bored through it.

[8] For a more detailed account of this fuze by Capt. Majendie, R.A., see *Proceedings of R. A. Institution*, vol. iv. p. 171.

which have windage is lighted by the flame which surrounds the projectile, and requires therefore no detonating arrangement to fire the composition.

The body is similar to that of the Boxer fuze for BL. R. O. The head is closed by a gun-metal plug,[9] and has two fire holes, through each of which a strand of quickmatch, doubled round a copper pin projecting down from the plug, passes, the projecting ends being laid in a groove round the head; this match in the groove is protected by a double band of tape, having a very thin strip of copper between the pieces of tape, the band being attached by two tacks and india-rubber cement, and covered with varnished paper. The copper strip projects from the band, and when it is pulled the ends of the match are exposed.

This fuze is intended for the projectiles of ML. guns having the GS. bouch. Like the fuze for BL. R. O., it contains 1·8″ of fuze composition and ·4″ mealed powder, which together burn 10 seconds when not in motion, but approximately only 9 when used with the shells of R. ordnance. The ML. O. 9-seconds fuze, Mark II., has increased priming for field and boat service, comparatively small charges being there used. Gun cotton is also provided as additional priming for ML. O. Boxer fuzes when firing shells with reduced charges, a short length of it being laid round outside the match.

17. The *5-seconds Boxer time fuze*, driven with meal powder which burns twice as fast as fuze composition, has side holes marked in half-tenths to adapt it to great nicety in boring. It is painted red, to distinguish it from the 9-seconds fuze, and is intended for use with shrapnel shell. There are two patterns of 5-seconds fuze, with heads adapted respectively to BL. R. and ML. R. guns. The ML. O. 5-seconds fuze, Mark II., has increased priming for field and boat service.

18. The two *20-seconds Boxer time fuzes* for ML. and BL. R. ordnance respectively are of similar construction as regards the head to the two 9-seconds fuzes for the shells of the same

[9] To prevent the great pressure of the air meeting the projectile, which when elongated and fired from a rifled gun proceeds point first, affecting the burning of the composition. The greater the pressure the more rapid is the rate of burning.

guns, but they contain 4″ of fuze composition, and burn from 18 to 20 seconds in shells of R. pieces; they, like large mortar fuzes, have no side channels, and only one row of side holes, disposed spirally round the fuze, commencing at 2″ and extending to 4″ (Fig. 73). They have a pellet, driven like a

Fig. 73.

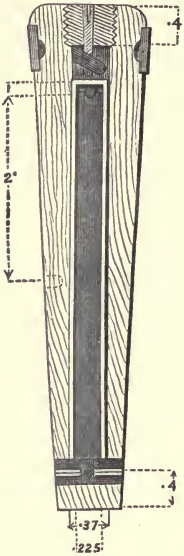
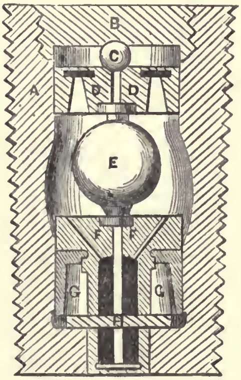


Fig. 74.



tube, across the composition bore at the bottom, in order to increase the flash.

19. The different parts of the *Pettman general service fuze* (Fig. 74) are—

A. Body.	D. Steady plug.	G. Lead cup.
B. Top plug.	E. Detonating ball.	H. Suspending wire.
C. Plain ball.	F. Cone plug.	

The steady and top plugs are cupped in the centre to receive the small *plain ball* of brass wire, which holds them apart; and, to prevent the ball adhering from corrosion, the cups are slightly larger in diameter than the ball. Round the top of the steady plug runs a groove filled with detonating composition, and two fire holes pass from the composition down through the plug.

The composition in the annular groove is covered with thin sheet brass. The detonating ball, which is coated with composition, is covered with two hollow hemispheres of sheet copper, and over these with silk. The cone plug (no longer coned) has three fire holes, and is supported by a copper wire which passes through the tube; but the hollow of the latter is enlarged below the wire to prevent its being choked. The lead cup (pure lead) does not rest on the bottom of the fuze, but is supported at the top on a shoulder on the cone plug. This fuze is adapted for shells having the GS. Bouch.[1]

On the discharge of the gun the suspending wire is broken and the lead cup crushed in consequence of the inertia of the cone and steady plugs and of the balls, which do not move instantaneously with the fuze and lead cup; sufficient space is therefore left for the disengagement of the balls, and the *plain ball* will in consequence of the rotation of the shell roll round the side of the chamber, and therefore on the composition in the groove. On impact the fuze is ignited by the concussion of the detonating ball on the inside of the body, or by the plain ball on the composition in the groove of the steady plug, which continuing to move, after the sudden check to the motion of the fuze, presses the plain ball between itself and the top plug.

20. The *Royal Laboratory Percussion Fuze* for shells of ML. R. guns is a modification of the Armstrong C. cap percussion fuze, the internal construction being the same. It consists of three principal parts—body, pellet, and guard.

The *body* (*a a*, Fig. 75) is cast with a solid head, but has a screwed-in bottom, primed with a perforated pellet of mealed

[1] Composition of which the different parts are made:—

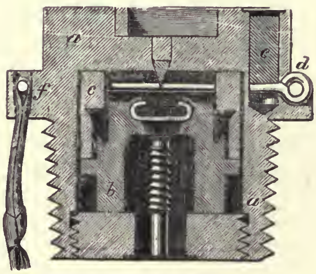
Parts of Fuze	Copper		Tin		Zinc	
	lbs.	oz.	lbs.	oz.	lbs.	oz.
Body and Top Plug	11	0	1	0	0	1½
Plain Ball	70	0			30	0
Steady Plug . . . . } Detonating Ball and Cone Plug } .	7	0	1	0		

The detonating composition in the steady plug and on the detonating ball consists of—

	Parts		Part
Chlorate of Potash . . .	12	Sulphur	1
Sulphide of Antimony . .	12	Mealed Powder . . .	1

powder, and closed by a brass washer. It has a thread outside to fit the GS. fuze-hole, and a square hole in the top for the GS. key, by which it is screwed in. A steel point projects downwards from the top. To avoid liability of accident in transport, a *safety-pin* (*d*) passes through the body and guard, and is secured by a brass ring (*f*) resting in a recess round the head; the ring has a tape lug, by which it can be raised when it is necessary to withdraw the pin after the shell has been placed in the muzzle of the gun. The hole left by the removal of the pin is closed, to prevent premature explosion,[2] by a *lead pellet* (*e*) working in a cylindrical hole above; the inertia of the pellet causes it to cover the hole either in ramming home or firing the shell.[3]

Fig. 75.



The *pellet* (*b*), of white metal (equal parts of lead and tin), has four projections or feathers outside, two rather higher than the others. It is driven with composition like a tube, but has a percussion-cap at the top, protected by a thin brass disc, which can be pierced if driven on to the steel point above by a violent shock; the cap has three holes at the bottom for the passage of the flame from it to the composition below.

The *guard* (*c*), made of gun-metal, is supported in the upper part of the body on the feathers of the pellet, preventing any forward movement of the latter.

Action.—When the gun is fired the inertia of the guard shears the feathers of the pellet, the guard then resting at the bottom of the fuze with its upper surface on a level with that of the

[2] From the flame of the charge which surrounds the shell in a ML. gun.
[3] *List of Changes*, § 2,191.

pellet. On the impact of the shell against an object, the pellet continues its forward motion when the top of the fuze is suddenly stopped, the cap, striking on the steel point, is fired, the flame ignites the composition in the pellet, and, blowing out the washer of the fire-hole in the bottom of the fuze, passes into and explodes the shell.

21. The *Armstrong C. cap Percussion Fuze* also consists of the same three principal parts, the body being, however, of a somewhat different construction, as the fuze is used with BL. R. guns, being placed below a time fuze or a plug, which closes the top of the shell.

The *body* is made of gun-metal, and is cast with a bottom, through which the fire-hole is drilled and primed with a perforated pellet of mealed powder protected by a brass washer. The top, which is of gun-metal and fitted in, has a steel point projecting down from its centre, and four holes through it closed by a thin brass washer; these holes were intended to allow of the flame from a time fuze (which in the segment shell was placed above the percussion fuze) passing into the pellet and so igniting the shell before impact. The body has a rim round it at the top to prevent its being placed in the shell head downwards. The safety pin is of twisted brass wire, and can be drawn out by the braid attached to it.

SECTION D.

22. It has been already pointed out that the charge of a rifled gun is less in proportion to the weight of projectile than that of a SB. gun; the reasons being that the strain is much greater in a rifled than in a smooth-bored piece fired with the same weight of projectile, and that a smaller proportional charge is quite sufficient for a rifled gun fired under ordinary circumstances, as, although its elongated projectile has a lower initial velocity, it exposes less surface to the resistance of the air, and does not lose its velocity so rapidly as a spherical projectile.

The BL. R. guns and the ML. R. 64-pr. have *service* charges of *one-eighth* the weight of the projectile. The heavy ML. R.

guns, from 7 to 12 inch, have a *battering* as well as the *service* charge. The latter is the charge fired under ordinary circumstances, and with common or shrapnel shell and case shot; the battering charge is employed with Palliser projectiles against objects protected by iron, when a very high velocity is requisite; the battering charge is liable to *score* or *gutter* the part of the bore over the projectile, but a wad (Bolton) is usually placed between the projectile and cartridge to lessen the injury as much as possible. The proportion of battering charge (pebble powder)[4] to projectile in the heavy rifled guns is about as follows:—For 7-in. $\frac{1}{4}$, for 8 and 9 in. $\frac{1}{5}$, for 10 and 11 in. $\frac{1}{6}$, and for 12-in. (23 tons) $\frac{1}{7}$.

Charges and Lengths of Cartridges for Heavy ML R. Ordnance.[5]

Gun	Battering				Full			
	R. L. G.		Pebble		R. L. G.		Pebble	
	Charge	Length	Charge	Length	Charge	Length	Charge	Length
	lbs.	ins.	lbs.	ins.	lbs.	ins.	lbs.	ins.
12-in. (25 tons)	67	18·9	85	22	50	15	55	14·75
11-in.	70	24·5	85	25·5	50	19	60	18·5
10-in.	60	25·5	70	25·5	40	18	44	16·8
9-in.	43	22·5	50	23	30			
8-in.	30	20·5	35	21·5	20			
7-in.	22	18·8	30	23	14			

23. There are three kinds of cartridges for rifled guns:—

Service cartridges.
Saluting "
Drill (or dummy) cartridges.

All, except for the ML. guns, are made of two pieces of serge, a body and a bottom, which are stitched together; the body is secured with an overlap of 1″ and three rows of stitches; it is hooped with worsted braid, a stronger material

[4] For charges over 50 lbs. the pellet or pebble (slow-burning powders) are used.

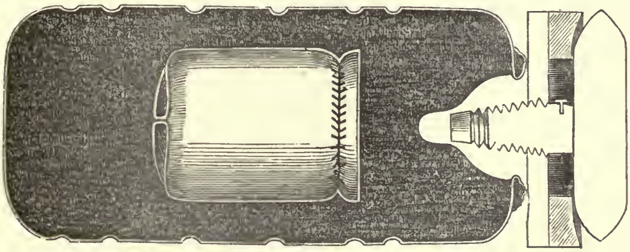
[5] *List of Changes*, § 2,103. The cartridges are about ·5 less in diameter than the bore.

than the plain worsted used for SB. cartridges, and it is choked with twine.[6]

A cartridge (with the lubricator) should fill the chamber of the gun, for if there be a vacant space between the cartridge and shot, when the gun is fired a greater strain will be exerted upon the bottom of the bore (vent piece, or slot, &c.) than would be caused by the explosion of a cartridge in contact with the projectile and with the end of the chamber.[7]

Some of the cartridges of BL. R. guns, if filled with their respective charges alone, are not long enough to extend from

Fig. 76.



the bottom of the bore to the base of the shot; but to give them the requisite length, a hollow paper cylinder is placed in the middle of the powder inside the cartridge (Fig. 76). The following cartridges have paper cylinders:—the 64-pr., 40-pr., and 20-pr. The 7″, 64-pr., and SS. 40-pr. cartridges have each a paper socket choked into the top, to receive the screw by which the lubricator is attached; in the LS. 40-pr. and lower natures the lubricator has no screw, and is choked into the cartridge at the top of the powder.

[6] Cartridges to hold 40 lbs. and over to be hooped with blue braid, double the width hitherto used.

[7] This has been accounted for in the following way. When the cartridge fills the chamber, the gas cannot expand until the shot moves, and therefore the force exerted is of the nature of a pressure; but if there is a vacant space, the gas expands, acquires momentum, and being then suddenly checked, a percussive force or blow is given both on the shot and bottom of the bore; the same effect is produced in a SB. gun when the shot is not *home*, in which case, as is well known, a cast-iron gun is liable to burst.

There are three sizes of *blank cartridges* for BL. R. guns:—

1st for 9 and 12-prs.	containing	1 lb.	of powder.
2nd „ 20-prs.	„	$1\frac{1}{2}$	do.
3rd „ 40-prs.	„	3	do.

These have no lubricators or wads, but paper cylinders to give them the requisite length.

The *drill cartridges* are made of blue serge, to distinguish them from others (which have white serge), and they contain a wooden cylinder, having a copper plate at the base, to prevent injury from the explosion of the tube, or from the rammer; the 7″, 64-pr., and SS. 40-pr. cartridges are provided with gun-metal sockets to receive dummy lubricators, made of wood and having gun-metal screws; the LS. 40-pr. and lower natures of cartridge have wooden dummy lubricators choked in. The drill cartridges of ML. R. guns are made of raw hide.

Cartridges for heavy ML. R. guns are packed in zinc cylinders for land service;[8] these serve both as metal cases and as cylinders to bring the charge up to the gun. The cylinder has a galvanized iron handle by which it can be carried, or by twisting the lid can, in the first patterns, be disengaged from the buttons which secure it to the body; in later patterns, the lid is held by two hooks, and it is fitted with a felt-ring saturated with beeswax.

For the 9-inch and higher natures, there are separate cylinders for full and battering charges, but for the 7-inch, one cylinder will hold either one battering or two full charges.

24. The solid residue (from the powder) left within the bore after firing would, with BL. rifled guns, clog the grooves and foul the bore if allowed to remain in it; but this residue is got rid of by the *lubricator*. The lubricator[9] consists of three parts (Fig. 76):—

The tinned-iron wad,
„ felt do.
„ millboard disc,

[8] *Ammunition*, by Capt. C. O. Browne, R.A., p. 136. *List of Changes*, § 2,103. Corrugated metal cases are used in the Navy, but not these zinc cylinders.

[9] Contrived by Major-General Boxer.

the first being next to the projectile, and the second between the two others.

The iron wad is made of two cups of tinned iron soldered together at the edges, and containing between them a lubricant consisting of equal parts of tallow and oil; the lubricant is poured in through a small hole at the bottom of the wad, which is closed by a metal disc soldered over it.

The felt ring is a disc of felt for the 20-pr. and lower natures of gun, but a felt ring for the 40-pr. and higher natures; the felt wad is glued on to the millboard disc, and the edges of both are dipped in beeswax.

When the lubricator is choked into the cartridge,[1] the millboard disc and the felt wad are attached by a wire to the iron wad, the wire being soldered to the latter. The SS. 40-pr. and higher natures have a wooden screwed stalk attached to the iron wad, and passing through the two other parts; it projects below the millboard disc, so that it can be screwed into the socket of the cartridge (Fig. 76).

The lubricator is placed between the charge and the projectile, and acts as follows: The explosion of the charge drives the iron wad up against the base of the projectile, flattens this wad out, the heat from the discharge probably melting the solder, and releases the lubricant, which is splashed forward in the bore. The felt wad serves two purposes: its interposition ensures the iron wad being evenly pressed open, instead of being blown to pieces, in which latter case the lubricant would not be distributed equally over the bore; it also acts as a mop in wiping up and carrying forward the lubricant, while the beeswax upon its edge gives a polish to the bore. The millboard disc affords a support to the felt wad, keeping its edges pressed out against the bore.

25. Tin cups are always used with BL. R. 7-inch and 64-pr. guns to prevent the escape of gas at the bottom of the bore, for which purpose they are placed behind the cartridge.[2]

[1] In LS. 40-pr. and lower sizes of cartridge.

[2] Cups are now ordered to be used with practice ammunition for the 40, 12, and 9-pr. BL. R. guns which have copper facings. Each cup is supposed to last several rounds—10 rounds with screw BL. guns, and 4 rounds with 64-pr. wedge gun.

26. Bolton wads, used to prevent the *scoring* of the bore, are made of pulp, prepared from 75 per cent. of old rags (known as tammies or woollens) and 25 per cent. of old tarred rope, formed in a mould and coated with waterproof varnish.[3]

[3] A certain number of papier-mâché wads, made prior to Bolton wads, are to be used up. Experiments were made in 1872 with different wads intended to prevent *erosion* or *scoring* in the bores of guns. Four ML. R. 7-inch guns, retubed to give a length of bore of 118 inches, were fired 500 rounds with Palliser shot of 115 lbs., three of the guns with wads, and one without.

Gun No. 200,	Charge 30 lbs. (Pebble).	Cowhide wad with projections.
„ „ 199,	„ 22 lbs. (LG).	„ „ „
„ „ 198,	„ „ „	Bolton wad with projections.
„ „ 299,	„ „ „	No wad.

No. 200 gun was so much scored as to require turning over if firing were continued; the other pieces were but little scored, and could fire 500 rounds more. No. 200 required re-venting five times; Nos. 199 and 299 twice. The cowhide wads were frequently projected as far as 300 to 600 yards in an entire state; but the Bolton wads invariably broke up. With the cowhide wads in both guns, the velocities were lower in the last 10 than in the first 10 rounds; but with the Bolton wads, or when no wads were used, the velocities of the last 10 were higher than those of the first 10 rounds. The highest velocities were obtained with the 22 lbs. charge when fired with cowhide wads, and the lowest when no wad was used. (*Proceedings of Department of Director of Artillery*, vol. x. pp. 75, 100). Tin cups were tried, but found objectionable, from their tendency to fly about in front of the gun. (*Proceedings of Department of Director of Artillery*, vol. ix. p. 141.)

CHAPTER X.

MEANS OF FIRING ORDNANCE. ROCKETS.

1. Different ways of firing ordnance.—2. Tubes.—3. Dutch or paper tubes.—4. Copper friction tube.—5. Quill friction tube.—6. Electric tube.—7. Primer for BL. R. guns.—8. Portfires.—9. Match.—10. Magnet.—11. General description and principle of the rocket.—12. Signal rockets.—13. Hale's war rockets.

This chapter will be divided into two sections:—

A. Tubes—Portfires—Match—Magnet. B. Rockets.

Section A.

1. The charge in the bore of a piece of ordnance may be ignited in various ways; that in general use in our service is by means of the friction tube, which is altogether the most simple and effective. Other tubes have also been employed which required locks, portfires, &c., to ignite them; and if no tube of any kind is at hand, the gun may be fired by pouring loose powder into the vent and using a portfire or slowmatch. Should the vent be closed or stopped up, if the gun be spiked for instance, the charge may be fired by a piece of quickmatch placed down the bore and ignited at the muzzle.

2. A tube consists of a *barrel* of quill, paper, or metal, about 3″ long (5″ for 10-in. guns and over), driven with mealed powder damped with methylated spirit, and at the top of the barrel is a cup or head, the construction and priming of which varies with the nature of tube; the barrels of all tubes are ·2″ in diameter. A hollow is made down the middle of the composition, so that the whole length may be ignited at once, and, a large amount of gas being thus generated in a small channel, it acquires sufficient force to fire a charge of gunpowder placed at some distance below the bottom of the tube.

'The peculiar action of a tube, viz. that of igniting gunpowder or a similar composition when placed at some distance from it, is due to the motion given to the heated gas by its own elastic force. The velocity with which the gas will issue from the tube will depend principally upon the amount of pressure which the particles have been subjected to in the cavity; now, this pressure increases in proportion to the quantity of gas generated, and diminishes as the space which is occupied by the gas increases. If this principle be taken into account, it is evident that a small cavity in a tube is more advantageous than a large one; for the quantities of gas are as the ignited surfaces, whereas the spaces occupied by the gas are as the squares of these surfaces; therefore, by increasing the cavity the quantity of gas is increased, and the amount of its elasticity will be at the same time diminished.'[1]

The different kinds of tubes in the service are:—

1. Dutch or paper.	3. Quill friction.
2. Copper friction.	4. Electric.

The first tube is fired by means of a portfire, the second and third by a lanyard, the fourth by means of copper wires leading from a magnet.

3. The barrel and cup of the *Dutch* or *paper tube* are both made of paper; the priming of the latter, which consists of mealed powder damped with methylated spirit, is worked into the form of a cone, and afterwards dipped in dry meal powder. The cap is of paper dipped in a solution of saltpetre, and secured underneath the cup with twine; this cup is not removed on firing. These tubes can be readily made on a deficiency of others, but they are not manufactured in the Royal Arsenal, and cannot be properly considered as service tubes.

4. The *copper friction tube* (Fig. 77) is made entirely of copper. A short piece of tubing, called a *nib-piece*, is fixed by solder and wire near one end of the barrel, and at right angles to it, a hole of communication being bored through the

[1] Lieut.-Col. Boxer's Manuscript Notes.

barrel into the tubing. A small piece of copper, termed the *friction bar*, having its surface roughened, is placed in the centre of the short tubing, the outer end being formed into a ring, to which the lanyard is hooked. A patch of detonating composition is placed above and below this strip, and the short tubing is compressed on to it by means of a pair of pincers. The strip, on being pulled smartly from the tubing, causes sufficient friction to ignite the detonating composition; the tube is closed at the bottom by shellaced paper, and at the top by shellac putty.

Fig. 77.

5. The *quill friction tube* is made on the same principle as the above, only quill is used instead of copper, the latter being objectionable for the naval service from the annoyance it might occasion to men between decks. In this tube the friction bar passes through a slit cut in the top of the barrel, and there is only one pat of detonating composition, which is placed above the bar; the bar is covered with ground glass and shellac, and its end is turned down to ensure ignition; over the pat is placed a little rifle powder, and above this a mixture of ground clay and beeswax, the whole being closed with a parchment cap. The head of the tube is woolded with copper wire to strengthen it, and a leather band is tied on, its end passing round the exposed part of the friction bar. The tube is fired with a metal crutch attached near the vent; this crutch supports the head and prevents its bending when the friction bar is pulled, and the lanyard passes through a guide plate fixed to the breech, so that it may be pulled in the requisite direction.

Both copper and quill friction tubes are fired by means of a lanyard, which is merely a piece of cord, having a metal hook at one end to fit into the ring of the *friction bar*.

THE DETONATING COMPOSITIONS FOR THE HEADS OF THE FRICTION TUBES.

Tubes	Chlorate of potash	Antimony crude	Mealed powder	Sulphur sublimed
	parts	parts	parts	parts
Copper friction tube . .	12	12	0	1
Quill „ „ . .	12	12	1	1

6. The beech-wood head of the *electric tube* is egg-shaped and has a hollow passing through the middle, into the bottom of which the top of a quill barrel, driven with composition in the ordinary way, fits; a piece of gutta-percha, filling up the hollow above the barrel, contains two copper wires running down it, but kept apart by the gutta-percha, and a small quantity of explosive composition, consisting of chlorate of potassa, phosphide of copper, and sulphide of copper, placed in a paper cap, is fitted on to the lower poles of the wires; the other ends of the wires are carried round the top of the head to two copper-lined holes passing through the head, one wire communicating with each hole. The tube is connected with the magnet by two copper wires, the end of each being placed in one of the copper-lined holes, and when the current circulates from the magnet, the spark passing across the break, from pole to pole of the wires at the bottom of the gutta-percha, ignites the explosive composition and fires the tube.

7. A *primer* is used with the 40-pr. and 7″ screw BL. guns. The *primer* is a supplementary tube placed in the horizontal part of the vent before the vent piece is placed in the gun, the object being to communicate the flame from the ordinary tube to the cartridge. It is merely a barrel about 2½″ long, made of leather paper, driven like a tube, and having three strips of loosely twisted worsted tied along it outside, so that it may fit the vent-piece, and that the gas may pass round it and not blow it out of the vent into the bore without being ignited.

8. The portfires used for *artillery* purposes are of two kinds, viz. *common portfires* and *slow portfires*.

The *common portfire* consists of a paper case about 16 in. long, into which is driven a composition which burns at the rate of rather more than one inch in a minute. The composition consists of—

	lbs.	oz.
Saltpetre (ground)	6	0
Sulphur (sublimed). . . .	2	0
Powder (mealed)	1	4

The *slow portfire* consists merely of paper impregnated with saltpetre, and rolled into a solid cylinder about 16 in. long, which will burn for two or three hours. These are readily made on a deficiency of other portfires. The solution with which the paper is impregnated consists of—

Saltpetre . . .	12 oz.
Water . . .	1 gallon.

9. There are two kinds of match, viz. *cotton quickmatch* and *slowmatch*. The former is merely cotton, coated with a composition of mealed powder, gum, and water, and is used for a variety of purposes, as for instance in firing trains of powder; also, under certain circumstances, ordnance, rockets, &c.

Quickmatch when not confined burns at the rate of 1 yard in 13 seconds, but when enclosed in a tube it is called a *leader* and explodes instantaneously, for the gas cannot escape as quickly as it is formed, but, passing through the tube, ignites the whole.

The Different Kinds of Quickmatch.

	Four-thread Match	Six-thread Match	Ten-thread Match
Cotton . . .	1 lb. 10 oz.	2 lbs. 2 oz.	2 lbs. 7 oz.
Water . . .	8 pints	9 pints	10 pints
Gum . . .	8 oz.	9 oz.	10 oz.
Powder . . .	20 lbs.	20 lbs.	24 lbs.

Slowmatch consists merely of hempen rope loosely twisted, and boiled in wood ashes and water.[2] It is very useful in firing charges of powder when it is necessary that some time should elapse between the ignition of the match and that of the powder; it burns at the rate of one yard in three hours.

[2] The proportions being—

Wood ashes . .	1 bushel	to 100 lbs. of yarn.
Water	50 gallons	

10. When there is any danger of a gun bursting, as in proof, it is fired by means of a *magnet* placed in a splinter-proof building, the current of electricity being conveyed to the tube (electric) by copper wires. The magnet consists of six small magnets, to the poles of which are fixed soft iron bars surrounded by coils of insulated wire. The coils of all the magnets are united together so as to form with the external conducting wire and the earth a single circuit; an axis carries 6 soft iron armatures in succession before each of the coils. By this arrangement all the magnets simultaneously charge the wire and produce the effect of a single magnet of more than 6 times the dimensions, whilst at the same time 6 shocks or currents are generated during a single revolution of the axis, so that when a multiplying motion is applied to the axis a very rapid succession of powerful currents is produced. The magnet is contained in a small box, having pressure screws to secure the wires, keys to press down and make the connection with the different guns when required, and a handle which when turned causes the armatures to revolve with great rapidity.

Section B.

11. A *rocket* consists of a cylindrical case of paper or metal, containing inflammable composition; to one end of the case is attached a head usually of a conical or cylindro-conoidal form, and the other end is closed, but has one or more vents or holes in it for the escape of the gas from the ignited composition. The composition is driven into the case over a conical spindle, passing to a certain distance up the centre, thus leaving a hollow space in the interior of the rocket, the base of the hollow cone coinciding with that of the rocket.

The object of having this cavity in the interior of the rocket is,—that a large surface of composition may be at once ignited when the rocket is fired, and so great a quantity of gas generated within the case that it cannot escape from the vent as quickly as formed, and therefore it exerts a pressure in every direction on the interior surface of the rocket. The pressures on the sides of the rocket mutually balance each other, but the pressure on the head is greater than that on the base, in consequence of the escape of gas from the vent or vents; it is this excess of pressure on the head over that on the base which causes the rocket to move forwards, this being merely a similar action to the recoil of a gun.

The force which produces motion in a rocket is therefore different from that which acts upon a projectile fired from a piece of ordnance; the former is a *constant* force producing accelerated motion in the rocket until the resistance of the air is equal to the force, or the composition is consumed; while the latter may be considered merely as an *impulsive* force, which ceases to act upon the projectile when it has left the bore of the piece.

A stick or long rod is attached to the base or side of a rocket of ordinary construction, which has no rotatory motion during flight, in order to counteract, by the resistance of the air upon it, any tendency to turn over, and to maintain the rocket during its flight as nearly as possible in the direction in which it is fired; when accuracy of flight is required, the stick should be strictly in prolongation of the axis of the rocket.

There are two descriptions of rockets used in the service, viz.

The signal rocket. The Hale war rocket.

The former, as its name implies, is employed for making signals, and the latter as a destructive projectile.[3]

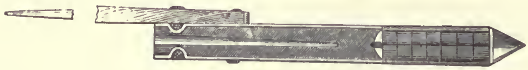
[3] Although rockets have been used for war purposes (it is generally supposed) for centuries in the East, and at an early date even in Europe, they were of little practical utility until improvements in their construction and manufacture were introduced by Sir William Congreve, at the beginning of the present century. Five natures of rockets were proposed by that officer, viz. 3, 6, 12, 24, and 32-prs.; the latter were, however, not retained in the service.

The case for the Congreve rocket was made of sheet iron, and the composition with which it was driven was stronger than the ordinary rocket composition. The composition was protected from the injurious action of the metal of the case by paper lining which, like the interior of the case, was painted with anti-corrosive. A hollow iron head, cylindro-conoidal in form, was riveted on to one end of the case, which could be filled with powder when intended to act as a shell, but left empty if only intended for a shot. The larger natures of rockets (24 and 12-prs.) could be used as carcasses by substituting for the ordinary head a conical one with six vents, and filled with carcass composition.

Every rocket, except those with carcass heads, was fitted with a fuze fixed in the base of the shell, and there was a small hole in the apex of the shell for the insertion of the bursting charge, and through which the boring bit was introduced when it was required to bore into the fuze composition; this hole was closed by a

12. The signal rockets in the service are of two natures, viz. 1 lb. and ½ lb. (Fig. 78). The case and head are made of strong paper, the former containing the rocket composition, and the latter the composition for the stars; the bottom of the case is choked in so as to form a single vent in the axis, and the stick is attached to the side of the rocket, a very defective arrangement, causing eccentricity in the form of the projectile, and unequal pressure of the gas from the vent upon the stick.[4]

Fig. 78.



These rockets are fired vertically or nearly so; when the composition is consumed, the bursting charge explodes the head and ignites the stars, which in falling produce a brilliant light, that can be seen to a great distance.

According to Robins, rockets between 1″ and 2″ in diameter ascend vertically to a height of from 450 to 600 yds.; those

metal screw plug, which could easily be removed, in order to insert the bursting powder. When the rocket was required to act as a shell at very long ranges, the fuze composition was not bored into, but as the range was reduced a greater quantity of fuze composition was bored out; and at the shortest ranges the whole of the fuze composition, and also a portion of the rocket composition, was bored through, to within 1½″ of the top of the hollow cone in the 24-pr. rocket, and to within 1″ in the other natures. It was considered by many officers that the time required for boring the fuze, and the danger of the operation, was not compensated by the increased effect produced by the bursting of the shell.

The bottom of the case was closed by an iron disc having a centre hole into which the stick was screwed, and five other holes, or vents (for the escape of the gas), equidistant from each other and from the centre hole. The stick thus placed in the axis of the rocket was a great improvement on the old way of attaching it to the side.

[4] The composition for signal rockets consists of—

	lbs.	oz.
Salpetre	4	0
Sublimed sulphur	1	0
Dogwood charcoal	1	8

The ingredients for the star composition are—

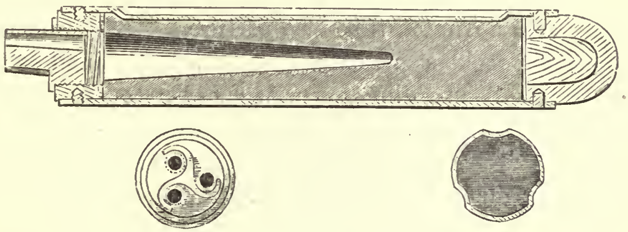
Sublimed sulphur	2 lbs.	Vinegar	1 quart
Saltpetre	8 ,,	Spirits of wine	1 pint
Sulphide of antimony	2 ,,	Isinglass	3½ oz.

with 1 lb. of mealed powder for dredging.

whose diameters are from 2″ to 3″ to a height of from 1,000 to 1,200 yds. He also ascertained from experiment that they could be seen within a circuit of from 35 to 40 miles, their time of ascent being 7 to 10 seconds.

13. The *Hale rockets* are contrived so that the gas issuing from the vents imparts a rotatory in addition to a forward motion; they therefore require no sticks (Fig. 79).

Fig. 79.



Base. Section.

It will be seen from the diagram of the base that there are three vents, and round one side of each vent is a circular metal plate or *half shield*, projecting about 1·5″ beyond the base; when the gas issues from the vents, its pressure on the three *half shields* causes the rocket to rotate, and gives its longer axis stability during flight; in this rocket there is no waste of gas, for that which propels the rocket also gives it a rotatory motion.

The cases are formed of *Atlas metal*, riveted and brazed. Each rocket is corrugated, in order to give a mechanical hold to the composition, and to prevent its being separated from the case by the rotation when fired. The hollow in the head is plugged with oak, and the inside of the case receives two coats of paint to prevent contact between the metal and the composition.

Nature	Total Weight		Diameter of Vents	Composition		
				Nitre	Sulphur	Charcoal
	lbs.	oz.	in.	parts	parts	parts
9-pr. . .	8	6	·4	68·75	12·25	18·75
24-pr. . .	25	12	·62	70	16	23

Four natures of these rockets were adopted, but only two will now be issued—

9-pr. for Field Service. 24-pr. for Fortresses.

Machines or *troughs* are provided to fire the rockets from.[5] The iron *trough* is supported on an iron tripod, and elevation can be varied by sliding a double bar connecting the front of the trough to the long leg of the tripod below; this leg is graduated, and the socket of the bar which moves along it can be clamped to preserve any required elevation. The rocket can be fired with a friction tube or a portfire.

The Hale rockets are employed, both in the land and naval services, for bombarding towns, in order to set fire to the houses, shipping, &c. It is difficult with rockets to obtain anything like accuracy of fire, and they can therefore be used only against objects covering a considerable extent of ground.

[5] They may also be fired by laying them upon the ground, the head of the rocket being slightly elevated; a number of the smaller natures placed in a row and fired in this manner would, no doubt, prove very effective against troops, particularly cavalry.

PART II.

PRINCIPLES AND PRACTICE OF GUNNERY.

CHAPTER I.

IMPORTANCE OF A KNOWLEDGE OF THE PRINCIPLES OF GUNNERY.

1. Gunnery at first but a rude art.—2. Attempts of Leonardo da Vinci and Tartaglia to lay down the principles of gunnery.—3. Contributions of Galileo and Newton to the science of gunnery.—4. Science of gunnery founded by B. Robins.—5. Neglect of Robins' suggestions.—6. Value of the investigations of scientific artillerists.—7. Increased difficulties in gunnery questions balanced by improved appliances.—8. Proper method of investigating gunnery questions.—9. Sir John Herschel's observations on the study of physical science.

1. It may be seen by reference to the history of artillery, that gunnery was practised as a rude art long before any attempt was made to discover the principles upon which it is based; and this was necessarily the case, for no sound data from which any principles could be derived were to be obtained when the guns and projectiles employed were so rough and inaccurate in construction. The practice from such pieces, fired with gunpowder very inferior in quality to that now used,[1] must have been very uncertain, and improvements in artillery *matériel* could only proceed as progress was gradually made in the mechanical and other kindred arts.

2. Leonardo da Vinci had shown,[2] in the fifteenth century,

[1] Tartaglia gives a great number of powders, the ingredients varying in their respective proportions; the first consisted of equal parts of saltpetre, sulphur, and charcoal.

[2] Lieut.-Col. Jervis, R.A., in his work called *Our Engines of War*, remarks upon the great and, for the age, wonderful knowledge displayed by the celebrated painter, sculptor, and engineer, Leonardo da Vinci. He says: 'We thus find him (Leonardo) pursuing his researches from the simplest questions in geometry and statics to some of the deepest laws of dynamics, especially those affecting the flight of projectiles, a theory then new amongst mathematicians.' Leonardo himself explains his manner of studying phenomena in order to arrive at safe

a knowledge of the laws affecting the flight of projectiles which was far beyond that possessed by any of his contemporaries, or by others who afterwards wrote upon the subject up to the time when Tartaglia published his celebrated Colloquies on the Art of Shooting.[3] This book would appear to have been the first serious attempt to reduce the rude practice of gunnery to certain definite principles, and was a remarkable work for the time in which it was produced; it gave a great deal of information concerning both the theory and practice of gunnery, as then understood, and proved Tartaglia to be a man of great talent and ingenuity. He explained the motion of a projectile, taking the resistance of the air into account, and the theory of gunpowder; and the accuracy of his conjectures, considering the state of the mechanieal and other sciences at the time, is surprising.

Up to the time of Tartaglia, and indeed for long after, it was generally supposed that a shot after leaving the bore of a gun proceeded for some distance in a right line; Tartaglia says, on the contrary, that 'a piece of artillery cannot shoot one pace in a right line.' He points out that the gas (aire exhalation, or wind) from the powder expels the shot, and that 'the more swifter a pellet doth flie, the lesse crooked is his range,' or, as we should say, the higher the velocity, the flatter the trajectory. He also says that the maximum range, *utmost random* as he calls it, should be obtained at 45° of elevation. He gives directions for sighting ordnance, and shows the use of the gunner's quadrant which he invented, besides entering into much detail regarding the rules to be observed in the manufacture of ordnance, carriages, and gunpowder. Tangent scales or elevating screws were not then used, but from the diagrams

conclusions thus: 'I will treat of the subject, but first of all I will make some experiments, because my intention is to quote experience, and then to show why bodies are found to act in a certain manner.' Leonardo was born in 1452. In the theory of gunnery he appears to have been a century in advance of his contemporaries. Hallam, in his *Introduction to the Literature of Europe*, says of him: 'In an age of so much dogmatism, he first laid down the grand principle of Bacon, that experiment and observation must be the guides to just theory in the investigation of nature.'

[3] *Three Books of Colloquies concerning the Art of Shooting*, dedicated to Henry VIII.

in Tartaglia's work, it would appear that the trail of the carriage was lowered into a hole in the ground when elevation was required.

Some of Tartaglia's ideas were sufficiently ludicrous; for instance, his notion of the cause of recoil, which he attributed to the rush of air into the bore to fill the vacuum left by the gas from the powder, and illustrated by the anecdote of a dog being sucked into the bore of a gun after its discharge. Moral effect seems to have been much valued at that time, for he gives a receipt for causing 'any great piece of artillerie to make in his discharge an exceeding great noyse, and a marveylous rore,' which was to be accomplished by putting in a piece of lead or shoeleather between the powder and wad, and a little quicksilver through the touchhole.

3. From Tartaglia's time to the appearance of Galileo's 'Dialogues on Motion,' printed in 1646, about a century after, many theories and tables of ranges of military projectiles were published, but, as Robins remarks, 'all egregiously fallacious, and utterly irreconcileable with the motions of those bodies, although some of them were the labours of such who had spent the greatest part of their lives in employments relating to the artillery.'

Galileo,[4] and after him Newton, showed clearly that this resistance must not be neglected; and the latter investigated

[4] Galileo proved by an elaborate geometrical demonstration that 'A Project, when it is carried by a motion compounded of the horizontal equable, and of the naturally accelerate one downwards describes by its lation or tract a semi-parabolic line.' In his Fourth Dialogue, treating 'Of Violent Motions or Projects,' he separates the projects from slings, bows, and cross-bows from those thrown by the force of gunpowder; and points out that projectiles 'of a lighter matter and have a cylindrical form, such as are arrows, their track or path will not sensibly deviate from the curve of a parabola.' In mortar firing he considered the resistance of the air might be disregarded, the charges and consequent velocities being so small, 'the impetus not being supernatural, the projects describe their paths exactly enough.' He however declared plainly that the very great, or as he calls them, *supernatural velocities* of projectiles fired with high charges from firearms will be resisted by the air, and consequently that the parabolic lines will be less inclined or curved at the beginning than at the end. The principle is laid down 'that the air exerts its power in two ways; first, in obstructing the lighter moveables more than the heavier, and in resisting the greater more than the lesser velocity of one and the same moveable.' His defini-

mathematically the trajectory of a projectile, supposing the resistance of the air to vary as the velocity; Bernoulli, in 1718, gave a solution of the problem where this resistance varies as the *square* or as *any power* of the velocity, but as Mr. Bashforth remarks, 'that solution was of no practical use in the state in which it was left by its author.'[5] The suggestions of these philosophers do not appear to have attracted the attention they deserved, for Robins states that he could only find one instance of any computations founded on Newton's doctrine.

4. To Benjamin Robins is due the credit of founding the *science* of gunnery, and of extinguishing the empirical and fanciful notions still prevailing when he published his 'New Principles of Gunnery,' in 1742. He made a great number of experiments, and invented the *ballistic pendulum*, an instrument which, although rough in construction in comparison with modern instruments for determining the velocities of projectiles, was as great a boon to the scientific artilleryman as the telescope was to the astronomer. Robins' 'New Principles of Gunnery' was translated into French and German, and commented on by Euler, and other distinguished mathematicians. In this work he described his experiments, and ably treated some of the most difficult questions, viz. the explosive force of gunpowder, and the effect of the resistance of the air, not only in retarding, but also in *deflecting* projectiles, an effect before overlooked. The value of his invention of the *ballistic pendulum* may be judged from the circumstance that upon the results of experiments with this instrument all modern theories relating to the science of gunnery entirely depended until within the last few years. Robins also contrived another instrument called the *whirling machine* (described in Hutton's 36*th Tract*), by means of which he endeavoured to determine

tion of *terminal velocity* is clear and accurate. 'Though a falling body ought to be continually accelerated in a duplicate ratio of the duration of its motion, however great the moveable may be, and let it fall from never so great an height, yet such will be the impediment of the air, that the body will be deprived of any further increase of its velocity, and reduced to an uniform and equable motion.' (See Galileo's *Four Dialogues*, translated by T. Weston, 1734.)

[5] *A Mathematical Treatise on the Motion of Projectiles*, Preface and page 45.

the resistance of the air to bodies of different forms moving with very low velocities of 10 to 20 feet per second. The investigations of Robins were carried on at the end of the same century by Dr. Hutton, of the Royal Military Academy, Woolwich, who, improving the apparatus used by the former, and after a long series of careful experiments, deduced a number of formulæ, from which some of the most difficult problems in gunnery may be approximately solved.

5. It may, perhaps, be asked, What have these theoretical questions to do with the practice of artillery? A sufficient answer will be found in the fact, that Robins, by his explanations of the true value of *rifling*, and of the advantages to be derived from the use of *elongated* projectiles, anticipated the late revolution in firearms by a hundred years. Had practical men attended to his suggestions, rifled guns might have been introduced in the last century. His prophecy was remarkable: 'I shall therefore close this paper with predicting, that whatever State shall thoroughly comprehend the nature and advantages of rifled barrel pieces, and, having facilitated and completed their construction, shall introduce into their armies their general use, with a dexterity in the management of them; they will by this means acquire a superiority which will almost equal anything that has been done at any time by the particular excellence of any one kind of arms; and will perhaps fall but little short of the wonderful effects which histories relate to have been formerly produced by the first inventors of firearms.'

6. From what has been said, it is clear that science has not unfrequently been in advance of practice.[6] The preceding remarks will serve to show the practical importance of a know-

[6] Eminent mathematicians have, however, sometimes lent their influence to obstruct the advance of gunnery. Euler, about three years after the appearance of Robins' *New Principles of Gunnery*, printed a translation, enriched with dissertations and learned calculations, investigating the action of the air upon a projectile considering all cases; 1st, when the projectile is perfectly round and the centre of gravity coincides with that of the figure; 2nd, when these centres do not coincide; 3rd, when the ball is not exactly spherical. Euler refused to admit the cause of irregularity of the movement of projectiles asserted by Robins, concluding a discussion with these words: 'Il n'est alors aucun cas où la mouvement progressif d'un boulet puisse être sensiblement altéré par le mouvement de rota-

ledge of the principles of gunnery, and may also serve as a warning not to despise the efforts of scientific men, who, taking interest in gunnery questions, and having investigated one or more of them, offer suggestions which may not at first sight appear to have much practical value, but may eventually prove of consequence to the service.

This remark must not, however, be interpreted as a wish to recommend the crude fancies of many so-called inventors, who, being ignorant of what has been done, revive old and useless discoveries; or the ideas of others, who *will* only allow the value of such facts or principles as apparently correspond with their own interests.

Since Hutton's time, his theories, and the practical deductions from his experiments, have been reinvestigated by ourselves, the French, Americans, and others; but as regards the laws relating to gunnery from smooth-bored ordnance, little, if anything has been added, until quite recently, to the knowledge of the subject, as fully laid down in his Tracts. The introduction of electro-ballistic instruments has given greatly increased facilities for the determination of many of the most complicated gunnery questions, and the results of recent experiments, as well as a description of these instruments, will be given in their proper places.

7. Although many questions of increased difficulty have been raised by the adoption of the *rifle* principle, great advantages are now derived from the advanced state of the mechanical and physical sciences. By the perfection to which machinery has been brought, the requisite materials for ordnance, carriages, or projectiles can now be easily worked, and great accuracy obtained in the manufacture of warlike stores. By the application of chemistry, we can ascertain the constitu-

tion.' The great authority of Euler caused his error to be accepted as a truth, and decisive experiments in the path indicated by Robins to be long delayed. Col. Favé, speaking of the consequences of Euler's error, remarks: 'Apprenons-le par cet example mémorable; nos connaissances scientifiques sont insuffisantes pour préjuger les phénomènes compliqués de l'artillerie.' (*Études sur le passé et l'avenir de l'artillerie*, vol. iv. pp. 221, 222; also Euler's *Observations upon Robins's 'New Principles of Gunnery,'* translated by H. Brown. London, 1777; pp. 313, 316.)

tion and the most advantageous employment of the many substances used in the military arts. By means of electricity we can, if requisite, fire ordnance without risk to the gunners, and we can ascertain with an exactness not previously possible the highest velocities of the projectiles we fire. And, lastly, by the skilful use of modern mathematical analysis, the results of experiments may be readily reduced to exact and definite principles, capable of application to practice.

8. It is then evident that artillerists must now be prepared to examine many questions which would not have come before them in former times. A few may turn their attention to improvements in artillery *matériel*, others may have to assist in carrying on experiments to ascertain the relative merits of different artillery stores, while many may only have to use the *matériel* provided for their batteries; but in any case a sound knowledge of the principles of gunnery is indispensable to an artillery officer. Some men are satisfied to remember one or two isolated facts, which, having been prominently brought before them, they can easily remember, and are never tired of quoting; but how few take the trouble to collect the results of a number of trials, and ascertain by reasoning upon them the right conclusions to be drawn! This, however, is the proper method to pursue, for gunnery is an inductive science, its theories and principles not being obtained by abstract speculation, but being derived from the data supplied by the collection and arrangement of a large number of well-ascertained facts. Let us not be afraid of what is often contemptuously termed theory, for nothing can be done in gunnery without a combination of theory and practice. Some of those most loud in condemnation of theory not unfrequently invent the most monstrous theories, simply at variance with the laws of nature, and which when examined account for nothing.

In considering the results of experiments, it must always be remembered that one or two isolated cases prove nothing, and that no fair comparisons can be drawn, unless trials have been made under like conditions, and in similar circumstances. We must, then, be sure to accept only those theories which rest on sufficient evidence. An incorrect theory extensively circulated is very difficult to eradicate. The tests of true theories are, that they account for known facts and predict phenomena, and it is generally found that they tend to simplicity.

9. Sir J. Herschel's observations on the study of physical science, which are most applicable to the study of gunnery, may here be quoted. He says that 'if the laws of nature on the one hand are invincible opponents, on the other they are irresistible auxiliaries,—

'I. In showing us how to avoid attempting impossibilities.

'II. In securing us from important mistakes in attempting what is in itself possible, by means either inadequate or actually opposed to the end in view.

'III. In enabling us to accomplish our ends in the easiest, shortest, most economical, and most effectual manner.

'IV. In inducing us to attempt, and enabling us to accomplish, objects which, but for such knowledge, we should never have thought of undertaking.'[7]

[7] *A Preliminary Discourse on the Study of Natural Philosophy*, p. 44, art. 35.

CHAPTER II.

THE FORCES WHICH ACT UPON A PROJECTILE WITHIN THE BORE OF A GUN.

1. THE machines used before the introduction of firearms, as the catapult, ballista, bow, &c., all required a considerable expenditure of force in order to prepare them for projecting their respective missiles; but with gunpowder, an intimate mixture of nitre, charcoal, and sulphur,[1] no mechanical effort is necessary, for by merely igniting a small quantity placed in the bore of a gun an enormous force is generated, owing to the very rapid development of highly heated and elastic gases. The progressive nature of the action is of a peculiar value, for, while the force is generated with sufficient rapidity to give the projectile a high velocity, sufficient time is allowed for the distribution of the strain caused by the force over the material of the piece. If the force were generated instanta-

[1] Nitre 75 parts, sulphur 10 parts, and charcoal 15 parts, in English powder. A good description of the ingredients and manufacture of gunpowder, with a short account of other explosive compounds, and a brief examination of the theory of the explosive effect of gunpowder, may be found in Major O. H. Goodenough's *Notes on Gunpowder*, 1868. In the last edition the subject has been much curtailed. For a detailed account of the manufacture and proof of gunpowder, see the *Handbook of the Royal Gunpowder Factory, Waltham Abbey*, by Capt. F. M. Smith, R.A.

neously, or nearly so, as with fulminating substances, the gun and projectile would be shattered to pieces. Gunpowder also possesses the advantages—that its action is under ordinary circumstances regular, equal charges of the same kind of powder giving about equal velocities; that it can be easily manufactured; that it can be safely used; and that, if properly stored, it is not impaired by keeping.[2]

2. The first step in any investigation of the principles of gunnery is to examine the nature and probable effect of the forces which act upon a projectile within the bore of a gun, and which influence both the velocity of the shot and the strain upon the metal of the piece. These forces are,—

The pressure exerted by the gas from the charge of gunpowder, or the *propelling* force.

And the following, which tend to retard the motion of the projectile through the bore:—

The resistance of the condensed air in front of the shot.

The resistance due to the friction between the shot and the bore.

The resistance of the projectile, in a rifled gun, to receive rotatory motion.

The resistance, in some rifled guns, due to the necessity of compressing the outer portion of the projectile.

3. As before explained, the circumstances relating to the action and force of fired gunpowder were for the first time thoroughly investigated by Robins; before his time the ideas entertained on the subject were very vague and fanciful. The most intelligible hypothesis appears to have been that of M. Hire, who supposed that 'the force of powder was owing to the increased elasticity of the air contained in and between the grains, in consequence of the heat and fire produced at the time of the explosion.' Robins remarks on this hypothesis, that the greatest addition its elasticity could acquire from the flame of the explosion would not amount to five times its

[2] Gun-cotton, so often proposed as a substitute for gunpowder, cannot at present be made sufficiently regular in its action for the charges of ordnance, although it is sometimes used with sporting small arms, and will no doubt be extensively employed for torpedoes, blasting, and other purposes.

usual quantity, and would not suffice for the two-hundredth part of the effect found to be exerted by fired powder.[3]

Finding, then, that the above theory did not account for the effects produced by the explosion of gunpowder, Robins endeavoured to ascertain by experiment the circumstances upon which the action of powder depended, and the amount of force developed at the moment of explosion.

It will be only necessary here to state the general conclusions drawn from the experiments, which were fully described by Robins in his 'New Principles of Gunnery':—

1st. Gunpowder fired either in a vacuum or in air produces by its explosion a permanent elastic fluid.

2nd. The elasticity or pressure produced by the firing of gunpowder is, *cæteris paribus*, directly as its density.

3rd. The elasticity of the fluid is augmented by the heat it has at the time of explosion.

4th. The pressure of fired gunpowder at the moment of explosion was equal to about 1,000 atmospheres, or 14,750 lbs. on the square inch.

5th. The moisture of the air affected the force considerably, the initial velocity 1,700 feet obtained on a dry day with a given charge and bullet being on a damp day reduced to 1,200 or 1,300 feet.

4. After Robins' experiments came those of Count Rumford, which were carried on at the end of the last century. From the results Rumford inferred that the force of fired powder amounted to more than 100,000 atmospheres, but the principles upon which he based this estimate were incorrect.[4] D'Antoni estimated the force of fired gunpowder at 1,800 atmospheres, and combated the hypothesis of the combustion of a charge being instantaneous, upon which assumption Robins's calculations were based.

Dr. Hutton, who continued Robins's experiments, found 1,000 atmospheres to be too low an estimate of the force of fired gunpowder; and, taking into account the resistance of the

[3] *New Principles of Gunnery*, p. 57.

[4] See Boxer's *Treatise*, chap. i. §§ 16, 17.

air to the passage of the shot through the bore, the gradual firing of the powder, the loss of force by the escape of gas through the vent and windage, the variable motion and density of the gas behind the ball, and several other circumstances which had been neglected by Robins, he concluded that this force amounted to 2,000 atmospheres. Both Robins and Hutton followed the same method in their researches, which was—first to calculate the initial velocity of the ball by means of equations based upon certain hypotheses, and then to compare it with the actual velocity found by experiment with the ballistic pendulum, so as to test the accuracy of the assumptions.

Piobert, who dwells at considerable length on Rumford's experiments, reduces the latter's estimate of the force of powder to 29,000 atmospheres, but states further that the force could be better reconciled with a limit of 12,000 atmospheres, and that, in practice, densities so great as to raise the tension of the gas to 5,000 atmospheres are never employed, on account of deficiency in the resistance of arms or materials.[5] From the recent investigations of Bunsen, Schischkoff, and other eminent chemists, it would appear that the force is equal to from 3,000 to 3,500 atmospheres.

Taking the pressure of the atmosphere at 14·75 lbs. on the square inch, the different estimates of the force of fired gunpowder in tons on the same area are—

Robins'	1,000	atmospheres	=	$6\frac{1}{2}$ tons
Hutton's	2,000	do.	=	13 ,,
Rumford's, corrected by Piobert . .	29,000	do.	=	$188\frac{1}{2}$,,
Piobert's practical limit	5,000	do.	=	$32\frac{1}{2}$,,
Modern chemists' .	3,500	do.	=	$22\frac{3}{4}$,,

Rumford's estimate, when reduced, is much beyond the force required to produce the known results, but Piobert's practical limit agrees very nearly with the result of recent experiment.[6]

[5] *Traité d'Artillerie théorique et expérimentale,* par G. Piobert, 1859, pp. 354, 360.

[6] See § 6.

5. It is, however, of little practical utility to attempt to determine the exact value of the explosive force of gunpowder, for the nature of the action in charges of equal weights will vary considerably, not only from atmospheric causes, or in consequence of imperfections in the manufacture or in the qualities of the ingredients, but with the *size*, *form*, *hardness*, and *density* of the grains, and the *form* of the cartridge. The smaller the grain, the less time is required for the conversion of each particle into gas; but the smaller will be the interstices between the grains forming the charge, and consequently the velocity of transmission of the inflammation from grain to grain will be less. On the other hand, as the size of the grain is increased, so will each take longer in burning; but, the interstices being larger, more grains will be successively ignited in a given time by the flame passing between them. It is found that if mealed powder be used for the charge of a piece of ordnance, the velocity of the projectile is greatly reduced, on account, doubtless, of a considerable portion of the powder being blown out unfired, in consequence of the slow combustion of the charge, the interstices between the grains being so small. The complete combustion of a charge of the ordinary large-grained service powder takes a very much less time, the greater part of the powder being probably converted into gas before the projectile has moved any distance up the bore; this rapidity of action, most desirable in a smooth-bored gun, being due to the facility with which the flame can pass through the comparatively large interstices between the grains. If the grains be considerably increased in size, as in some of the powders made expressly for heavy rifled pieces, the action is again reduced in rapidity, each grain taking a comparatively long time to consume.

Both the ignition of each particle and the velocity of transmission of the inflammation through the charge will be influenced by the form of the grains. As the ignition proceeds in each grain from the exterior surface in concentric layers, it is evident that a spherical or cubical grain will require more time for its complete combustion than an elongated one of similar weight, which exposes a larger ignited surface. But should the grains be flat or angular, they will pack closer than spherical grains, and leave less space between for the passage of the flame, so that on this account the velocity of transmission of the inflammation will be decreased, and the combustion of the charge be slower.

The force exerted by a given charge of gunpowder will also vary with the calibre of the piece from which it is fired, for as the bore is decreased in diameter, so must the cartridge be lengthened, and longer time be therefore required for the complete combustion of the powder; the projectile will therefore most probably be moved to a greater distance when a less quantity of powder has been converted into gas, and more space be thus allowed for the expansion of the gas formed.

The theoretical investigation of this complicated problem, the force of fired gunpowder, presents so many difficulties, and such various results have consequently been arrived at respecting the necessary data for calculation—viz., the *quantity of gas generated*, the *heat evolved*, and the *rapidity of the inflammation*, upon which circumstances the explosive force depends—that attempts have been made, as before stated, to ascertain experimentally the actual pressures and velocities produced by charges of powder in the bore of a gun.

6. The following results, obtained from the experiments with the *Noble chronoscope* and the *crusher*, will serve to illustrate the remarks made above concerning the effect of varying the size, form, and density of the grains of gunpowder upon the nature of the action of a charge.

The gun employed in the experiments was an iron built-up smooth-bored piece of 8 inches calibre, weighing 6½ tons, and having a bore 126 inches long; the shot were cylindrical in form, and weighed 180 lbs. The initial velocities and maximum pressures obtained with the four different powders named below are given in the table on the next page.

1. RLG. service powder.
2. Russian prismatic powder.
3. Pellet service powder.
4. Pebble powder No. 5.

The Rifle Large Grain is the service cannon powder, in grains which pass through a sieve of four meshes, but are retained on one of eight meshes to the inch. The pellet and pebble powders, both intended for heavy ordnance, consist of large pieces instead of small grains, so that the initial strain may be reduced in consequence of the longer time required for the complete combustion of each grain. The pieces of the pellet powder are all of uniform size and cylindrical shape, about $\frac{1}{2}$ inch long and $\frac{3}{4}$ inch diameter, with a perforation at one end. The pebble powder is in irregular-shaped lumps, retained between sieves of $\frac{5}{8}$ and $\frac{4}{8}$-inch meshes respectively. The prismatic powder, which is much used in Russia and Prussia, is made into hexagonal cakes, having sides $\frac{3}{4}$ inch long, nearly an inch (·92) thick, and pierced with seven holes ·17 inch in diameter. It may thus be seen that the particles of the 1st and 4th powders are of irregular shapes, while those of the 2nd and 3rd are of regular geometrical forms.[7]

Nature of Powder	Charge	Initial velocity	Maximum pressure (per square inch)
	lbs.	f. s.	tons
RLG.	30	1324	29·8
Russian Prismatic . .	32	1366	20·5
Service Pellet . . .	30	1338	17·4
Pebble No. 5 . . .	35	1374	15·4

It is doubtless desirable to have the particles of a powder of the same shape and size, so as to obtain as nearly as possible a uniform rate of combustion; but with some powders thus made, as the prismatic, the small cakes are said to break up just after ignition, so that the expected regularity of burning is not obtained. Means are now being taken to make the particles of the pebble powder more regular in form.

As the density of the grains is increased, so will the velocity of the projectile and the strain upon the metal of the piece be decreased; and, with considerable differences in densities, the reduction in velocity will be in a higher ratio than that in the

[7] Mean weight of one piece taken from the weight of 10 pieces:

Pebble	59 grains
Pellet	85 ,,
Prismatic	598 ,,

density of the powder. With the 10-inch gun it was found that a 70-lb. charge gave

Density	Velocity (f. s.)	Maximum Pressure (tons square inch)
1·732	1,474	29
1·782	1,432	21

As *density* retards the burning of each particle, so *hardness*, obtained by pressing when moist, causes the ignition to be slower.

Capt. A. Noble (late R.A.) has recently made experiments to determine the force exerted by charges of gunpowder exploded by electric agency, in very strong closed iron vessels, fitted with a crusher gauge. From their results the conclusion was drawn that the maximum pressure of fired gunpowder, unrelieved by expansion, is about 40 tons on the square inch.[8] It has, however, been before stated (at page 18) that, with very large charges and heavy projectiles, much higher pressures than this have been exerted locally in the bore of a gun, as shown by the crusher gauge; and, as Capt. J. P. Morgan, R.A., points out: 'Rumford, Rodman, and the (Explosive) Committee all find these pressures manifesting themselves somewhere about 30 tons.'[9]

7. In speaking of the force exerted by the gas generated on the ignition of a charge of gunpowder, it is usual to employ the term *pressure*, but it has long been considered that the force resembles in its action rather an impulse or blow than what is generally understood as a mere pressure, that it is, in fact, *dynamical* rather than *statical*. Captain Boxer, R.A., in his criticism of Count Rumford's experiments, pointed out the necessity of recognising this principle. He wrote thus: 'In considering the experiments of Count Rumford, together with his deductions therefrom, particularly with regard to the bursting of the barrel, we perceive two very erroneous prin-

[8] *Lecture on Explosive Agents*, delivered by F. A. Abel, Esq., F.R.S., to the British Association at Edinburgh, Aug. 1871, p. 19.

[9] The Explosive Force of Gunpowder, in *Proceedings of R.A. Institution*, vol. vii. p. 430. In this paper both the theoretical and practical investigations of the subject are very carefully examined.

ciples upon which he founded his determination of the force of the gunpowder. The first consisted in measuring the force, which in this case must have been percussive, and consequently variable, by the breaking weight, which exerted a constant pressure. These two forces are evidently quite incommensurable with each other; and the estimation of the force upon this principle was very far from correct.'[1] Major Rodman, however, came to the conclusion 'that although the pressure exerted by exploded gunpowder is developed with very great rapidity, yet it does not, in its effect upon the gun, partake of the nature of a blow.'[2] This deduction, which was arrived at merely from the results of three rounds with the pressure gauge, a not very accurate test, can hardly be said to have been conclusive, but the results of recent experiments with the *crusher* appear to confirm it, as regards powders burning slowly and regularly; with powders which burn more rapidly and with less uniformity, the *crushers* were decidedly compressed without increase in velocity, indicating that the force partook more of the nature of a blow than of a pressure.

Robins estimated from experiment (firing light tow wads) that the velocity of the flame of gunpowder by expansion was about 7,000 feet per second; and he pointed out that as the flame dilates itself with a velocity much beyond what it can communicate to a bullet by continued pressure, a ball placed at some distance in front of the charge will not be moved by continued pressure but by actual percussion; hence its velocity should be greater. The work done upon the ball depends, however, not only upon the force of the gas, but also upon the space through which the force is exerted; and this deduction respecting increase of velocity will therefore only hold good up to a

[1] Captain (now Major-General) Boxer's *Treatise on Artillery*, 1853, p. 7.

[2] *Experiments on Properties of Metals for Cannon, and Qualities of Cannon Powder*, by Capt. T. J. Rodman, 1861, p. 178. This deduction was founded upon the fact that the indentation made in the copper by the tool of the pressure gauge was not perceptibly enlarged after the first round. A slowly applied pressure of given intensity may be repeated almost indefinitely without perceptibly increasing the indentation first made, but every blow of equal intensity will produce increments of indentation at each repetition.

certain distance between ball and charge. Robins also pointed out that a gun is subjected to severe strain if the ball is at some distance in front of the charge. 'For a moderate charge of powder, when it has expanded itself through the vacant space, and reaches the ball, will, by the velocity each part has acquired, accumulate itself behind the ball, and will thereby be condensed prodigiously; whence, if the barrel be not of an extraordinary firmness in that part, it must, by this reinforced elasticity of the powder, infallibly burst.' The truth of this reasoning he proved by firing a *good Tower musquet* with the ball sixteen inches from the bottom of the bore, when 'the part of the barrel just behind the bullet was swelled out to double its diameter, like a blown bladder, and two large pieces, of two inches long, were burst out of it.'[3]

8. When a charge of gunpowder is ignited in the bore of a gun, the gas exerts equal force in every direction, and, therefore, neglecting windage, the pressure on the bottom of the bore is equal to that on the base of the shot, and the pressures on the top and bottom as well as those on the sides of the bore balance each other. As the shot moves towards the muzzle, so will the space in which the gas is confined be increased and the pressure be decreased.[4] A curve representing the pressure of the gas might easily be constructed on the assumption that the whole charge is converted into gas before the shot moves, but this is not the case in practice.

From the results of the experiments with the chronoscope and crusher, diagrams representing *curves of pressure* and *velocity* were drawn;[5] these show clearly the gradual increase of the velocity of the shot and the decrease of the force exerted by the gas as the projectile moves along the bore of a gun, and

[3] *New Principles of Gunnery*, p. 115.

[4] By Marriotte's law the pressure is inversely as the volume.

[5] These curves, which may be found in the *Preliminary Report of Committee on Explosives*, are constructed like the *range curve* described in Chap. vii. of this Part. In the pressure curve, the horizontal line is divided into feet and tenths for length of bore, and the vertical line into tons for pressures; in the velocity curve, the horizontal line is divided as before, but the vertical line into hundreds of feet for the velocities.

that a powder may impart a lower velocity to a projectile than another which causes a less maximum strain. This may be observed by a comparison of the respective velocities and pressures with equal charges of the RLG. and pellet powders, and may be accounted for by considering that the initial velocity will depend, not upon the *maximum force* exerted upon the base of the projectile, but on the *mean force* and the *time* during which this mean force may be supposed to act upon it; also there is probably a much greater escape of gas by windage with a quick than with a slowly burning powder; the curves show that, although the RLG. powder exerts a much greater maximum force than the pellet, this force rapidly decreases in intensity, and the pressure of the latter powder is greater than that of the former throughout almost the whole length of the bore; the force of the pellet powder is, in fact, better distributed both as regards velocity and strain.

9. The force exerted by a given charge of gunpowder will vary according to the position of the point first ignited. If the whole of the powder were instantaneously converted into gas, this would not be the case, but, as the combustion proceeds gradually, from grain to grain, its rapidity must depend upon the distance through which it has to travel from the point of ignition. It must, then, be evident that if a charge be ignited near the centre, the inflammation can proceed in both directions at the same time, and the combustion of the powder will be complete sooner than if the cartridge had been lighted at either end, when it could only proceed in one direction. In the former case both the strain upon the metal and the velocity of the projectile are doubtless increased. This point will be again referred to in the remarks on initial velocity.

10. The column of condensed air, which is driven through the bore in front of the projectile, exerts no doubt a very considerable retarding force, tending to decrease the velocity of the shot; the strain at the lower part of the bore of the piece can however be little, if at all, influenced by it, for, as the projectile will not at that part have acquired a high velocity, the resistance of the air can be but feeble. The retarding

effect of the air upon the projectile will depend upon the velocity of the latter, as well as upon the diameter and length of the bore; as the enclosed air cannot escape laterally, its resistance most probably differs in character from that opposed to the shot during flight, and would not therefore follow the same law.

11. Another resistance is the friction between the projectile and the bore of the gun. With spherical projectiles which merely bound through the bore of a SB. piece, this resistance is doubtless only slight, but, with elongated projectiles, which can neither roll nor bound, but must slide along the bore, it is far greater, depending chiefly upon the weight of the projectile and on the nature of the materials used respectively for the bore and the studs of the projectile, or other part in contact with the metal of the gun. The friction is of two kinds, that of *quiescence* which opposes the first movement of the projectile, and is more variable than the friction of *motion*, which continues to act with uniformity[6] against the shot while moving through the bore of the piece.

The friction of motion would appear from experiment to be independent of the amount of surface in contact and of the velocity of the moving body, when no unguent is used. The friction, in the first instance, prevents the shot moving, and according to its amount will be the time given for the combustion of the charge, and therefore the tension of the gas, which must affect both the velocity of the projectile and the strain upon the gun. The greater the quantity of powder converted into gas before the projectile moves, the greater the force exerted on the metal of the gun and on the base of the projectile when in motion; and as the latter moves through the bore, so will the friction act upon it as a retarding force, and, to some extent, increase the strain upon the piece.

12. In a rifled gun resistance is also caused by the tendency of the shot to proceed forwards without the rotatory motion, but whether this resistance causes any appreciable increase in the strain by retarding the movement of the shot is a disputed

[6] The coefficient remaining the same. See Moseley's *Mechanical Principles of Engineering*, p. 161, § 133.

point, with respect to which no reliable facts have been experimentally determined; but, to reduce it to a minimum, the grooves of most of our heavy rifled guns have been given what is termed a *gaining* or *increasing twist*, so that the rotatory motion is only very gradually imparted as the projectile moves towards the muzzle. In some rifled guns, such as our Armstrong BL. pieces, which fire lead-coated projectiles of larger diameter than the bore, a very considerable resistance must be offered by the lead to compression, and the strain from a given charge must be very much greater than with other systems of rifling, where the projectile has merely to slide along the bore.

To ascertain the amount of resistance (statical) offered to the projectile in a BL.R. 12-pr. Armstrong gun, 9 shot were forced through the bore by hydraulic pressure, five being heated to about 140°, the other four being cold. A pressure of from 9 to about 14¼ tons was required to force the heated, and a pressure of from 16¼ to 20 tons to force the cold, shot through the *grip*; to move the shot along the bore a pressure of from 3 to 5½ tons was necessary, except at between 20 and 30 inches from the muzzle, when the pressure had, in some cases, to be increased to 11 tons.[7]

Some experiments were made by Dr. J. Anderson to ascertain the tendency of different methods of rifling to split the gun. A number of cast-iron cylinders were rifled, several on each system, and into them were fitted corresponding plugs of steel to represent the projectiles; the steel being a stronger metal than the cast-iron, the experiment was continued until a form of rifling was arrived at in which the steel plug was broken before the cylinder was split open. 'The experiment consisted in fixing one end of the plug, representing the projectile, in a frame which was immovable, its other end being within the cylinder. The cylinder was fixed in the centre of a lever fulcrum, and capable of having a torsional motion given to it, by the application of weights on the extremity of the lever.' The following results were obtained:—

[7] *Proceedings of O. S. Committee*, vol. iii. p. 22.

Lancaster	Oval	7·02	Breaking weight in tons at circumference.
Armstrong	3-grooved shunt	25·65	
Whitworth	Hexagon	28·07	
Scott	2 grooves opposite each other	29·00	
L. Thomas	3 ribs	35·09	
Scott	3 grooves	35·30	
Armstrong	10-grooved shunt	46·50	

At the last weight the plug broke, and the cylinder showed a slight crack.[8]

13. The following deductions may be gathered from what has been said :—

The resistance opposed to the motion of a projectile in the bore of a gun depends upon the form and weight of the projectile, upon the circumstance of the piece being smooth-bored or rifled, and upon the system of rifling adopted.

The projectile will commence to move when the force of the gas has become greater than the resistance offered to motion.

The time necessary for the conversion into gas of the quantity of the powder required to move the projectile will depend upon the nature of the gunpowder used, the form of the cartridge, and the point of ignition of the latter.

The maximum strain upon the metal of the gun will mainly depend upon the rapidity of the conversion of the powder into gas.

The initial velocity of the projectile may not, however, be in proportion to the *maximum* strain, but it varies as the work done on the shot, or as the *mean pressure* into the space through which it may be supposed to act ; or,

$$P S = \frac{W V^2}{2 g}$$

where P = mean pressure of gas
S = space through which P may be supposed to act
W = weight of projectile
V = velocity of projectile
g = force of gravity

and if S be a very small interval a fair approximation to the mean strain exerted through it in the bore of a SB. gun may be calculated by this formula.

[8] *Proceedings of R.A. Institution,* vol. iii. p. 263.

CHAPTER III.

INITIAL VELOCITY.

1. Importance of knowing the initial velocity of a projectile.—2. Methods of determining initial velocities.—3. Circumstances which affect initial velocities.—4. Charge and weight of projectile.—5. Windage.—6. Length of bore.—7. Position of vent.—8. Chambers.—9. Diameter of cartridge.—10. Calibre in a rifled gun.—11. Twist of grooves.—12. System of rifling.

1. A PROJECTILE on leaving the bore of a gun will have acquired its maximum velocity, termed the *initial velocity*, and it is of the greatest importance to determine this velocity, an accurate knowledge of it being essential to the solution of many of the chief problems in gunnery. The initial velocity is in fact the starting point in most of the practical questions, and must be known in order that the results of artillery fire may be properly compared, and just deductions be drawn from them.

2. Before instruments had been contrived to ascertain experimentally the velocities of projectiles, attempts were sometimes made to deduce them from observations of the ranges of bullets or shot; but nothing of any value could thus be found, except in cases of mortar shells fired with small charges giving very low velocities; for the ranges of balls fired under similar conditions are liable to be affected by many circumstances, such as variations in the diameters or weights of the balls, and in the amount or quality of the powder, the wind, or the variable rotation of the projectiles. By noting the time of flight a nearer approximation could probably be made to the true velocities, but without delicate instruments the times could not be obtained with sufficient minuteness.

A great number of instruments or machines have been devised to record the velocities of projectiles fired from ordnance or small arms; they may be divided into two classes, the first including those depending upon mere *mechanical* arrangement, and the second those in which *electricity* is employed to obtain the requisite action. A brief description of both classes will be found in the Appendix, and it is only necessary to remark here that until the last few years the ballistic pendulum, belonging to the first class, was the only trustworthy instrument for determining the velocities of projectiles, but that it has now been superseded by instruments such as those of Navez, Bashforth, and Noble, in all of which electricity is employed; a great number of experiments have been recently made with these instruments, and some of the numerous results will be given in their proper places.

3. The initial velocities of projectiles being influenced by many different circumstances, it is of great importance to ascertain experimentally the variations due to these circumstances, and to endeavour to obtain from them simple formulæ or rules which can readily be applied in practice. The circumstances affecting the velocities of projectiles fired from *any* piece of ordnance, which are—

Amount of charge	Position of vent
Weight of projectile	Form of chamber
Windage	Diameter of cartridge
Length of bore	

will first be considered, and afterwards those which influence the velocities of the projectiles of *rifled* guns only, viz.—

Calibre, Twist of rifling, System of rifling.

4. As the *charge* and *weight of projectile* are usually taken together, they are included in the same article. The following formulæ were deduced by Dr. Hutton from an extensive series of experiments, carried on by himself at Woolwich with the aid of the ballistic pendulum.

The velocities generated by the action of *different charges* of powder in the same gun upon balls of *equal densities* are nearly as the *square roots* of these *charges*; or

$$v : v' :: \sqrt{c} : \sqrt{c'}$$

$$v = v' \sqrt{\frac{c}{c'}} . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The velocities generated by the *same charge* of powder in the same gun upon balls of *different densities* will be *inversely* as the *square roots* of the *weights*; or

$$v : v' :: \sqrt{w'} : \sqrt{w}$$

$$v = v' \sqrt{\frac{w'}{w}}. \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The velocities generated by *different charges* of powder upon balls of *different densities* will be nearly in the ratio of the *square roots of the charges, divided by the square roots of the weights of the balls*; or

$$v : v' :: \sqrt{\frac{c}{w}} : \sqrt{\frac{c'}{w'}}.$$

$$v = v' \sqrt{\frac{cw'}{c'w}}. \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The *initial velocities* of elongated projectiles, equal in weight, fired from the same rifled gun with different charges, do not in many cases vary as the square roots of the charges; however, they sometimes follow the law, as may be seen from the table below.

PRACTICE WITH A 7″ WROUGHT-IRON 3-GROOVED SHUNT RIFLED MORTAR; SHELL FILLED 87 LBS.[1]

Charge	Observed initial velocity	Calculated initial velocity 6 lbs. taken as charge	Difference
lbs.	f. s.	f. s.	f. s.
1	294	287	7
2	415	406	9
3	515	498	17
4	584	575	9
5	647	642	5
6	704	704	0

By substituting, in the last equation, 1600 for v, as found by experiment when $\frac{c'}{w'} = \frac{1}{3}$, the following empirical formula for the initial velocity of a ball fired from a SB. gun was obtained:—

$$V = 1600 \sqrt{\frac{3c}{w}}, \quad . \quad . \quad . \quad . \quad . \quad (4)$$

[1] This table gives the results of experiments made by Lieut. W. H. Noble, R.A., for the late O. S. Committee.

when V = initial velocity,

c = the charge (in lbs.),

w = the weight of ball (in lbs.).

As, however, the velocity would be affected by the amount of windage, a variable[2] coefficient a was substituted in the formula for the number 3.

The last formula should be used only for the velocities of projectiles fired from smooth-bored ordnance of 17 to 19 calibres in length.

With regard to the effect of increase of charge upon velocity, Dr. Hutton stated, as the result of his experiments, 'It appears that the velocity (initial) of a ball increases with the increase of charge only to a certain point, which is peculiar to each gun, when it is greatest; and that, by further increasing the charge, the velocity gradually diminishes till the bore is quite full of powder. That this charge for the greatest velocity is greater as the gun is longer, but yet not greater in so high a proportion as the length of the gun is; so that the part of the bore filled with powder bears a less proportion to the whole bore in the long guns than it does in the shorter ones; the part which is filled being, indeed, nearly in the inverse ratio of the square roots of the empty part.' [3]

The first part of this statement may be accounted for in two ways—1st, If the charge exceeds a certain amount, some portion of it will be blown out of the bore unfired; 2nd, The work on the ball being $= PS$, where P is the mean pressure and S the space through which it may be supposed to be exerted, as P is increased by adding more powder S is diminished, so that beyond a certain point, although P may be very great, S may be so small that PS would be decreased, and consequently impart a lower velocity to the projectile.

It is necessary to observe that none of the above expressions will give trustworthy results if the projectiles be very different

[2] The values of a found by experiment were—

		a
For windage of	·233	3·2
,, ,,	·2	3·4
,, ,,	·175	3·6
,, ,,	·125	4·4
,,	·09	5·

[3] Dr. Hutton's 37th Tract.

in weight or the charges vary very much in amount. For as the heavier projectile will require greater force to move it, more time will be allowed for the conversion of the powder into gas, and the maximum pressure will act through a longer space; should there, however be windage, the escape of gas will be greater with the heavier shot which takes longer to move. With very large charges the space through which the force acts will be diminished, and with very small charges more heat will be absorbed, as the surface of the bore is greater in proportion to the charge, and the shot is longer in passing through the bore.[4]

Several general formulæ, or those which are intended to give the velocities of projectiles fired from different pieces of ordnance, have been proposed by Piobert, Didion, and other writers on gunnery, but none of these are of much practical utility, for they all contain *constants* determined by experiment for particular conditions, and if the kind of powder, the windage, length of bore, or other circumstances vary, these constants require modification. The initial velocities of most of the service projectiles have been recently determined by experiment, and they will be found in tables in the Appendix.

It would doubtless be desirable to ascertain for a given bore the charge and weight (and therefore length) of projectile, which would give the *maximum energy* to the shell with a certain limit of strain, and without liability to abnormal strains.[5] In a SB. gun, the form of the projectile being spherical, the weight of a shot or a shell is determined by the calibre, and the effect of weight on the velocity of a spherical projectile, according to Hutton's experiments, has been given; but in R. guns, the weights of the projectiles may be greatly varied by the adoption of different lengths. It has been stated (page 18) that the pressure in the bore of a R. gun does not appear to rise materially beyond a certain weight of projectile; the velocity will, however, decrease as the weight is greater, but

[4] See Boxer's *Treatise on Artillery*, p. 53.

[5] It is a question whether by increasing the length of the projectiles of some of our R. guns and decreasing the charge, their power might not be augmented; the twist of the grooves would probably have to be increased for longer projectiles.

no definite law on this point has been obtained from experiment.

5. In guns having *windage* a considerable amount of force is lost by the escape of gas over the projectile. Dr. Hutton found in his experiments 'that a very great difference in the velocity arises from a small difference in windage;' and Major Mordecai ascertained that nearly $\frac{1}{3}$rd of the powder was wasted by a windage of ·14 inch in a 24-pr. gun. The amount of gas lost through windage must evidently be in proportion to the difference in area between a cross section of the bore and a great circle of a spherical, or the base[6] of an elongated, projectile, and not to the mere linear differences between the windages given in tables of ordnance. Thus,

If D = diameter of bore, d = diameter of projectile.

$$\text{Area of windage} = \frac{\pi}{4}(D^2 - d^2).$$

The amount of gas which is lost will also depend upon the resistance offered by the projectile to motion, and the form of the shot. The greater the force required to move the shot, the longer the time for the escape of gas over the projectile, so that the waste of gas should increase with the weight of the shot; for the same reason there should be a greater loss of gas with an elongated than with a spherical projectile of equal diameter and weight, or in a rifled than in a smooth-bored gun, if the calibres and windages are alike. It must, however, be remembered that the elongated form of a projectile will serve to confine the gas as it escapes within narrow limits, and by retarding its motion diminish the waste; the gas can expand immediately after reaching the highest point of a ball, but not with an elongated projectile until it has passed over the cylindrical portion or body.[7] It would appear from Major Mordecai's experiments that in smooth-bored guns, *the loss of velocity by windage is proportional to the windage*; this point has not however been determined for rifled guns.

[6] If the rear end of the elongated projectile be tapered, the area of a section through its largest diameter must be taken.

[7] It is doubtless this confinement of the escaping gas, within the narrow channel formed between the elongated projectile and bore, that causes the *scoring* of the latter when very large charges are used in the heavy ML. R. guns.

6. It has already been pointed out that if the *length of the bore* of a gun be not sufficient to allow of the decomposition of the whole charge, a portion of the powder will be blown out unfired, and be therefore wasted. If the whole charge were instantaneously converted into gas, a given velocity would be obtained from a shorter gun than when the combustion, as is the case with gunpowder, is gradual; and it has been shown that in the same bore the velocity varies with the nature of powder used, the size and form of grain, &c., affecting the rate of burning. The initial velocity will increase with the length of bore up to a certain point—viz., when the retarding forces have become equal to the accelerating force of the gas, but, as also pointed out, this limit is never practically reached, as it would entail too great length and weight in the gun.

The conclusions drawn by Dr. Hutton on this point from his own experiments were—

'It appears that the velocity (initial) with equal charges, always increases as the gun is longer, though the increase in velocity is but very small in comparison to the increase in length, the velocities being in a ratio somewhat less than that of the square roots of the length of the bore, but greater than that of the cube roots of the same, and is, indeed, nearly in the middle ratio between the two.

'It appears from the Table of Ranges, that the range increases in a much lower ratio than the velocity, the gun and elevation being the same; and when this is compared with the proportion of the velocity and length of gun, in the last paragraph, it is evident that we gain extremely little in the range by a great increase in the length of the gun, with the same charge of powder. In fact, the range is nearly as the fifth root of the length of the bore, which is so small an increase as to amount only to about one-seventh part more range for a double length of gun.'

In the bore of a rifled gun the charge has to do more work than in that of a smooth-bored piece, in order to overcome the additional resistances and impart a given velocity to a shot, but as the projectile in the former piece is not set in motion so quickly as in the latter, there is more time for the conversion of more of the powder into gas before the shot moves, so that there is a greater pressure throughout the bore. In a rifled gun, however, the charges are less in proportion to the weight of the projectile than in a smooth-bored piece, and lower velocities are therefore obtained from the former.

An experiment, the results of which are given in the Table, was made to ascertain the loss of initial velocity, due to reduction in the length of the bore of a rifled gun, which after every five rounds, was shortened by about a calibre:—

Gun, 68-pr. block rifled on Jeffrey's system.
Calibre, 5·1 inches.
Number of Grooves, 6.
Twist of Grooves, Uniform, 1 turn in 120 calibres.
Projectile, Cylindro-ogival with lead base, weight 36½ lbs.
Charge, 4½ lbs.

The following Table shows the velocity at intervals of 6 inches of bore, from 18 to 144 inches, interpolated by Capt. W. H. Noble, R.A. from the results of the practice.

Velocities with different Lengths of Bore.

Inches	Velocity f. s.	Inches	Velocity f. s.	Inches	Velocity f. s.
18	850	66	1270·5	114	1384
24	952	72	1292	120	1393
30	1018	78	1310	126	1402
36	1073	84	1326	132	1411
42	1127	90	1341	138	1419
48	1175	96	1353	144	1425
54	1216	102	1365		
60	1246	108	1375		

7. It has been before pointed out that the velocity of the projectile and the strain upon the metal of the gun will be influenced by the *position of the vent*. Let several simple cases be taken (Fig. 80).

(1) Should the vent be placed at the end of the bore, and in the axis of the piece, as in the screw BL. R. Armstrong guns,[8] the charge will in all probability be rapidly ignited, as the flame from the tube strikes the cartridge in the direction

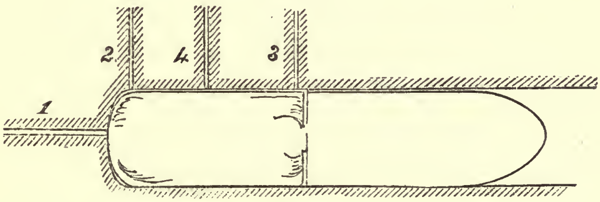
[8] See Fig. 33.

of its length, and the gas is unable to expand behind the charge; but, as the ignition must proceed from one end of the cartridge to the other, a comparatively long time will be required for the complete combustion; both the velocity and strain would, however, be increased if, as in the Whitworth cartridge, a hollow is preserved through its longer axis by means of a metal cylinder, the cartridge then firing like a common tube.

(2) The vent may, however, be placed at the top, but still at the end of the bore, or close to it, as in the service SB. pieces;[9] in this position the flame from the tube striking in a direction across the back of the cartridge, the ignition of the charge will proceed less rapidly than in case (1); the velocity will not be so high, but the strain will probably be less. A practical advantage of the vent being at the end of the bore is, that any unfired powder or remnants of cartridge will be most probably blown out of the bore.

(3) If the vent be placed over the front of the charge, the ignition would have to proceed through the same distance as in the previous cases, but the projectile will doubtless have

Fig. 80.



moved further before the whole of the powder is decomposed, and there would be greater waste of gas by windage, so that the velocity should be less than in either of the former cases; there would also be a great chance of unconsumed portions of the cartridge being left in the bore.

(4) By placing the vent over the middle of the cartridge, the ignition can proceed in both directions, and the complete combustion should be quicker than in the other cases, except when the cartridge has a hollow through its axis; both velocity

[9] See Figs. 1, 30.

and strain should therefore be increased, and this is found to be the case in practice.

Dr. Hutton stated,[1] as a result of his experiments, 'that no difference is caused in the velocity or range by varying the weight of the gun, nor by the use of wads, nor by the different degrees of ramming, nor by firing the charge of powder in different parts of it.'

The last statement, that the velocity is not affected by firing the charge in different positions, is, however, at variance with the result of a recent experiment, as may be seen from the table below.

Practice with 42-pr. Balls fired with a Charge of 14 lbs.; Length of Cartridge 12·75″, Cartridge ignited in Six Different Positions, Five Rounds Fired with each Vent.

No. of vent	Distance of vent from bottom of bore	Initial velocity
	in.	f. s.
1	0·0	1773
2	1·1	1782
3	2·2	1789
4	3·5	1816
5	4·9	1861
6	6·4	1811

As before stated (Art. 21, p. 23), a recent order directs that the vents are to be placed so as to ignite the cartridge at about four-tenths of its length from the bottom of the bore.

It is also found that the velocity is increased by the use of certain wads in a rifled gun having windage; for, in the experiment given in note 3, page 160, the mean velocities of the first and last 10 rounds were:—

With cow-hide wads	1,434 f. s.
Bolton do.	1,430 „
Without wads	1,419 „

8. As pointed out in Chap. i. Part I., the bores of SB. ordnance intended to fire small charges have chambers, to obtain the full effect of the powder upon the projectile. Many experiments have been made to determine the *form of chamber*

[1] In his 37th Tract.

that will give the highest initial velocity. Those carried on in England in 1787, and in France in 1819, are described in Boxer's 'Treatise on Artillery,' pp. 84, 85; and it would appear, from the results of both, that a chamber with a neck less in diameter than the chamber gives the highest velocity; but such a form is obviously objectionable for practical reasons.

9. Variation in the *diameter of the cartridge* affects the initial velocity of the projectile. Should the cartridge fill the bore, the combustion must proceed gradually through the charge from the point first fired: but if the cartridge be reduced in diameter, so that an *air space* is left round it, the gas can pass along this air space, and thus ignite the whole charge in less time. On the other hand, as the diameter of the cartridge is reduced, its length and the air space are both increased; a greater length of cartridge requires longer time for complete combustion, and increase in the air space, by giving more room for the expansion of the gas, tends to decrease its tension.

It is then probable that by slightly reducing the diameter of the cartridge the velocity will be increased, but that a further reduction might decrease the velocity; and the results of experiments would appear to confirm this view. Major Mordecai's experiments, in America, with a 24-pr. gun, of 5·82 inches calibre, and a 6 lbs. charge, gave the following results:—

Cartridge		Velocity of Ball
Diameter	Mean Length	
in.	in.	f. s.
5·0	8·3	1692
5·35	7·35	1701
5·82	6·85	1590

And it was found from experiment in this country, that by decreasing the diameter of a cartridge for a 68-pr. gun from 7·4″ to 6″, and thereby lengthening it from 10·3″ to 15·3″, the initial velocity of the projectile was decreased from about 1,570 to 1,500 f. s.

A reduction in the diameter of the cartridge, leaving an *air space* round it, decreases the injury done to the bore of the gun. For with the air space the gas presses equally upon the bore throughout the length of the cartridge; but when the latter fills the bore, the gas first generated presses with great force upon only a very small portion of the metal, and tends to enlarge it.[2]

10. Let the circumstances affecting especially the velocities of projectiles fired from rifled ordnance be now considered.

In a SB. gun the calibre remains the same for similar spherical projectiles of equal weights, but two R. pieces firing shot or shell of the same respective weights may differ considerably in calibre; for if an elongated projectile requires a less diameter to suit a smaller bore, its weight can be maintained by adding to its length.

The initial velocity will then vary with the *calibre* of the rifled gun; decrease in the diameter of the shot which entails increase of length is favourable, as will be shown, to *range* and *penetration;* but as the diameter is lessened, the pressure of the gas from the powder will be exerted on a smaller area, and, unless the charge be augmented, the projectile will have a lower *initial velocity.* In fact, the area of the base upon which the gas acts varies as the square of the diameter of the shot, and the pressure will necessarily be in the same ratio; the loss of velocity by decrease of diameter of projectile is shown in the table below.

Ordnance	Charge	Projectile		Initial velocity
		Weight	Diameter	
	lbs.	lbs.	inches	f. s.
Britten's (32-pr. rifled) .	5	50·35	6·24	1209
Armstrong's 40-pr. . .	„	41·28	4·75	1197
„ 3-grooved shunt	9	68·40	6·4	1283
Whitworth's 70-pr. . .	„	68·56	{ 5·5 / 5 }	1132
Armstrong's 70-pr. . .	10	74·60	6·4	1271
Whitworth's 70-pr. . .	„	68·56	{ 5·5 / 5 }	1199

Besides the area of the shot which receives the pressure being less as the calibre is decreased, the gas will, if the diameter of the bore be much reduced, exert a less (mean)

[2] See account of French experiments in Boxer's *Treatise*, p. 81.

force per square inch; for the cartridge must be longer, and will therefore require more time for its complete combustion.[3]

11. The influence of the *angle of twist* of the grooves upon the velocity has not yet been satisfactorily determined by experiment; the resistance opposed to the motion of the shot, and therefore the work to be done by the powder, increases with the angle of twist, and the velocity should for this reason be less; but it must be remembered that this greater resistance may cause delay in setting the shot in motion, and may thus give time for the ignition of a larger portion of the charge, and so produce a greater pressure through a longer distance.

Experiments were tried with twists of—

1 in 30 calibres	1 in 50 calibres
1 „ 40 „	1 „ 60 „

but the initial velocities differed so little as to be considered practically alike.

An experiment with *increasing* and *uniform twists* showed, however, considerable difference in initial velocity. Five rounds were fired with each twist from an 8-inch gun, the shot (hollow), weighing 179 lbs., and the charge being 30 lbs.

	Mean initial velocity
The increasing twist gave . .	1303·3 feet
„ uniform „ „ . . .	1338·6 „

The uniform gave higher; the increasing twist more regular, velocities.[4]

The decrease in velocity with the increasing twist was probably due to the fact of less pressure being necessary to move the shot, which, at starting, required no rotatory motion;

[3] Sir J. Whitworth is an advocate of small calibre, long projectiles, high charge, and sharp twist of grooves. Capt. J. Sladen, R.A., in a Paper on *Flat Projectiles* in the *Proceedings of R.A. Institution*, vol. viii., has fully discussed the practical advantages of small calibre. Mr. B. Britten insists on large calibre, heavy projectiles, and small charges. Both Capt. Sladen and Mr. B. Britten suggest that an initial velocity of over 1,200 or 1,300 f.s. is unnecessary; for as the former says: 'below 1,200 f.s. the resistance of the air commences to diminish very rapidly, compared to what it is above that velocity, so that less work is taken out of the shell.' See note 5, p. 196.

[4] *Extracts from Proceedings of O. S. Committee*, vol. iv. p. 253.

consequently, the projectile moved when a less amount of powder had been converted into gas, and the *mean* pressure was less than with the uniform twist.[5]

12. Hitherto it has been found that the mere *system* or *method of rifling* does not greatly affect the initial velocity, but further experiments would be necessary to furnish sufficient data on this point.

[5] The increase in the range obtained with the uniform twist was not sufficient o be of practical importance, being equivalent to only about $1\frac{1}{2}$ lb. of charge.

CHAPTER IV.

FORCES WHICH LIMIT THE TRAJECTORY OF A PROJECTILE.

1. BEFORE proceeding it is necessary to give a few definitions, in order to avoid confusion of terms.

(1) The *trajectory* is the curved line described by the centre of gravity of a projectile in passing from the gun to the object.

(2) The velocity with which a projectile leaves the bore of the gun from which it is fired is termed its *initial velocity*.

(3) The *final* or *remaining velocity* of a projectile is its velocity at the end of any given range.

(4) If a body be allowed to fall in the atmosphere, there is a certain limit to the velocity it will acquire, and this is attained theoretically when the resistance of the air has become equal to the accelerating force of gravity; the motion of the body will then be uniform, and is called its *terminal velocity*.

2. A projectile, when it has left the bore of a piece of ordnance is acted upon by two forces, which limit its range, viz.—

The force of gravity;

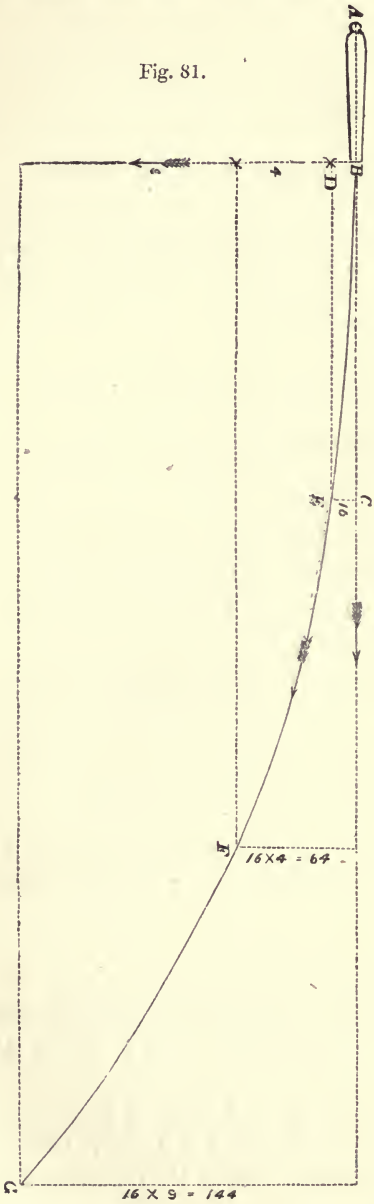
The resistance of the atmosphere.

Let us examine briefly the effect of the first of these forces upon a shot fired horizontally from a gun, the axis of which is represented by AB (Fig. 81).

If the projectile were acted upon by the force of projection alone, which ceases immediately it has left the bore, it would, by the first law of motion, proceed onwards in the direction AC

with a uniform velocity, and would, in consequence, pass over *equal spaces in equal times;* let us suppose it to pass over the distance BC in one second of time. From the equations—

Fig. 81.



$$v = gt \quad . \quad . \quad . \quad . \quad (1)$$

$$s = \tfrac{1}{2}gt^2 \quad . \quad . \quad . \quad (2)$$

it follows, that if the shot subject only to the *action of gravity* were allowed merely to drop from B, it would descend in the vertical direction BD, and would drop through a distance BD equal to about 16·1 f. s. in one second, having acquired a velocity of 32·2 f.s. Since, however, the projectile would have moved over the distance BC in the same time, if the parallelogram $BDEC$ be constructed, it will, by the second law of motion, have arrived at the point E at the end of one second. Also, because gravity is an accelerating force, and, from (2), the *spaces* through which a body under the influence of gravity will fall in successive seconds are as the *squares of the times*, the trajectory or path of the shot will pass through the points FG, and it will thus describe a *parabolic curve*, $BEFG$, as shown in the figure. The properties of this curve being known, the trajectory, time of flight, &c., of any projectile could be readily calculated if in its flight the shot was merely subject to the two above-named forces. With low velocities of 200 or 300 ft. per second, the parabolic theory gives tolerably accurate results, and the following formulæ may therefore be found useful in certain cases of practical gunnery, such as vertical fire with small charges:—

Let V = initial velocity,
R = range, on a horizontal plane,
T = time of flight,
a = angle of projection,
x, y = horizontal and vertical co-ordinates of any point measured from the point of projection as origin.

The equation for the trajectory is, $y = x \tan a - \dfrac{gx^2}{2V^2\cos^2 a}$ . . (3)

$$R = \frac{V^2 \sin 2a}{g}, \quad \ldots\ldots\ldots \quad (4)$$

$$T = \frac{2V. \sin a}{g} = \tfrac{1}{4}\sqrt{R \tan a} \quad \ldots\ldots \quad (5)[1]$$

We must now consider the second force, viz. the *resistance of the atmosphere*, which so modifies the curve as to render the parabolic theory inapplicable for the purposes of calculation with a high velocity. To projectiles moving with high velocities there is a very considerable resistance from the atmosphere: this was formerly supposed to vary as the square of the velocity, although Robins considered that when the velocity exceeded 1,100 or 1,200 ft. a second, the resistance would instantly be nearly trebled. Dr. Hutton stated that the resistance appeared, from his experiments, to increase gradually up

[1] $$T = \frac{2V. \sin a}{g}$$

$$T^2 = \frac{4V^2 \sin 2a}{g^2}$$

Dividing by equation (4), and taking g = 32 ft.

$$\frac{T}{R} = \frac{4 \tan a}{2g} = \frac{\tan a}{16}$$

$$\therefore T = \tfrac{1}{4}\sqrt{R. \tan a}$$

to about 1,500 ft. per second (with the 2-inch ball), when its ratio to the velocity was as the 2·153 power of the latter, but that when the velocity exceeded this, the ratio again diminished, for at the velocity of 1,600 ft. it was as the 2·152 power, and so on, till at the velocity of 2,000 ft. it was only as the 2·136 power.[2]

It has, however, been established by the results of recent experiments, more especially by those of Professor Bashforth,[3] that the resistance of the air to projectiles, moving with velocities of from 1,100 to 1,400 feet per second, varies approximately as the *cube of the velocity*, a ratio sufficiently accurate for practical purposes.

The following table will show clearly the extent to which the range of an ordinary projectile fired with a high velocity is decreased by the resistance it meets with from the atmosphere:—

Ranges of a 32-lb. shot, fired with an Initial Velocity of 1,600 ft. per second, in Vacuo and in Air.

1°	2°	3°	4°	Elevation
yds.	yds.	yds.	yds.	
930	1840	2786	3709	Range in vacuo
780	1160	1460	1690	„ air
1·19	1·58	1·90	2·19	Ratio

From this it appears that at 1° the range in vacuo exceeds that in air by about $\frac{1}{5}$th, but at 4° the former is more than double the latter.

3. The *resistance* which a projectile meets with in moving through the atmosphere depends chiefly upon its *velocity*, the *magnitude of the surface* it presents to the resistance, and its peculiar *form*. In the case of ordinary spherical projectiles, supposing the *resistance* to vary as the cube of the velocity, if d = the diameter of a ball, and v = its velocity, the *resistance* opposed to its motion will be as

$$d^2v^3.$$

The experimental resistance to a ball moving with a given velocity being known, the resistance to any other spherical

[2] Dr. Hutton, in his 37th Tract, explains the nature of this resistance.

[3] The *Reports on Experiments made with the Bashforth Chronograph* can be obtained at H.M. Stationery Office. Price one shilling.

projectile having a different velocity can be readily determined by means of this ratio.

Example :—If a round shot fired from a 68-pr. gun experiences a resistance of 1,000 lbs. when moving with an initial velocity of 1,580 f. s., what would be the resistance to the shot of the 100-pr. when leaving the bore with a velocity of 1,650 f. s.?

$$1{,}000 : R :: 8^2 : 9^2$$

$$:: \overline{1{,}580}|^3 : \overline{1{,}650}|^3$$

$$R = \frac{1{,}000 \times 9^2 \times \overline{1{,}650}|^3}{8^2 \times \overline{1{,}580}|^3}$$

$$= 1{,}441 \text{ lbs.}$$

The actual amounts of resistance in lbs. to projectiles, spherical and elongated, of different diameters moving with varying velocities, will be found in Tables in the Appendix. They have been calculated from the results of Professor Bashforth's experiments.

The velocity the ball loses in consequence of the resistance, or its *retardation*, will, however, depend also upon its weight, being, in fact, *inversely as the weight*, and the weight is proportional to the cube of the diameter, so that the *retardation* of the ball will be as

$$\frac{d^2v^3}{d^3}.$$

If two shot of different diameters are fired under similar circumstances, that is, supposing the angles of elevation of the guns from which they are respectively fired are the same, the initial velocities equal, and the densities of the shot alike (for instance, should they be two cast-iron solid shot), it appears, from what has just been said, that the shot of the largest diameter will range to a greater distance than the other, the *resistance* to each being as to d^2, whereas the *retardation* is inversely as d^3; consequently, for equal ranges, the elevation of the piece from which the larger shot is fired may be reduced, and the chance of its striking the object fired at will therefore be greater than that of the smaller ball, the trajectory of the latter being more curved.

If a spherical shell and solid shot of equal diameters, the weights of which are of course different, be fired consecutively from a gun, at the same elevation, and with equal charges, their initial velocities will be inversely as the square roots of their respective weights (Equation (2), p. 194), the velocity of the shell being therefore the greatest; the shell will, however, in consequence of its inferior weight, be more retarded by the resistance of the atmosphere than the shot, so that, although at short ranges, when firing shell, the elevation of the gun would be rather less than when firing solid shot, at longer ranges the elevation would be about the same, whether shot or shell were fired; and beyond a certain distance would be even less for the shot. For instance, it was found by actual practice, in the Woolwich marshes, that at a range of 1,400 yds., the 32-pr. gun of 56 cwt. required about the same elevation whether shot or shell were fired, but at 1,000 yds. the shell required about one-fourth less than the shot.[4] In the Tables of Ranges given in the 'Handbook for Field Service,' the ranges of the shell for the same gun are greater than those of the shot up to 5° of elevation, when they are both equal, viz., 1,910 yds., after which the ranges of the shot exceed slightly those of the shell.

If balls of equal diameters but of different weights or densities, as solid shot and shell, are fired from the same gun with charges bearing the same proportion to their respective weights, their initial velocities will be equal,[5] as will appear from the formula for initial velocity (Pt. ii. Chap. iii., Art. 4). The ranges at *point blank* or small elevations will not differ to any great extent, but at angles of elevation giving long ranges, the times of flight for which will be considerable, the retardation of the heavier ball will be much less than that of the lighter, and consequently it will range to a greater distance.

If an elongated projectile and a ball of equal weight be fired with the same initial velocity and angle of elevation, the former will be less retarded, and will consequently range further than the ball; for, the diameter of the elongated projectile being smaller than that of the ball, the elongated

[4] The service charge of 10 lbs. used with both shot and shell.

[5] Any difference would arise from the charges not being of equal length.

projectile will not oppose so great a surface to the resistance of the air as the ball.

For instance, if a 12-lb. elongated projectile and a 12-lb. ball be moving with the same velocity, the resistance of the air may be assumed to vary as the squares of their respective diameters.

The diameter of the 12-lb. elongated projectile = 3 in.
do. do. ball . . . . . . = 4·5 in.
∴ resistance will be as 9 : 20·25
or as 1 : 2·25.

From this it appears that the resistance opposed to the ball is more than twice that which acts against the elongated projectile; and this comparison, though rough (for the obliquity of the axis and the form of the point of the elongated projectile are not considered), is sufficiently accurate to account for the results obtained in practice.

It will hence be obvious that as an elongated projectile is lengthened (its weight remaining the same), so, the diameter being necessarily decreased, a longer range will be obtained with the same initial velocity. The long ranges of projectiles fired from rifled arms now in use are due to the substitution of elongated for spherical projectiles. The initial velocities of the former are usually much lower than those of balls fired from smooth-bored arms; but as, in consequence of their peculiar form, elongated projectiles offer so much less surface to the resistance of the air, their velocities are maintained for a longer time than those of balls. That this is practically the case may be seen by an inspection of the following Range Table:—

Gun	Projectile	Initial velocity	Elevation					
			1°	2°	3°	4°	5°	6°
		f. s.	yds.	yds.	yds.	yds.	yds.	yds.
12-pr. smooth-bored.	Spherical	1769	700	1000	1200	1400	1600	1800
,, rifled . .	Elongated	1184	680	1015	1335	1655	1956	2218
32-pr. smooth-bored.	Spherical	1690	790	1160	1460	1690	1910	2110
40-pr. rifled . .	Elongated	1164	720	1100	1455	1810	2160	2505

It has been shown that with spherical projectiles, the shot being heavier than the shell, it is less retarded by the air, and consequently maintains its velocity longer; but this may not be the case with elongated projectiles, which, whether shot, common shell, or shrapnel, can be made equal in weight for the same gun by varying their lengths according to their respective densities; and it will be shown that better practice can usually be made with elongated shell than with the shot, on account of the weight of the former being distributed farther from the axis.

4. The *retardation* of a projectile is influenced by the *form* of both its *fore* and *hind* part, but especially by the shape of the former. One of three different forms is generally employed for the head of an elongated projectile—*conical*, *conoidal*, or

Fig. 82.

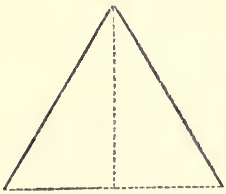


Fig. 83.

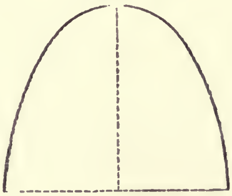
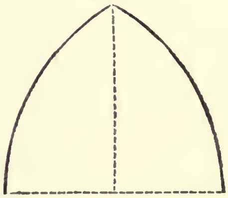


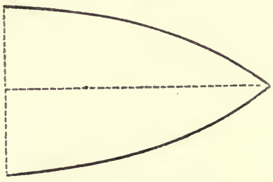
Fig. 84.



ogival. Figures 82, 83, and 84 represent sections of these different forms.

Fig. 82 is the section of a *cone*; Fig. 83 the section of a *conoid*, or a figure generated by the revolution of a conic section about its axis.[6] Fig. 84 is the section of a pointed arch, which is termed by the French *ogival*. Sir Isaac Newton in his 'Principia' gave a form of body (Fig. 85), which would, in passing through a fluid, experience less resistance than a body of any other shape.

Fig. 85.



Newton's Form.

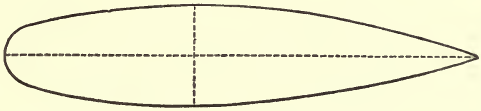
Piobert proposed the form represented in Fig. 86, which he considered would encounter the least resistance in passing through the air. Its length is five times its greatest diameter, and its largest section is placed at $\frac{2}{5}$ths of the length from the base.[7]

[6] It is, therefore, threefold, answering to the three sections of the cone, viz. elliptical conoid or spheroid, hyperbolic conoid, and parabolic conoid.

[7] *Cours d'Artillerie*, p. 15.

The following table [8] of resistances to bodies of different forms, moving with low velocities of 10 feet per second, is

Fig. 86.



Piobert's Form.

constructed from the results of Dr. Hutton's experiments with the 'whirling machine' invented by Robins :—

Form of the body	Experimental Resistance	Theoretical Resistance
1. Hemisphere, convex side foremost .	119	144
2. Sphere	124	144
3. Cône, angle with the axis 25° 42′ .	126	53
4. Disc	285	288
5. Hemisphere, flat side foremost . .	288	288
6. Cone, base foremost	291	288

The experimental resistances to 2 and 3 are about the same, notwithstanding the sharp point of the latter. The resistances to the three last, which theoretically ought to be double of the two first resistances, are experimentally much more, in fact $2\frac{1}{2}$ times as much.[9]

The next table is taken from Piobert's 'Cours d'Artillerie,' p. 15, and contains the results of experiments made by Borda in the last century, with velocities of 3 to 25 feet a second :—

Form of the Base of Prism	Experimental Resistance	Theoretical Resistance
1. Triangle, base foremost . . .	100	100
2. Triangle, apex foremost . . .	52	25
3. Demi-ellipse	43	50
4. Ogival	39	41

From this table it appears that the ogival form experienced the least resistance.

[8] Extracted from Boxer's *Treatise on Artillery*, p. 152, Art. 299.

[9] Dr. Hutton's remarks on these experiments will be found in his 36th Tract, vol. iii. p. 190.

The following table gives the result of an experiment[1] made to determine the relative *retardations* of elongated projectiles having heads of different shapes, and fired at high velocities. From the table it would appear that the projectiles with *ogival* heads were less retarded than those having heads of either of the other forms tried. Five rounds were fired with each form from a 40-pr. BL. gun, the charge being 5 lbs.

Projectile		Observed velocity		
Nature (elongated)	Weight	At 40 yards	At 500 yards	Loss in 460 yards
	lbs.	f. s.	f. s.	f. s.
Service cylindro-conoidal . . .	41·21	1201	1103	98
Cylindro-hemispherical . . .	41·26	1205	1093	112
„ parabolic	41·16	1199	1088	111
„ conical	41·08	1191	1074	117
„ ogival	41·22	1192	1122	70
Cylindrical, or flat-headed . .	47·0	1152	982	170

The flat-headed projectiles lose their velocity very quickly, and, as will be shown, require a very high velocity of rotation to prevent their turning over in flight even at moderate ranges.

Experiments were made by the Rev. F. Bashforth in 1866 to ascertain the resistance of the air to elongated projectiles having heads of various forms. The gun was a ML. R. 40-pr., and the charge 5 lbs. The following results were obtained:—

	Form of Head	Weight of Shot	Velocity of Shot	Resistance to Shot
		lbs.	f. s.	lbs.
Solid	Hemispherical . . .	39·34	1250	178·2
	Hemispheroidal . . .	38·69	—	139·6
	Ogival (1 diameter) . .	39·56	—	147·9
	„ (2 diameters) . .	38·50	—	146·8
Hollow	„ (1 diameter) . .	21·81	1500 1250	253·1 146·2
	„ (2 diameters) . .	21·94	1500 1250	241·5 139·9

As the same charge was used for hollow and solid shot, the former had a higher initial velocity, and therefore a higher velocity of rotation, giving greater steadiness. It would, how-

[1] By Capt. W. H. Noble, R.A., for the late O. S. Committee.

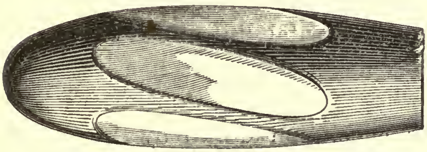
ever, appear that the respective resistances to hemispheroidal and ogival heads differ but slightly.

An interesting fact in connection with the resistance of the air to projectiles was observed by Lieut. J. Sladen, R.A. On comparing the results of Professor Bashforth's experiments with elongated projectiles having hemispherical heads and spherical projectiles, he found that the relative resistances are as

1,345 : 1,531

or the resistance to a spherical shot is nearly $\frac{1}{7}$th greater than that to an elongated projectile with hemispherical head. 'It seems difficult to conceive that the pressure on the front of each shot can be other than the same, seeing the same form is presented to the air in both cases; so that the difference in total pressure must be wholly accounted for by the difference of the minus pressure on the rear of the shot, thus conclusively showing that the rear part of a shot has some influence on the resistance which the shot meets with from the air.'[2] This is undoubtedly the case, as pointed out by Hutton, who, from his experiments with the whirling machine, found that—'when the hinder parts of bodies are of different forms, the resistances are different; though the fore parts should be exactly alike, and equal; owing, probably, to the different pressures of the air on the after parts;'[3] also by Piobert, and later by Sir H. Douglas[4] and Sir J. Whitworth, the latter of whom, after making numerous experiments with projectiles of various forms, fired with high velocities, found that the shape represented in Fig. 87, having a tapering base, gave the best results as regards range.

Fig. 87.



When the velocities of a projectile at two points in the trajectory near together are known, the amount of resist-

[2] Extract from a letter of Lieut. Sladen to the writer.
[3] 36th Tract, vol. iii. p. 192.
[4] *Naval Gunnery*, 5th edition, p. 218.

ance offered by the air at the mean velocity can be thus found:—[5]

Let w = weight of projectile
v = velocity of projectile at one point
v' = " " at the other point
s = space in which the velocity is reduced from v to v'
p = resistance required.

Then $\frac{wv^2}{2g}$ = work required to give w the velocity v,

and $\frac{wv'^2}{2g}$ = " " " v'.

$\therefore \frac{wv^2}{2g} - \frac{wv'^2}{2g}$ or $\frac{w(v^2-v'^2)}{2g}$ = work required to reduce velocity of w from v to v'.

but $ps = \frac{w(v^2-v'^2)}{2g}$, p being supposed uniform through the small space s

$$p = \frac{w(v^2-v'^2)}{2gs}.$$

and, as the distance between the points is small, p will give a very close approximation to the resistance to the projectile moving with the mean velocity $\frac{v+v'}{2}$.

If several resistances are determined in this manner from velocities obtained in practice, a *curve of resistance* like that used by Hutton may be constructed, which will give the resistances at all intermediate velocities. The method of forming the curve is the same as that described in Chap. VII., for a *range curve*, only the horizontal line must be divided into equal parts for velocities, and the vertical line into equal parts for resistances.[6]

5. As before stated, the conclusion drawn by Dr. Hutton from his experiments was, that the ratio of the resistance of

[5] Two other methods for finding the resistance, one employed by Dr. Hutton, are given in Boxer's *Treatise*, p. 98. The pressure in the bore of a gun can be determined in a similar manner, v' being taken as the higher velocity, and $v'-v$ being the additional velocity given by the gas to the projectile in passing over the interval between the two points.

[6] Hutton's *curve of resistance*, and the tables made from it, are given in his 34*th Tract*, vol. iii. p. 108; also in Boxer's *Treatise*, p. 100.

the air to the velocity of a projectile gradually increased up to about 1,500 feet per second, but that when the velocity exceeded this the ratio again diminished. His explanation of the probable cause of this varying ratio was as follows:—[7]

'Thus then we see that the resistance against the ball is twofold (besides that arising from the unknown degree of compression before the ball)—the one arising from percussion, by the ball striking and displacing the particles of air in its path, and which increases continually in the duplicate proportion of the ball's velocity; and the other from the weight of the atmosphere, increasing with that velocity, to which, being of the nature of pressure, it is proportional, but arriving at its maximum[8] when that is equal to or exceeds the velocity of air into a vacuum, after which it is a constant quantity for all greater degrees of velocity. These circumstances, then, very well show the reason why the experimental resistance proceeds in a ratio increasing gradually more and more above the square of the velocity, till this exceeds twelve or fourteen hundred feet, the motion of air into a vacuum, and then rather decreases again. So that it appears that the whole estimatable resistance consists of two parts, of which the one part is proportional to the square of the velocity, and the other is simply as the velocity only.'

'And as it appears that there is no single integral power whatever of the velocity, or no expression of the velocity in one term only that can be proportional to the resistances throughout,' 'we must therefore have recourse to an expression in two terms, or a formula containing two integral powers of the velocity, as v^2 and v, the first and second powers, affected with general coefficients, m and n, so that the formula will be

$$mv^2 + nv = r, \text{ the resistance,'}$$

m and n being determined by experiment.

[7] In his 37th Tract.

[8] 'This asserted maximum is in itself very improbable, and M. Didion declares that there is none deducible from Hutton's experiments. Hutton's attempt to account for this supposed maximum, by reference to the velocity with which air rushes into a vacuum, is extremely fanciful—because the after-pressure is not great to begin with; it diminishes rapidly as the velocity is increased, but perhaps never entirely vanishes.'—*Description of a Chronograph*, by Rev. F. Bashforth, B.D. Bell and Daldy, 1866. On this point, see note 8, p. 220.

In later experiments, different powers of the velocity have been introduced. In General Didion's formula, the first term is proportional to the square, and the second term to the cube of the velocity. M. de St. Robert, of the Sardinian Artillery, has in his formula made the first term proportional to the square, and the second term to the fourth power, and this formula has been applied, with some alteration in the coefficients, by Col. Mayevski, of the Russian Artillery, who carried on experiments in Russia in 1858.

Upon these expressions for resistance various formulæ have been founded for calculating the final velocity, range, and other gunnery problems, those of Hutton and Didion giving fair approximations as regards the trajectories of spherical projectiles.[9] Didion endeavoured to adapt his formulæ to the flight of an elongated projectile by assuming that the resistance to it is about ⅔rds of that to a spherical projectile of equal diameter, a rough assumption founded apparently on data obtained from experiments at Metz, in 1858, upon the ranges and times of flight of projectiles fired from rifled ordnance.

The *cubic law* of resistance (r as v^3) appears to have been first recognised by Captain Welter,[1] as applicable, however, only to the flight of *spherical* projectiles, and it was so used at Metz in 1862. M. Hélie,[2] having ascertained by examination of the results of experiments, at Gâvre in 1859–60–61, that this law could be extended to the flight of elongated projectiles with comparatively low velocities, adopted it for them in his 'Traité de Balistique,' published in 1865. The law has however, been thoroughly investigated by the Rev. F. Bashforth, B.D.,[3] who, working quite independently of the French school,

[9] In comparing these formulæ by calculating the final velocity of a 68-pr. shot at 500 feet range Lieut. (now Captain) W. H. Noble found that Hutton's gave the most accurate result, Didion's giving 58 feet, and Hutton's 51·7 feet more than the experimental velocity.—*Report of Ballistic Experiments*, 1863, p. 89.

'It is manifest that for high velocities both Hutton's and Didion's laws give fair representations of the resistance of the air, Hutton's being rather better than Didion's.'—*Reports on Experiments made with the Bashforth Chronograph*, 1869, p. 64.

[1] Professor at the School of Application of the Artillery and Engineers at Metz.

[2] Professor in the French School of Marine.

[3] Professor of Applied Mathematics to the Advanced Class of Artillery Officers, Woolwich.

stated,[4] in 1865, in a report on the results of an experiment in Woolwich marshes with his newly invented chronograph, that 'the resistance of the air *throughout the range used* varied as the (velocity)^3.' Only eighteen rounds were fired, but they were quite sufficient to indicate a law of resistance varying approximately as the cube of the velocity. Mr. Bashforth's experiments were continued with elongated projectiles in 1866–67–68, and with spherical projectiles in 1868, and a large series of the most valuable results obtained, with projectiles of different weights, fired with varying charges from 3, 5, 7, and 9-inch guns, which confirm the approximate truth of the cubic law, *within the limits* of the velocities used in his former experiments. But when the velocities of the elongated ogival-headed shot were made to vary between 900 and 1,700 feet, it was found that the cubic law would not hold good throughout. Professor Bashforth found, as Dr. Hutton had before ascertained, that the resistances were not proportional to any single power of the velocity, and the general results of his experiments[5] showed that, for ogival-headed projectiles, the resistance of the air varies roughly as,—

The 6th power	of velocity	for velocities of	900 to 1,000 f.s.
,, 3rd	,,	,,	1,100 ,, 1,350 ,,
,, 2nd	,,	,,	above 1,350 ,,

Also that the resistance is practically proportional to the section of the projectile, or d^2.

Newton proposed the square of the velocity as the law of resistance, based on the supposition that the shot is at every moment penetrating an *undisturbed* medium, which only holds for velocities higher than the velocity of sound.[6]

[4] Report of Experiments, dated Dec. 18, 1865.

[5] The great value of the results of these experiments arises from the circumstance that they were obtained with the Bashforth chronograph, which is capable of registering the velocities at a number of different points (usually 10) in the trajectory. With instruments of the Navez class, such as were used at Gâvre, each velocity requires a separate instrument, so that when two or more are required to take the velocities at different points in the trajectory, errors are liable to arise from the circumstance that no two instruments, even of similar construction, will probably give exactly the same results.

[6] Tables calculated from the results of experiments with the Bashforth Chronograph, 1871, p. 21.

The following simple formula, derived from the cubic law of resistance, gives the relation between the velocities V and v at two points of the trajectory at a distance x apart:—

$$v = \frac{V}{1 + cVx}$$

where V = initial velocity.
v = final velocity.
c = a coefficient depending upon the weight, form, and diameter of the projectile.

Mr. Bashforth uses $2b$ instead of c, and states 'As it was found impossible to express the resistance of the air by any useful function of the velocity, for the sake of simplicity of the formula, the cubic law has been retained in connection with a varying coefficient of resistance; the values of the coefficient have been determined experimentally for ogival-headed shot for all velocities between 900 and 1,700 feet, and for spherical shot for all velocities between 850 and 2,150 feet.'[7]

The coefficient c depends upon the weight, section or (radius)^2, and form of the projectile; but for similar forms it will vary as $\frac{R^2}{W}$ and $c = b\frac{R^2}{W}$, b being a constant to be determined by experiment.

For elongated projectiles moving with velocities of from 1,500 to 1,050 f. s., Mr. Bashforth, finding the coefficient varied but little, gave

$$b = \begin{cases} \cdot 000063 \\ \quad \text{to} \\ \cdot 000060. \end{cases}$$

but, as before pointed out, the coefficient is constantly varying with the velocity.[8]

[7] *Reports on Experiments*, pp. 114, 152.

[8] For spherical projectiles M. Welter's value of $b = \cdot 000082$. For elongated projectiles having velocities of from 1,070 to 700 feet, M. Hélie gave

$$b = \begin{cases} \cdot 000038 \\ \quad \text{to} \\ \cdot 000031. \end{cases}$$

Captain W. H. Noble, R.A., who made experiments with Navez-Leurs instruments, proposed the following values of the constants with the service elongated projectiles:—

Mr. Bashforth derived from experiments, in 1865–6, the respective values of b for elongated projectiles having heads of different forms[9] :—

Gun	Form of Head	Value of b
12-pr. BL.	Service	·000064
40-pr. M.L.	½ sphere	·000077
—	½ spheroid	·000060
—	Ogival (1 diameter)	·000063
—	Ogival (2 diameters)	·000060

6. The following example will show the practical use of the above formula; the projectile is supposed to move in a straight line, the curve of the trajectory not being taken into account.

Calculate the velocity with which a 9-in. Palliser shell, weighing 250 lbs., would strike a vessel at 300 yds. range.

v from 1,500 to 1,100 feet $b = \cdot 000063$
,, 1,100 to 1,000 ,, $b = \cdot 000050$
,, 1,000 to 600 ,, $b = \cdot 000035$

and for spherical projectiles—

$$b = \cdot 000081;$$

Capt. Noble stated that he found the change in the coefficient to occur between 1,100 and 1,000 ft., and he attributed it to the relief of pressure which the front of the projectile experienced when the velocity becme lower than that at which air will fill a vacuum. Professor Haughton afterwards pointed out that air could not travel faster than *sound*, but this suggestion was made long ago by Robins, who, as before said, considered that when the velocity exceeded 1,100 or 1,200 ft. per second, the resistance would instantly be nearly trebled, and observed 'that the velocity at which the moving body shifts its resistance is nearly the same with which sound is propagated through the air.' Professor Bashforth suggests that any maximum value of the coefficient may depend upon the relation of the velocity of the shot to the velocity with which a disturbance is propagated through the air. It must not, however, be forgotten, that if the vacuum be nearly complete in rear of the shot, which is probably the case at certain high velocities, the relief of pressure behind would amount to a force of about 100 lbs. on the head of a 3-in. projectile, and to as much as 950 lbs. on that of a 9″ shot, quite sufficient to cause rapid change in the coefficient, although there is no such thing, as Hutton and Boxer pointed out, 'as a sudden and abrupt change in the law of resistance.' The effect of tapering off the hind part of a projectile in lessening the resistance, by giving greater facility to the air to rush in behind and support the base, has already been pointed out at p. 215.

[9] The b in the table when multiplied by $\frac{R^2}{W} = c$, or = Mr. Bashforth's $2b$. The coefficients derived from experiments with ogival-heads struck with radii of 1½ diameter may be used for other ogival-heads used, or approximate forms with more or less pointed apex.—*Tables from Experiments with Bashforth's Chronograph*, p. 21.

The initial velocity of the shell = 1,340 ft., and the diameter = 8·9 in.

$$\text{Here } v = \frac{V}{1 + cV.x}$$

$$V = 1340 \text{ f. s.}$$

$$x = 900 \text{ feet}$$

$$c = \cdot000062 \frac{R^2}{W}$$

$$\text{and } R = 4\cdot45 \text{ inches, or } \cdot375 \text{ feet}$$

$$W = 250 \text{ lbs.}$$

$$c = \cdot000062 \frac{\overline{\cdot375}|^2}{250}$$

$$= \cdot000000034875$$

$$v = \frac{1340}{1 + \cdot000000034875 \times 1340 \times 900}$$

$$= \frac{1340}{1 + \cdot042059}$$

$$= 1286 \text{ feet.}$$

The velocity thus found will be a fair approximation, when the correct coefficient is employed;[1] but if accuracy be required for a number of different velocities, the coefficient must be changed for each; for this purpose Mr. Bashforth gives two tables, one of the coefficients for elongated projectiles with velocities of from 900 to 1,700 ft. per second, and the other for those of spherical shot with velocities ranging between 850 and 2,150 ft., and, for convenience of calculation by means of tables of reciprocals, he puts the formula thus:—

$$\frac{1000}{v} = \frac{1000}{V} + (2000b)s$$

and the value of the coefficient $2000b$ must be deduced for each shot and velocity from the values of $2000b \frac{w}{d^2}$ in the table. The velocities of 7, 8, and 9-in. ogival-headed projectiles, and

[1] In the coefficient above, the *radius* of the shot is given in *feet* and expressed by R; but in that used for making out the tables of the Report, the *diameter* is expressed in inches by d.

those of spherical shot, at intervals of 100 ft. as given by Mr. Bashforth, will be found in tables in Appendix.[2]

As in the experiments made with the ballistic pendulum, or with different electro-ballistic instruments, the resistances to low velocities have not been determined, it may be as well to state briefly the results obtained with low velocities of 10 to 20 ft. per second, by means of the whirling machine. Robins, who invented the instrument, made many experiments with it before the Royal Society; some of these showed within the limits tried that—the resistance of the air varied as the square of the velocity.[3] Dr. Hutton also experimented with it in 1786–87, and some of the results with bodies of different forms have already been given in § 4. He also arrived at the following conclusions,—

(1) That the resistance is nearly as the surface; the resistance increasing but a very little above that proportion in the greater surfaces.

(2) The resistance to the same surface, with different velocities, is, in these slow motions, nearly as the square of the velocity; but gradually increasing more and more above that proportion, as the velocity increases.

It is not proposed to give the somewhat complicated formulæ for the solution of other problems relating to the trajectory of a projectile in the air, such as those to determine the range, angle of elevation, angle of descent, time of flight, and a few others, for, although interesting mathematical applications, they are comparatively of little practical use; especially as the answers to them can be readily obtained on any practice ground. The distance covered by a shot within a given height from the ground can, as will be shown, be ascertained from the angle of descent.

7. Should the *initial* velocity V be known, and the *final velocity* v be calculated by the above formula, the angle of eleva-

[2] Professor Bashforth has recently published *A Mathematical Treatise on the Motion of Projectiles*, founded on the ample data obtained from his own experiments.

[3] The instrument, as well as the experiments made by both Robins and Hutton, are fully described in Hutton's 36*th Tract*.

tion a required for the gun in order that its projectile may strike an object at a distance x can be roughly determined thus:—

$$\frac{V+v}{2} = \text{mean velocity},$$

$$\frac{x}{\text{mean velocity}} = \text{time of flight}.$$

The height of the imaginary point above the object upon which the axis of the piece must be directed can be found from the formula,

$$s = \tfrac{1}{2}gt^2,$$

and the angle (a) from

$$\tan a = \frac{s}{x}.$$

8. The maximum range of a projectile, fired with a given initial velocity in vacuo, would be obtained at an angle of 45° of elevation; for, from equation (4), Art. 2 of this Chapter, it appears that R varies as sin $2a$, and R will therefore be greatest when

$$2a = 90, \text{ or } a = 45°.$$

In the air, however, the resistance increasing with the velocity, as the latter is greater, the angle of elevation to give the maximum range decreases, for the trajectory will differ more from a parabolic curve. With high velocities, such as 1,600 ft. a second, the angle to give the maximum range to a ball in the air is found both by theory and practice to be about 32°;[4] a 56-lb. shot fired with a charge of 16 lbs. giving an initial velocity a little higher than 1,600 ft., ranged at this angle 5,720 yds.; in vacuo the range at 32° would have been 23,946 yds., and at 45°, 26,666 yds. Elongated projectiles range much further than balls; for instance, a shot weighing 175 lbs. fired from a rifled gun (L. Thomas') at 37½° ranged 10,075 yds.; and a projectile weighing 250 lbs. fired with a charge of 50 lbs. (in a tubular cartridge) at an angle of 33° from a Whitworth gun ranged 11,243 yds., or about 6⅓ miles.

9. Experiments were carried on in Russia by Colonel Mayevski, of the Russian Artillery, in 1858, and the actual trajectories of

[4] Art. 93, p. 63, Sir H. Douglas' *Naval Gunnery.*

projectiles, fired from a cannon of tolerably large calibre under different circumstances, that is with different charges and elevations, were determined. The trajectories were also calculated by formulæ somewhat similar to those given by Gen. Didion, the calculated and actual results agreeing very nearly, as will appear by the table below.

For these experiments a bronze SB. *canon de* 24 was used, and the ordinates of the trajectories of the projectiles fired were ascertained by their passage through wire screens stretched across the range at different distances. The velocities of the projectiles at a fixed distance from the muzzle of the gun were obtained by means of the electro-ballistic apparatus of Major Navez. The mean weight of the projectiles fired was 26·69 lbs. (Eng.), and the mean diameter 5·868 in.

TABLE OF TRAJECTORIES.[5]

Charge	No. of rounds	Elevation	Initial velocity	Ordinates at distances of										
				yds. 12	yds. 116	yds. 233	yds. 350	yds. 466	yds. 583	yds. 700	yds. 816	yds. 933	yds. 1050	
lbs.		°	f. s.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	
8	22	1¾	1731	1·116 1·119	10·10	18·85 18·45	24·67	28·68 28·51	29·42	26·90 26·90	20·33	9·76 10·	–5·47 –5·3	Obs. Cal.
5	23	2	1367	1·301 1·29	11·56	20·76 20·07	26·27	28·43 28·27	27·02	19·69	9·49 10·31	Obs. Cal.		
3	25	2½	1073	1·611 1·61	14·06	24·37 23·70	29·85	30·64 29·92	25·47	14·76	–2·43 –2·28	Obs. Cal.		
1·5	22	3½	713	2·217 2·23	18·03	27·33 27·01	27·48	17·41 17·74	Obs. Cal.					
·75	22	5½	453	3·417	25·07 25 46	30·06 29·85	13·41 12·98	Obs. Cal.						

10. The two following formulæ[6] are used for determining the *terminal velocities* of balls. Should this ball be a cast-iron solid shot:—

$$v = 178\sqrt{d}.$$

But if the ball be of a different weight to a cast-iron shot, as for instance a shell, or a leaden bullet, &c.,

$$v = 178\sqrt{\frac{s}{s'}d},$$

in which s = weight of the shell or bullet, and s' = weight of a solid ball of the same diameter.

[5] In the table given in the *Occasional Papers of the R. A. Institution*, Nov. 1859, the ranges are in sagènes, one of which is equal to seven English feet.

[6] Boxer's *Treatise*, p. 111.

As there is a certain limit to the velocity acquired by a falling body in consequence of the resistance of the atmosphere, there must also be a limit to the penetration obtained by projecting balls at high angles of elevation; in practice, however, as in the case of mortar shells, which are, perhaps, never thrown high enough to attain terminal velocities, there is doubtless a certain range peculiar to each nature beyond which but little additional penetration would be obtained, although by increasing the range the shell would descend from a greater height.

CHAPTER V.

DEVIATION OF PROJECTILES AND PRINCIPLES OF RIFLING.

1. Very great irregularities occur in the paths described by projectiles fired from smooth-bored ordnance. It is a fact, well known to all practical artillerists, that if a number of solid shot (or any other projectiles) be fired from the same gun, with equal charges and elevations, and with gunpowder of the same quality, the gun-carriage resting on a platform, and the piece being laid with the greatest care before each round, very few of the shot will range to the same distance; and, moreover, the greater part will be found to deflect considerably (unless the range be very short) to the right or left of the line in which the gun is pointed. This will appear evident by an inspection of tables giving the results of the most careful experimental practice (Table XXI., Appendix).

With rifled guns the fire is far more accurate, but still the ranges and deflections are subject to variations of greater or less amount. The term *deviation* must be understood to mean not only the deflections right or left of the line of fire, but the differences between the ranges of similar projectiles fired under like conditions from the same gun.

2. The causes of the deviations of projectiles, whether fired

from SB. or R. guns, and independently of inaccuracy in *laying* and variable position of the gun-carriage, are—*wind*, *variable projectile force*, and *rotation of the earth.*

3. The French have treated the question of deviation caused by wind mathematically,[1] giving formulæ for calculating the amount of deflection, and tables containing the deflections for different projectiles at a given range and for a wind having an average velocity. It is, however, difficult to procure a satisfactory instrument for measuring the force of the wind,[2] and calculations or tables for giving deflections from this cause are of little practical utility.

Should the wind blow in gusts and be changeable in direction it is difficult to allow for it in *laying* the piece; but with a steady breeze blowing in a pretty constant direction, a few rounds will be generally sufficient to show the allowance necessary for it. The velocity of the wind is very low compared with that of the shot, but it remains usually nearly the same throughout the flight of the projectile, whereas the velocity of the latter decreases rapidly; it therefore frequently happens that the wind appears to have a greater effect towards the end of the range, and it may be often noticed in practice that shot deviate in a rapidly increasing curved line.

The wind if strong will greatly affect the ranges of projectiles, decreasing or increasing them according as it may be blowing up or down the practice ground. The lower the velocity of a projectile the greater will be the time allowed for the wind to cause deviation: as, for instance, with mortar shells, on which, having low velocities and long times of flight, the wind exercises a very disturbing influence. The greater the density of the projectile, the less will its motion during flight be affected by wind; thus shells are more influenced by wind than shot.

The wind often exercises a considerable disturbing effect upon an elongated shot during its flight, rendering it difficult to

[1] Didion's *Traité de Balistique*, p. 398.

[2] An ingenious instrument for registering the direction and force of the wind has been contrived by Mr. Howlett. He calls it the *anemograph*, and it records the action of the air in the form of a map on paper. A description of it will be found in *Military Breech-loading Rifles*, by Captains Majendie and Browne, R.A.

obtain great accuracy of fire at long ranges, even from rifled guns, except in very calm weather. If the centre of gravity of an elongated shot be placed in, or very near the middle of, the long axis, the force of the wind will be pretty equally distributed over the whole length of the projectile. Should, however, the centre of gravity be placed far in advance of, or behind, the centre of figure, the force of the wind will press unequally upon the shot, and uncertain deflections will most probably occur, as was the case with the egg-shaped bullets proposed by Robins.[3]

4. It is almost impossible to manufacture large quantities of powder of perfectly uniform quality, but, supposing it could be accomplished, the force from a given charge would be liable to variation according to the state of the atmosphere, and the condition of the powder as affected by the time it had been in store; it will also be frequently found in practice that the charges have not been weighed out with perfect accuracy, nor the gun loaded so that the shot is always in the same position with respect to the charge. The consequence is that very few projectiles of equal weights fired from the same gun with what are called equal charges leave the bore with exactly the same initial velocity.

5. The deviation of a projectile caused by the rotation of the earth from west to east is a complicated problem; the

[3] In 1747, Robins suggested an elongated bullet of an egg-like form:—'For,' he says, 'if such a bullet hath its shorter axis made to fit the piece, and it be placed in the barrel with its smaller end downwards, then it will acquire, by the rifles, a rotation round its longer axis; and its centre of gravity lying nearer to its fore part than its hinder part, its longer axis will be constantly forced by the resistance of the air into the line of its flight; as we see, that by the same means, arrows constantly lie in the line of their direction, however that line be incurvated.' The results of experiments with these bullets of Robins' are thus given by Col. Beaufoy, in his work called *Scloppetaria*: 'At long distances, that is from 300 to 600 yds. when fired from a gun of $\frac{6}{10}$ in. bore, they were found much less liable to deviation than at 200 yds. and under, with this peculiarity, that in windy weather, whereas balls are usually driven to leeward of the object, these had a diametrically opposite effect. It was found, however, that these balls were subject to such occasional random ranges as completely baffled the judgment of the shooter to counteract their irregularity.' Their deviations to windward no doubt arose, like those of rockets, in consequence of the centre of gravity of the projectile being so far forward, and, as such deviations must always be exceedingly variable, they cannot be corrected by the laying of the gun.

principle that *this rotation* will have impressed upon the shot on leaving the bore a tendency to move with the same velocity in the same direction as the point upon the surface from which the gun is fired, is readily comprehended, but not its application to some particular cases.

The question was elaborately treated by the celebrated mathematician Poisson,[4] whose method of investigation, and the deductions from it, have been generally accepted; it will, however, be sufficient here to give the latter, for projectiles fired in the *northern* hemisphere.

When firing from	N. to S.	the deflection is to	W.
,,	S. ,, N.	,,	E.
,,	W. ,, E.	,,	S.
,,	E. ,, W.	,,	N.

So that the deviation is in all cases to the *right*,[5] in the *northern* hemisphere. It must also be observed that in firing from W. to E. the range is increased.
E. ,, W. ,, decreased.

but in firing due north or south the range is not altered.

On this point Professor Price says:—'When the shot is fired due north or south the range in that direction is not altered.

'When the shot is fired due east the range eastwards is increased or diminished, according as the angle of elevation of the gun is less than or greater than 60°.

'When the shot is fired due west the range is increased or diminished according as the angle of elevation is greater than or less than 60°.'[6]

[4] In the *Journal de l'École polytechnique*, tom. xvi.

[5] In Professor B. Price's *Infinitesimal Calculus*, vol. iv. p. 442, it is stated that the deviation is to the *right* in three cases, but to the *left* in the fourth, viz. in firing due *north* it is to the *west*. 'When the shot is fired due north or south, the range in that direction is not altered, but there is always a deviation of the shot westwards.' In reply to a letter on this point Mr. Price was good enough to send me the following correction:

'P. 442, line 8, after "westwards" insert "so long as θ is less than $180° - \tan^{-1}(3 \tan \lambda)$; and this deviation vanishes if $\theta = 180° - \tan^{-1}(3 \tan \lambda)$; and the deviation is eastwards if θ is greater than $180° - \tan^{-1}(3 \tan \lambda)$."'—*C. H. O.*

[6] Price's *Infinitesimal Calculus*, vol. iv. p. 442.

In practice, ordnance are not fired at a greater angle than 45°, so that the effect upon range at angles over 60° may be disregarded.

In the southern hemisphere these effects would be reversed.

Captain (now Major-General) Boxer gives an example in his 'Treatise on Artillery,'[7] from which it would appear that a ball fired due *south* in the latitude 52° from a 56-pr. gun, with a charge of 17 lbs. and elevation of 35°, giving a range of 5,600 yds. in thirty-four seconds, would have a right or *west* deflection of 10·914 yds.[8]

Deviations of Projectiles from Smooth-bored Ordnance.

6. The principal causes for these deviations are—

(1) Windage;

(2) The imperfect form and roughness of surface of the shot;

(3) Eccentricity of projectile arising from a want of homogeneity.

Windage causes irregularity in the flight of a projectile from the fact of the elastic gas acting in the first instance on the upper portion of the projectile, and driving it against the bottom of the bore; the shot re-acts at the same time that it is impelled forwards by the charge, and strikes the upper surface of the bore some distance down, and so on, by a succession of rebounds, until it leaves the bore in an accidental direction, and with a rotatory motion, depending chiefly on the position of the last impact against the bore.

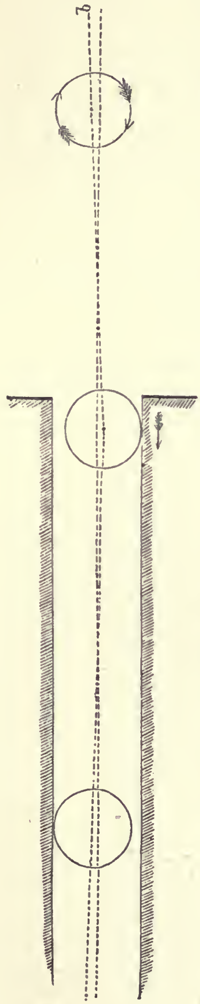
Thus, should the last impact of a (concentric) shot when fired from a gun be upon the right-hand side of the bore, as represented in Fig. 88, the shot will have a tendency to deflect to the left in the direction *b*, while at the same time a rotation will be given to it in the direction indicated by the arrows; the effect of this rotation will, however, cause the ball

[7] P. 175.

[8] Lieut. W. F. Richardson, R.E., in a paper on the 'Deviation of Projectiles unconnected with Rifling,' in the *Proceedings of the R. A. Institution*, p. 464, gives a table of the deviations of projectiles, from the Armstrong 100-pr., L. Thomas' gun, and 13-in. mortar, due to the rotation of the earth.

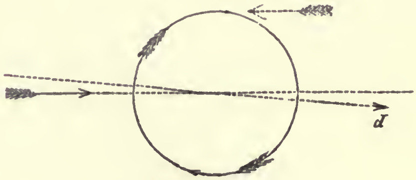
during its flight to bear off gradually to the right, so that the deflection will not be to the left but to the right, unless the range be short. Many explanations have been given to account for the effect produced upon the trajectory by the rotation of the shot, but the most satisfactory is that of Magnus, which is accordingly inserted here.

Fig. 88.



In order to simplify the question, the only case fully explained will be when the shot is rotating, as in Fig. 89, but it will be evident that the following remarks would equally apply to a ball striking the bottom

Fig. 89.



of the bore, when the rotation of the fore part would be from above downwards, and instead of deflecting to the right, the range of the ball would be decreased, as shown by *d*. Suppose the ball to rotate in an opposite direction, the results would be reversed; that is to say, if a figure represented a rotation imparted by the ball having impinged on the left side of the bore, the deflection would be to the left; but should the same figure show a rotation caused by an impact on the top of the bore, the range would be increased. Should the shot on leaving strike any intermediate part of the bore, a compound effect would be produced, according to the position of the point of impact.[9]

[9] It was asserted by Robins, 'That almost all bullets receive a whirling motion by rubbing against the sides of the pieces they are discharged from; and that this

7. Professor Magnus, of Berlin, made a number of careful experiments some few years ago, to ascertain the causes for the deviations of projectiles; and, as they appear to afford the most probable explanations for the different results observed in practice, it is considered necessary to give some account of them here: those relating to spherical projectiles only will be described at present.

The first object was to determine the relative amount of atmospheric pressure exerted on different parts of the projectile, when the latter has imparted to it a motion of translation as well as a motion of rotation. It was assumed that the relative pressures upon the projectile are the same, whether it is made to move with a certain velocity through the air, or whether a current of air is impelled with the same velocity against the projectile.

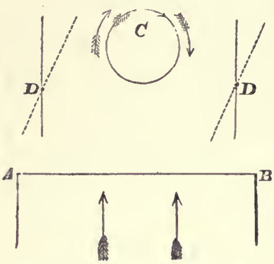
whirling motion of the bullet occasions it to strike the air oblique to the track of the bullet, and consequently perpetually deflects it from its course.' Shot cannot be cast with perfectly smooth surfaces; consequently a certain amount of friction arises between these surfaces and the atmosphere.

The manner in which the ball is deflected, according to Robins, may be thus explained:—As the air in front of the ball will in the above case be greatly condensed, while almost a vacuum will be formed behind the ball, a great resistance will be offered by the friction of the air in front, which will not be counterbalanced by a corresponding resistance behind, and therefore the ball will have a tendency to deflect in the opposite direction to that given it by striking the right side of the bore. This is shown in Fig. 89, the dotted arrow representing the resistance caused by the friction of the air to the rotation, and which not being balanced by a corresponding resistance to the opposite hemisphere will cause the ball to deflect in the direction (*d*).

Robins' experiment before the Royal Society in 1746 (see Boxer's *Treatise*, p. 165) is very curious, and fully bore out his ideas with regard to the effect that the air has upon balls during their flight. Having fired a bullet from a musket through two screens into a wall, in order to ascertain the direction of its trajectory, he then bent the end of the barrel to the left, at about three or four inches from the end, and at an angle of 3° or 4° to the straight portion. When a bullet was now fired, it, as may be supposed, passed through the screens to the left of the track followed by the former bullet, but on the wall it struck considerably to the right of the point of impact of the first. The second bullet, fired when the barrel was bent, thus described a doubly curved line, one curve being caused by gravity, and the other by the resistance of the air to the rotation of the bullet; for in passing out of the barrel, the bullet naturally sliding against the right side, a rotation from the left to the right was imparted to it, and the air resisting the rotation, as before explained, would cause this gradual bearing off to the right.

Observations being more easily made on a cylinder than on a sphere, a brass cylinder (see Fig. 90), about $1\frac{1}{2}''$ in diameter and $4''$ high, was used to represent the projectile, and it was arranged so that it could be made to rotate rapidly on a concentric or eccentric vertical axis. The current of air was produced by means of a rotating fan, the direction in which it was driven being perpendicular to the axis of the cylinder; the nozzle (AB) which delivered the stream, was five inches wide, so that the cylinder might be within the current whatever the position of its axis; the depth of the nozzle was three-quarters of an inch. Two light movable vanes (DD) were placed on each side of the cylinder, so that their pivots were equidistant from the mouth of the blower, and from a vertical plane passing through the centre of the current and the axis of the cylinder.

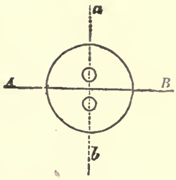
Fig. 90.



If the cylinder be at rest and the current of air impelled against it, the pressures will manifestly be equal on both sides of the axis, and the vanes are found to place themselves parallel with the current. But when the cylinder is made to rotate from left to right, as indicated by the arrow in the circumference of C, Fig. 90, the portion of air in contact with it (arrows round the cylinder, see Fig. 90) is also made to rotate in the same direction. The cylinder being made to rotate, and the blower being also applied, it is found that the vane on the left side of the cylinder, when the current of air from the blower and the rotating current follow the same direction, approaches the cylinder; but the vane on the other side, where the two currents move in opposite directions, is found to recede from the cylinder. It would appear from this that on the left side there is a diminished pressure, and on the right side an increased one, compared with the pressures on the cylinder when at rest. In order to obtain the most distinct effects, the velocity of the air produced by rotation must be nearly as high as that of the current of air from the blower.

It was shown by M. F. Savart that if two jets of liquid, flowing with the same velocity from circular orifices of the same diameter, meet each other, when their axes are in the same straight line, the two together move laterally and in a plane perpendicular to the jets. This may be illustrated in the case of gases by the ordinary fish-tail burner, the flame being in a plane at right angles to that passing through the two perforations from which the flame issues; thus in Fig. 91, AB represents the plane of the flame, and *ab* that passing through the perforations. Also in the experiment with the cylinder, on the right side, where the current of air from the blower moves in an opposite direction to the air rotating with the cylinder, when the two currents meet they move laterally, an increased pressure being therefore exerted on the vane, forcing it outwards, and on the cylinder; whereas on the opposite side, in consequence of the two currents of air moving together, the pressure is decreased, and the vane approaches the cylinder.

Fig. 91.

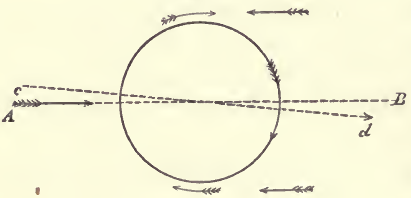


In order to prove that the difference of pressure upon the opposite hemispheres of the ball is sufficient to cause it to deviate, Professor Magnus devised the following experiment:—'A light beam of wood, about four feet in length, is suspended from its centre by a thin wire, so as to form a sort of torsion balance; from one end of this beam a brass rod descends carrying a brass ring, within which a light brass cylinder (similar to that described above) turns very freely on an axis, in the same manner as a common terrestrial globe turns within its brazen meridian. At the other end of the beam a counterpoise is adjusted. The blower before cited is placed below the beam, so that it may be made to turn horizontally about a point nearly coincident with the prolongation of the suspending wire, while the mouth is about 2″ from the cylinder. The plane of the ring being made perpendicular to the direction of the blast, the cylinder is now made to rotate rapidly from right to left, or *vice versâ*, by means of a thread wound round its axis, in the same manner that a humming-top is spun.

While this is in a state of rotation, the blower is put into action. The beam then with the cylinder revolves, and may be made to describe a large portion of a circle, the direction of its orbit depending on the direction which is given to the rotation of the cylinder on its axis.'[1]

8. Let these principles be applied to the case of ordinary spherical projectiles fired from guns. If a ball leaves the bore rotating on a vertical axis, the fore part of the ball moving from left to right, supposing the observer to be behind the piece, it follows from what has been previously said that there will be a diminished pressure on the right side, and an increased one on the left side of the ball, which will therefore deviate to the right: this is shown in Fig. 92, in which AB represents the direction in which the ball is impelled, *cd* that of the deviation, and the small arrows outside the ball the directions of the two currents of air on both sides. In like manner, if the fore part of the ball turns from above downwards, the increased pressure will be above and the decreased below, and the range would therefore be diminished. In one case alone will there be no deviation from the causes described, and that is when *the axis of rotation of the ball is tangential to its trajectory.*

Fig. 92.



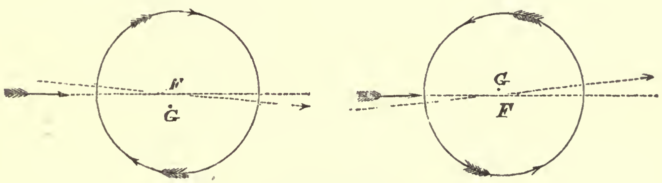
It has been already explained that the velocity of the air rotating with the ball must be nearly as high as that of the opposing current, in order that the pressure on one hemisphere caused by the meeting of the two may have sufficient power to produce very evident deviations; this will in some measure explain the fact that the lateral deviation is found in practice to increase in a higher ratio than the distance, for the velocity of translation decreases much more rapidly than that of rotation, and therefore the velocities of the two separate currents will become more nearly equal.[2]

[1] *Journal of U. R. S. Institution*, p. 403.

[2] It appears that if a shot rotates on any axis when leaving the bore of a gun,

From the above explanations, either of Robins or Magnus, it appears that a ball leaving the bore of a gun rotating on any axis, except one *parallel to that of the bore*, will deviate according to the direction of the rotation; and they will account for the results of experiments with *eccentric* projectiles. Should the centre of gravity of a shot not coincide with the centre of the figure, the shot is found to deviate according to the position of the centre of gravity when the ball is placed in the bore of the gun. Should the line joining the centre of gravity and the centre of the figure of a projectile be not parallel to the axis of the bore, the charge of powder will act upon a larger surface on one side of

Fig. 93. Fig. 94.



Eccentric shot.

the centre of gravity than on the other, so that there will be a rotation from the lightest to the heaviest side. If Fig. 93 represent an eccentric shot, the centre of gravity (G) of which is below its centre of figure (F), the powder acting on a larger surface above (G) than below, will give it a rotation as indicated by the arrows; and, from what has been previously said, its deviation will be to the side upon which the centre of gravity lies. This is the case in practice, for it is found by experiment[3] that if a shot be placed in a gun, so that its

it will deflect in the same direction according either to Robins or Magnus; the rotation of the air round the projectile, as explained by the latter, is no doubt caused chiefly by the friction between it and the ball.

[3] Experiments were carried on at Shoeburyness and Portsmouth, in 1850, and again at the former place in 1851 and 1852, at the suggestion of Sir H. Douglas; the object of these experiments being, 'To ascertain whether the deviations of eccentric projectiles were so regular as to admit of being allowed for in pointing the gun; and whether any result might appear to disprove the maxim, that spherical and homogeneous projectiles are the truest in their flight.' The report of the Ordnance Select Committee on these experiments stated 'That no useful application of

centre of gravity is to the right of the vertical plane, passing through the axis of the bore, the shot will deviate towards the right, and *vice versâ*; also, if the centre of gravity be upwards the range will be increased, and if downwards, diminished. Figs. 93 and 94 will illustrate these remarks.

It is found in practice that shot deviate in a curved line, either right or left, the curve rapidly increasing towards the end of the range. This most probably occurs from the velocity of rotation decreasing but slightly, compared to the velocity of translation of the shot as before explained; or, if a strong wind is blowing steadily across the range during the whole time of flight, this deflecting cause being constant, while the velocity of the shot diminishes, the curve will manifestly increase with the range. The trajectory is therefore a *curve of double curvature*, its projection on either a horizontal or vertical plane being a curved line.

The Principles of Rifling.

9. By a successful introduction of the rifle system in the construction of ordnance and projectiles, the chief causes of deviation are very greatly diminished. The object of rifling the bore of a piece of ordnance (or a musket barrel) is to give the projectile a rotatory motion on an axis *parallel to that of the bore*, or *coincident* with the *line of fire*. By giving this rotation to a spherical projectile, the pressure of the air will be equally distributed on the opposing surface, thus obviating the chief cause of deflection, and securing greatly increased accuracy.

10. *Balls* were fired from the rifled arms first introduced, but it was soon found that *elongated projectiles* could be successfully employed with these pieces; and, as so many advantages were secured by the adoption of the elongated forms for bullets or shot, the use of spherical projectiles has been discontinued ex-

the eccentric principle can be made in general service, and that its use is limited to cases in which a more extended range may be required than is practicable under ordinary circumstances.'

Tables showing the results of the experiments carried on at Shoeburyness are given in Boxer's *Treatise*, p. 167.

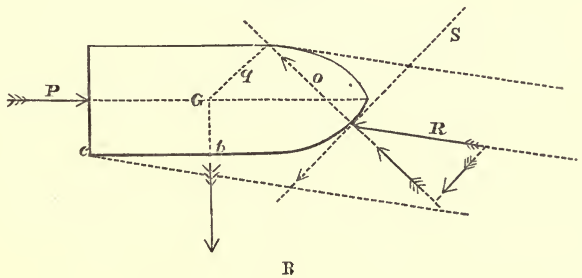
cept for smooth-bored ordnance. Elongated projectiles cannot be used with advantage if fired from smooth-bored pieces, except at very short ranges, for, the pressure of the air acting unequally upon them when they have left the bore, they soon turn over in their flight, and accuracy of fire is then lost.[4] The following remarks will explain the cause of this turning over in the air of elongated projectiles fired without rotatory motion round their longer axis.

As the effect of the pressure of the air differs according to the shape of the head of the projectile, both a conoidal and flat head are here given in Figs. 96 and 97. In each of these Figs. R acts below a, and is half-way between the dotted lines, which include between them a space representing the opposing current of air, and slope upwards towards the shot, as the centre of gravity will commence to descend from the line of fire directly the projectile leaves the bore;[5] it is evident that these lines should be parallel to AB, the trajectory.

[4] Some experiments were carried on at Landguard Fort, in 1776, to ascertain the comparative ranges and accuracy of long and round shot fired from smooth-bored ordnance. The form of the long shot was cylindrical, with hemispherical ends. 'The weight of the oblong shot was more than double that of the ball, but the windage of the former was about one-tenth of an inch less. The ranges with the oblong shot were, of course, considerably less than with the balls; but it does not appear from these trials that the variations, or errors, were greater than they are with round shot.'—*Naval Gunnery*, by Sir H. Douglas, p. 73. Elongated projectiles, having their centres of gravity very near the head, might probably be fired from SB. guns with good effect at ranges of 600 to 700 yds.

[5] Resolve R into two forces O and S (Fig. 95), the latter acting as tangent to the curve, and representing the friction between the air and surface of shot, which is therefore very small. The former, O, acting as normal to the tangent, and representing the resisting force of the air, which causes the movement of the head of the shot. Draw q from G perpendicular to O; then $O\,q$ is the moment tending to turn the point up, and will continue to act until O passes through b at right angles to $c\,b$.

Fig. 95.



The effect of R in Fig. 96, is to give the shot a rotation round one of its shorter axes, the point being turned up, as shown by the dotted lines. In fact, a pressure exerted anywhere, and at any angle, between a and b, that is, before and below the centre of gravity G, will raise the point; and a force exerted behind and below G, between b and c, will depress the point, no matter whether G is placed in the middle or nearer either end of the shot.

Now, in Fig. 97, the pressure R will not raise but depress the head, as shown by the dotted lines;[6] and if R acts anywhere between a and b, the same effect will be produced; but if R acts between b and c, the head will be raised, as with the cylindro-conoidal shot in Fig. 95.

Fig. 96.

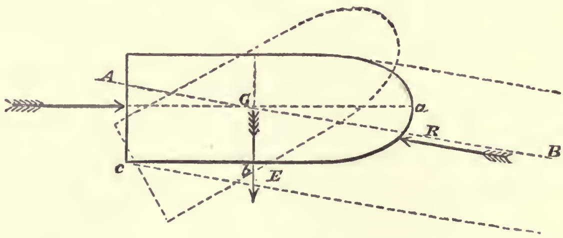
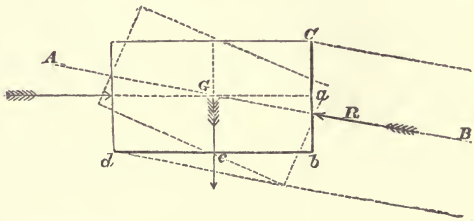


Fig. 97.

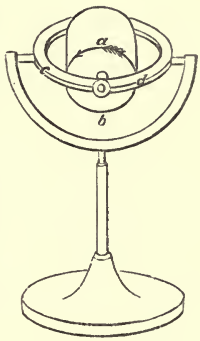


P represents the force of projection.
G „ „ gravity.
R „ resultant of the air's resistance, which must be parallel to the trajectory AB described by G, the centre of gravity of the shot.

[6] If the pressure R, acting upon the flat head below a, be resolved, the component O pressing perpendicular to the end Cb of the shot, and therefore parallel to its long axis, will pass below the centre of gravity.

11. These effects may be demonstrated practically by means of a *gyroscope* provided with a small elongated shot, instead of the disc used for ordinary experiments. The projectile must be made with the greatest care, so that its centre of gravity coincides exactly with that of the two rings within which it is placed: the rings are so arranged that one can turn round a vertical axis, and the other round a horizontal axis, the projectile being therefore free to turn in any direction. A cylindrical portion of metal extends beyond the base of the shot, in prolongation of its longer axis, round which the string is wound to give the required rotatory motion to the projectile.

Fig. 99.

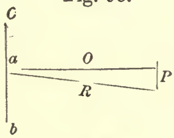


As the shot in the gyroscope has no motion of translation, a strong current of air must be directed upon it, so as to represent the resistance of the atmosphere to a projectile moving with a high velocity. The diameter of the nozzle of the blower should be equal, or perhaps rather larger than that of the shot, and the centre of the blast should be directed below the point of the shot, in the position indicated by R in Figs. 95 and 96.

12. The rotatory motion given to an elongated projectile round its longer axis in passing through the bore of a rifled piece, imparts stability to this axis, thereby preventing the projectile from turning over, and causing it to proceed in the desired direction with but little deviation. It must be evident from the above remarks, that if an elongated shot were fired *in vacuo* it would require no rotatory motion, as there would be no disturbing force to upset it during flight.

The component P parallel to Cb represents merely the friction between the air and the surface of the end, and is therefore very small indeed compared to O, the resistance opposed to the motion of translation.

Fig. 98.



Three different ways of giving the requisite rotatory motion to a projectile suggest themselves.

(1) By mechanical means inside the bore of the gun.

(2) By the action of the gas (from the gunpowder) upon the shot inside the bore.

(3) By the pressure of the air upon the projectile after it has left the bore.

In order to obtain rotation by the two latter methods, the projectile is provided with wings, spiral grooves (either round the exterior surface or running through the metal), or other contrivances for the gas inside the bore, or the air during flight, to act upon; but by none of these have satisfactory results been obtained in practice, and it is not therefore necessary to describe them. The different methods of giving rotation in the bores of rifled guns have been already explained (Part I. Chap. II.).

13. In order to secure accuracy of fire, it is essential that the axis of the projectile should correspond with that of the bore of the gun; for, otherwise, the axis of rotation will be variable, and the deflection of the projectile uncertain. Should the axis of the shot on leaving the bore be unsteady, the projectile will have the *wabbling* motion so frequently observed in experimental practice.

When a considerable portion of the cylindrical part of the shot bears against the grooves of the bore, the projectile fitting the bore tightly, as is the case with almost all rifled small arms having leaden bullets, or with ordnance rifled on the *expansion* or *compression principle*, the axis of the bore and shot must coincide, and, if the requisite conditions of twist, charge, form of projectile, &c., be properly carried out, accuracy of fire will be secured.[7] When there is any *windage*, as in the case of all muzzle-loading rifled pieces with hard projectiles having *ribs* or *studs*, and no centering arrangement, there will be a slightly oblique movement of the axis of the projectile, which, on leaving the bore, will have a two-fold rotatory movement, one round its own axis, the other from the axis itself having a rotatory motion; the latter will gradually subside, and the projectile become steady in flight. This

[7] As in some of our own BL. R. guns, and in the German BL. R. 4-pr.

double movement is the cause of the comparatively inaccurate practice of some ML.R. guns at very short ranges.[8] If the shot be furnished with *ribs* running along the cylindrical part, or with *studs* correctly placed (their number and position depending upon the form of the shot and the situation of its centre of gravity), and adapted to *centre* the projectile, its axis will, no doubt, on leaving the bore, be practically steady.

14. As stated on page 12, the *velocity of rotation* varies with both the charge and twist of the grooves.

The velocity of rotation required by a projectile will depend chiefly upon the *initial velocity*, the *form*, and *density*, and *distribution of the material*, of the shot, and also upon the *position of its centre of gravity*. As the *initial velocity* of a shot is increased, so will the *resistance of the air tending to upset the projectile be greater*.

Long projectiles require a more rapid rotatory motion than short ones of equal weight; for the resultant of the resistance of the air, which, pressing in front of the centre of gravity of an elongated shot and below the point, tends to give the projectile a rotation round its shorter axis, acts with a greater leverage as the length of the shot is increased.

It is necessary to give a flat-headed projectile a greater velocity of rotation than a conoidal or ogival pointed shot; for the current of air meeting the shot, instead of having merely, as with the latter forms, to pass round the pointed head, presses with the flat head upon a surface almost at right angles to the previous direction of the current, and consequently exerts a very much greater force proportionally, tending to upset the shot. This is found to be the case in practice.[9]

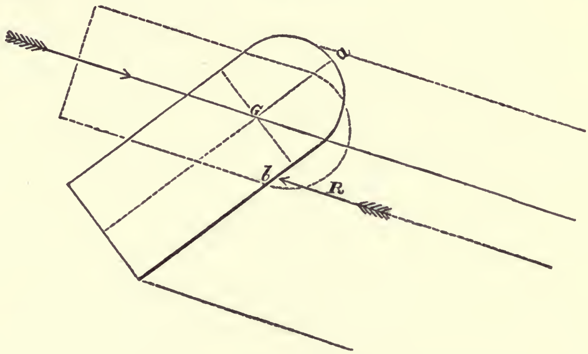
The greater the density of a projectile, the less will its

[8] This double movement was pointed out to the writer many years ago (in 1856), by Mr. J. F. Heather, of the R. M. Academy. M. Panot, in explaining the 'Theory of the Flight of the Cylindro-conical Ball,' in a work published in Paris, 1851, says: that 'the ball, instead of describing the plane curve known as its trajectory, describes a spiral around that curve without coinciding exactly with it.' *Reports of Experiments with Small Arms*, Appendix I., p. 11, by officers of the Ordnance Department of U.S. Army, 1857.

[9] The velocity of rotation given by the rifled BL. 40-pr. is not sufficiently high to keep a flat-headed shot steady during flight, except at very short ranges. See experiment described in a paper on 'The Derivation of Elongated Projectiles,' *Proceedings of R. A. Institution*, p. 180, vol. iv., quoted in Art. 18 of this Chapter.

velocity of rotation be decreased by the resistance of the air during the time of flight; as, for instance, a leaden shot would retain its velocity of rotation longer than one made of cast iron; consequently, as the densities of shot are increased, so may their respective velocities of rotation be diminished.

Fig. 100.



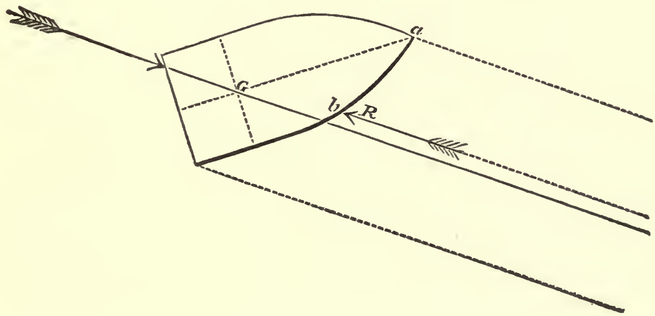
A hollow elongated projectile will be steadier during flight than a solid shot of equal weight, for the mass being distributed further from the axis, the radius of gyration is lengthened. Thus it is found in practice that elongated shells are steadier in flight than shot from the same gun, when the latter are, as in our service, of the same weight as the shells.

If the centre of gravity of a shot is very far forward, as in Fig. 100, the resultant of the resistance of the air acting at *b*, behind the centre of gravity, the hinder part of the shot would be pressed upwards, if the velocity of rotation be *very low*, so that the axis might correspond very nearly during flight with a tangent to the trajectory.

In this case (with a very low velocity of rotation), an irregular motion of the axis will generally result from the opposite tendencies of the forces which act upon the shot; the air endeavouring to press up the hind part of the shot, while the rotatory motion resists any such change in the direction of the longer axis. With the centre of gravity in this position, there is little fear of the shot turning over even with a low velocity of rotation, but in order that the axis may be stable, a rapid rotatory motion must be given to prevent any wabbling motion which might arise from the cause explained above.

Should the centre of gravity be situated near the base, a very high velocity of rotation is requisite to compel the shot to proceed point first. In Fig. 101, the pressure R of the air acting

Fig. 101.



at b, would doubtless turn up the point a, and cause the shot to rotate round its shorter axis, unless counteracted by a very rapid rotatory motion round the longer axis.

Colonel Jacob, in his remarks on the bullet he adopted, the centre of gravity of which was near the base, says: 'It has, however, a strong tendency to fly with the wrong end first, exactly contrary to the behaviour of the *Minié*; and to counteract this perversity, a great twist in the rifle grooves—giving a rapid spiral motion to the ball in its flight—is necessary.'[1]

A very high velocity of rotation is advantageous as regards accuracy of fire, but is objectionable for the following reasons:—That the strain upon the metal of the gun will be very great, as the charge must be comparatively large, and the grooves will require a sharp twist, much resistance being thereby caused to the motion of the projectile; that the projectile after grazing will deflect considerably; and that should the projectile be a shrapnel or segment shell, the pieces would spread laterally to too great a distance to be effective. It will generally be

[1] *Rifle Practice*, p. 65 (3rd edition): 'Col. Jacob latterly increased the length of the cylindrical part of his bullet, no doubt in order to throw the centre of gravity more forward.'

sufficient, as far as accuracy is concerned, to give an elongated projectile such a velocity of rotation that the axis may be stable during the whole time of flight for the longest required range, and with the lowest charge to be used; should the rotation be not sufficiently rapid at any part of the trajectory, the axis of the shot will become unsteady, and inaccuracy of fire will be the result. To determine theoretically the velocity of rotation, which ought to be given to a projectile of definite form, would be a very difficult problem, and therefore recourse must be had to actual experiment to obtain approximately the velocity required.[2]

The Deviations of Elongated Projectiles.

15. An elongated shot fired from a rifled gun is subject to a peculiar deviation termed (from the French) *derivation*, and sometimes in this country called *drift*. It is found in practice, that pointed elongated projectiles fired from rifled guns giving a *right-handed rotation*, always deviate to the *right*; and in a few cases tried with guns giving a *left*-handed rotation, the deviation is to the *left*.[3] This peculiar deviation, called as before stated *derivation*, is generally constant for the same ranges of shot fired from a rifled piece; it can therefore be allowed for in *laying* the gun, a horizontal slide being graduated and attached to the vertical tangent scale used for giving elevation.[4]

Various explanations have been given to account for the *derivation* of shot fired from rifled guns, but it will be sufficient to point out the two causes which have been assigned to account for this deflection.

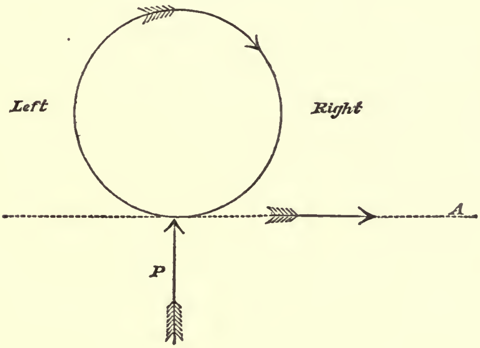
[2] The private opinion of the inventor usually decides the turn of the grooves and the charge required for his gun, upon both of which the velocity of rotation of the projectile depends; and in many cases such opinions have been derived from the observation of the results of many trials; but a long course of very careful experiments is necessary to establish laws that could be generally applied. By firing a gun a great number of times with a projectile of certain form, and altering the charge and inclination of the grooves until accurate shooting is obtained, it can be practically determined what turn and charge are necessary for this particular gun and projectile; but no general laws can by such a method of proceeding be derived. Many experiments of this kind have been made by private individuals, as Col. Jacob, Sir W. Armstrong, Sir J. Whitworth, Bart., &c.

[3] See tables of practice in paper on 'Derivation of Elongated Projectiles,' by Major Owen, R.A., *Proceedings of R. A. Institution*, vol. iv. p. 181.

[4] The *derivation* is now allowed for by inclining the tangent scale to the left.

16. Firstly.—A shot rotating rapidly, and at the same time falling in the air, will experience a greater pressure underneath than above, and will, therefore, roll as it were upon the denser air below. Thus Fig. 102, representing the section of a shot rotating in the direction indicated by the arrow, P, the excess of pressure, exerted by the air below over that above the shot, will cause the latter to roll to the right towards A.

Fig. 102.



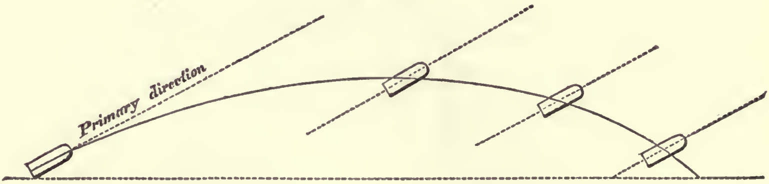
When the time of flight is short, the pressures above and below will not differ to any great extent, and it is evident that the more rapid the rotation, the greater should be the deflection (from this cause), which however is not found to be the case in practice. This cause may operate in part to produce the *derivation* with pointed shot, but will not account for several observed facts: as, besides the discrepancy noticed above, it is found in practice that flat-headed shot do not deviate in the same direction as pointed projectiles fired with the same rotatory motion.

Secondly.—When an elongated projectile is fired from a rifled gun it leaves the bore rotating rapidly round its longer axis; and if the initial velocity were *very low*, the projectile experiencing but slight resistance from the atmosphere, the longer axis would remain (as in vacuo) during the whole time of flight parallel or nearly so to its primary direction, as shown in Fig. 103. That this is the case may be clearly seen by firing small wooden shot with velocities of from 10 to 20 ft. per second.[5]

In explaining the complicated effect produced by the resistance of the air upon an elongated projectile moving with a *high* velocity, the projectile will be supposed to have what is termed a *right-handed* rotation; that is to say, the upper part turns from left to right, with reference to an observer placed behind the gun (as in Fig. 102); for the direction of the grooves of rifled pieces are almost invariably made so as to give such rotation.

After the projectile has left the bore, the resultant of the resistance of the air (as already explained) will, unless the centre of gravity be very far forward, act upon a point in front of the centre of gravity and below the longer axis, at all angles of

Fig. 103.



elevation given in practical gunnery. Now the effect produced by this pressure will depend chiefly upon the form of the head of the projectile; therefore, in the first place, the effect upon a pointed head will be considered, and, secondly, that upon a flat head.

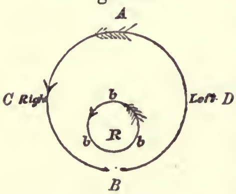
Before, however, proceeding, it will be as well to remind the reader of the enormous force exerted by the resistance of the air upon a projectile when moving with a very high velocity. The amount of resistance opposed by the air to elongated projectiles of different diameters at varying velocities may be seen in Table XX. in the Appendix.

17. If Fig. 96 represent the elongated projectile of the

[5] I have frequently shown this by firing such shot from an instrument contrived for me by Mr. Colbrook, Modeller of the R. M. Academy, Woolwich. The respective right and left deflections of pointed and flat-headed elongated *paper* shot projected with right-handed rotation can also be shown by the same instrument.—C. H. O.

gyroscope, it will be found that a pressure, *R*, exerted anywhere between *a* and *b*, will, as explained in Art. 10, raise the point *a* (when the projectile is not rotating), or, in fact, will produce a similar effect to an upward pressure exerted at the point *E*. Supposing, however, the projectile to be rotating rapidly in the direction indicated by the arrow in Fig. 104, and the pointed end is *facing* the spectator; then, if a pressure be exerted at *B* (corresponding to *E* in Fig. 96), the point of the projectile will not rise (at least perceptibly), but will move laterally in the direction *C*, that is to the right with reference to an observer behind the gyroscope; if a pressure be exerted at *D* (Fig. 104), the point will fall; if at *A*, the point will move laterally in the direction *D*, or to the left, with reference to an observer behind the gyroscope; lastly, if a pressure acts upon the rotating body at *C*, the point will rise. Now, should a pressure be exerted on any intermediate part of the circle *ACBD*, as for instance between *B* and *D*, then the motion of the point of the projectile will be compounded of the motions caused by respective pressures at *B* and *D*, that is to say, the point will move laterally to the right (with reference to an observer *behind* the gyroscope) and droop at the same time. If a strong blast of air be directed upon the fore part of the rotating projectile, the centre of the current being a little below the point, but in the same vertical plane with it, as shown by the dotted lines in Fig. 96, so as to represent the resistance of the air to a projectile moving with a high velocity, the pointed end will first move slowly to the right (towards *C*, Fig. 104), effects being afterwards successively produced by the blast similar to those which would be caused by a pressure acting gradually round the circle *ACBD*, as already described. In fact, the part of the axis in front of the centre of gravity will describe a cone, the point of the shot moving round in a circle, while the centre of gravity remains at rest. The rotation being in this case *right-handed*, the circle will be described from *right to left*, the line of pressure *R* passing through the centre of the circle; this movement of the point in a circle *bbb* is shown in Fig. 104, the spectator here looking at the point. The reason for the point of the projectile moving as described may be thus explained: Poinsot showed, in his 'New Theory of the Rotation of Bodies,' that 'rotatory motions about different axes which intersect in a point are compounded exactly by the same law as the simple forces applied at this point.' Thus the rifling gives the projectile rotatory motion about its long axis, while the resistance of the air tends to impart a rotatory motion about its short axis, intersecting the former and at right angles to it; the shot rotates therefore about an axis between the two others (diagonal to them), and passing through their point of intersection. If pressure be exerted *behind* the centre of gravity instead of *in front*, or on the fore part of a projectile rotating with a *left-handed rotation*, the above effects will be reversed.

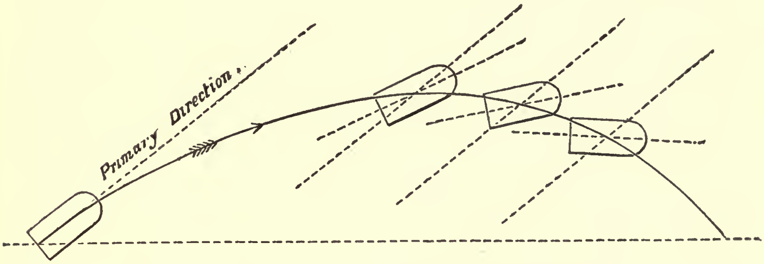
Fig. 104.



To apply these observations practically. If a pointed projectile (Fig. 96), having a right-handed rotation, be fired with a high velocity, the resultant of the air's resistance *R*, which would tend to raise the point if the projectile be not rotating, will, it must be evident from what can be observed with the gyroscope, give the point *a* a lateral movement to the right. As this lateral movement of the point proceeds, so will the resultant act more and more to the left of the vertical plane, passing through the longer axis of the projectile, and therefore, as with the blast or the pressure acting on the gyroscope in Fig. 104, between *B* and *D*, the point will soon begin to droop. In fact, there is no doubt but that the longer axis of an elongated shot does not remain parallel to its primary direction, when the *velocity is high enough* to create considerable resistance; but the point of the shot will first move to the right, then downwards, still keeping to the right, and describing a portion of the circle, the continuance of the motion depending upon the *time of flight* and the *velocity maintained.* As the velocity becomes low the circular motion of the point will gradually cease; but in practice during the few seconds of flight, which generally elapse, as the velocity is pretty high throughout, there is probably sufficient time and pressure not only to turn the point to the right, but to bring it down nearly on to the trajectory. It is not intended here to maintain the popular notion, that the longer axis of an elongated shot remains during flight continually a tangent to the trajectory, for this cannot possibly be correct, except in the case of the shot having its centre of gravity, as in an arrow or rocket, very near the fore end. Practically, however, on account of the drooping of the point, the longer axis may throughout a considerable portion of the time of flight approximate *very nearly* to a tangent to the trajectory, as in Fig. 105.

Those who deny that there is any circular motion of the point of a shot moving with a very high velocity, must be

Fig. 105.



prepared to assert that the enormous pressure of the air's resistance produces the same effect whether it acts against the point or any other part of the head, which would certainly be contrary to all received mechanical principles.[6]

The point of an elongated shot fired with a right-handed rotation being turned to the right by the resistance of the air, this resistance will act obliquely on the shot, and cause *derivation* to the right. Here then is another cause, independently of the rolling effect before described, for the peculiar deflection of elongated projectiles fired from rifled ordnance.

The motion of the point of an elongated shot, and the consequent *derivation* arising from this motion, have been pointed out by Professor Magnus, of Berlin. He says: 'We deduce

[6] The motion of elongated projectiles in the air has been treated mathematically by General Mayevski in a paper entitled 'De l'Influence du Mouvement de Rotation sur la Trajectoire des Projectiles oblongs dans l'Air,' inserted in the *Revue de Technologie militaire*, tom. v. 1865. Paris et Liége.

then from these experiments (with the gyroscope), that the deviation of elongated projectiles arises from the fact, that the resistance of the air has a tendency to raise their points. It is true that this raising is hardly sensible to the eye, because the forces which act upon the mass of the projectile are combined in such a way that the point, instead of being lifted, only moves on one side, and always to the right in the case of *right-handed* rotation.

'Consequently, the projectile assumes an oblique position to the direction of the air's resistance, and is thereby in its further progress depressed on the side towards which the apex is turned, while the air's resistance acts against it as against an inclined plane, and thus produces the deviation.'[7]

Before proceeding to notice the effect of the air upon a flat head, it will be better to illustrate the preceding remarks, explaining the cause of derivation, and the drooping of the point of a shot during flight, by stating some of the results of practice. The following experiment was, at the suggestion of Professor Magnus, made by a Royal Commission appointed to carry on artillery experiments at Berlin.[7] A number of projectiles were fired with a charge and consequent velocity so low that an observer could follow them with the eye, and even note with accuracy the position of their axes; the following were the results obtained:—

(1) 'All the observers stationed at intervals along the range unanimously agreed, that the axis of the projectile during the whole time of flight remained *nearly tangential* to the trajectory, but nevertheless that, in the descending branch, it was easily seen that the point of the projectile was a *little higher* than could have been the case had the axis remained *accurately tangential* to the trajectory.'

(2) 'It was also admitted by all that, as much from the motion of the projectiles as from the furrows made in grazing the ground, in all the rounds fired, the point of the shot at the instant of touching the ground had a deviation to the right' (as shown in Fig. 106).

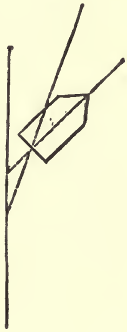
[7] *Magnus on the Deviation of Projectiles*, Berlin (1860), second edition.

[8] *Ib.*; *Occasional Papers of R. A. Institution*, vol. i. p. 443

'It follows from the results of these direct observations that, during the motion of translation of an elongated projectile, the axis does not only not agree exactly with the tangent, but that it makes a certain angle with the vertical plane drawn through this tangent, and that the deviation thus arising from this is to the right.'

Many who are constantly employed in noticing the flight of shot assert most positively that when the velocity is not too high, they can clearly see the projectiles descend with their points downwards. It is difficult to say whether this is a mere optical illusion, but the effects, on targets, which can be examined at leisure, are more satisfactory evidence than that of the mere view of a shot during flight. Now it is almost invariably found that the holes made in targets are circular, even when elongated shot descend at considerable angles; for instance, some 40-lb. shot fired at 7° and 10° of elevation, the angles of descent for which would be about 9° and 13° respectively, cut circular holes out of vertical targets made of thin wood covered with sheet lead. The most probable explanation of this fact must evidently be that the point of the shot had drooped during flight, so that, on striking, the longer axis was nearly perpendicular to the plane of the target. It would doubtless be most difficult to ascertain the exact position of the longer axis of a shot at any particular part of the trajectory, but this is hardly wanted; for if at ranges generally required we can be pretty sure that the point will droop so as to allow the shot to strike nearly point first, there need be no fear but that the necessary practical results will be obtained. This drooping of the point is of importance, for did the axis remain parallel to its primary direction during flight, the projectile would, most probably, when fired at any but a very low angle, on striking an object of hard material and solid structure, as a wall, &c., turn up against it lengthways, and therefore produce but trifling effect.

Fig. 106.



This has not, however, been found to take place in the experiments hitherto made, but, on the contrary, the penetrations of elongated shot at considerable ranges are always remarkably great. There is little fear of shot turning up against an object unless the velocity both of translation and rotation be very low, and the angle of fire very high.[9]

18. The effect produced on a cylindrical or *flat-headed* projectile will now be noticed. A pressure exerted upon the head and below the longer axis, as R in Fig. 97, will, as before explained (Art. 10), when the projectile is not rotating, cause the head to droop, or will produce an effect similar to a downward pressure acting at C; just the opposite to what is observed with a pointed shot. Now if a pressure be exerted, or a current of air be directed, upon a flat-headed shot, having a rapid right-handed rotatory motion, the centre of the front end will describe a circle, but from *left to right*, instead of from right to left, as with the conoidal head; a conical motion of the axis will take place, but in the contrary direction, arising from the resistance of the air tending to depress instead of to raise the head as with the pointed shot. From this it might be supposed that the *derivation* of flat-headed shot would be to the *left* instead of to the right, or at any rate that it would be *more to the left* than that of the pointed projectiles.

That this is really the case may be seen by an examination of the annexed Tables of Practice:—

The gun was fitted with new-pattern sights, and no allowance given for deflection, the axis of the piece pointing therefore along the range on both days.[1]

[9] From the fact of the rotation imparted to a projectile giving its longer axis stability, it was at first almost universally admitted that this axis remained during flight parallel to its primary direction, as in Fig. 103; and this idea appeared to be borne out by the assertions, that the holes made in targets by elongated projectiles were generally elliptical and not circular, and that the lower and hinder part of the shot was frequently flattened by the graze, thus showing that the hind part of the shot must have touched the ground first. These holes in targets are, however, seldom elliptical; also, the instances of shot flattened behind are rare, and this flattening may probably be produced by the ground when the point of the shot is rising from the graze. As before observed, the axis of a shot would remain parallel to its primary direction if the projectile was opposed by only a very slight resistance, but the enormous force exerted by the air against a shot moving with a high velocity must produce some motion of the point, unless the force acted directly upon the point and through the long axis, which it cannot do in ordinary cases.

[1] The tables and the remarks on them are extracted from Major Owen's paper

TABLE I.

REPORT OF PRACTICE. SHOEBURYNESS, APRIL 9, 1864.

Barometer, 30·3 in.
Wind—South-east, 2.

Direction of wind.

No. of round	Elevation	Projectile: Nature	Projectile: Mean weight	Time of flight	Range	Deflection: Left	Deflection: Right	Remarks
	°		lbs.	sec.	yds.	yds.	yds.	
1	2	Special shot (flat-headed) Centre of gravity towards point	47·0	2·9	890	2	—	/
2	,,		—	2·9	899	2·4	—	<
3	,,		—	3·0	900	4	—	/
4	3		—	4·2	1234	2	—	These shots were unsteady.
5	,,		—	3·9	1149	2·6	—	
6	,,		—	4·0	1215	2	—	
7	4		—	5·0	1396	4	—	
8	,,		—	5·2	1456	4·4	—	
9	,,		—	5·0	1398	2	—	
10	,,	Service shot (cylindro-conoidal)	41·5	5·4	1795	line		/
11	,,		—	5·3	1751	line		/
12	3		—	4·0	1432	·4	—	/
13	,,		—	not obs.	1387	line		/
14	2		—	3·0	1014	line		/
15	,,		—	3·3	1024	·4	—	/

TABLE II.

REPORT OF PRACTICE. SHOEBURYNESS, APRIL 18, 1864.

Barometer,
Wind—South, 2.

Direction of wind.

No. of round	Elevation	Projectile: Nature	Projectile: Mean weight	Time of flight	Range	Deflection: Left	Deflection: Right	Remarks
	°		lbs.	sec.	yds.	yds.	yds.	
1	2	Service shot (cylindro-conoidal)	41·5	3·1	1018	8	—	/
2	,,		—	2·9	1014	1·6	—	/
3	3		—	4·2	1407	1·2	—	/
4	,,		—	4·0	1364	—	4	/
5	4		—	5·3	1755	—	2·2	/
6	,,		—	4·2	1706	—	1·6	/
7	,,	Special shot (flat-headed) Centre of gravity towards base	47·0	4·6	1362	8	—	\
8	,,		—	4·6	1336	10	—	\
9	,,		—	4·5	1369	7·4	—	\
10	3		—	3·6	1093	6	—	Broken on graze.
11	,,		—	3·9	1145	5	—	/
12	,,		—	3·7	1094	12·6	—	\
13	2		—	2·8	830	4·6	—	\
14	,,		—	2·8	821	4·4	—	/
15	,,		—	2·8	855	1·2	—	/

The following were the mean deflections obtained on April 9, Table I.:—

	2° yds.	3° yds.	4° yds.
Service shot	·2 left	·2 left	line.
Special shot (centre of gravity towards point)	2·8 left	2·3 left	3·46 left.

The mean deflections on April 18, Table II., were—

	2° yds.	3° yds.	4° yds.
Service shot	1·6 left	1·4 right	1·9 right.
Special shot (centre of gravity towards base)	3·4 left	7·8 left	8·46 left.

On both days the wind blew from right to left, and will account for some of the service shot having a slight deflection to the left; every one who has seen much practice is aware that the right deflection of the service shot is hardly sensible at low angles of elevation, and that a little wind blowing from right to left is sufficient to counteract it.

No. 1 round with service shot, Table II., has been purposely omitted, for the deflection 8 yds. left is evidently a very wild one, there being no such eccentric graze (at 2°) recorded in the practice returns given in Tables I. and II., or in numerous other practice returns examined.

On April 9, Table I., it was noticed that at 2° the special shot were steady during flight; at 3° they were unsteady near the end of the range; and at 4° they were unsteady for some distance before grazing. As might have been supposed, the left deflections of the special shot with preponderance behind were greater than those of the special shot with preponderance in front.[2]

19. The results of the experiments have then established the following facts:—

(1) That elongated projectiles with rounded or pointed heads deflect to the *right* at ordinary ranges when fired with *right-handed* rotation.

on the 'Derivation of Elongated Projectiles,' *Proceedings of R. A. Institution*, vol. iv. p. 185. The practice was made at the suggestion of the writer of this work. It was not intended to ascertain the amount, but merely the direction, of the derivation of flat-headed shot, and thus to test the explanation of Professor Magnus respecting the cause of derivation of elongated projectiles. The gun did not give sufficient rotation for flat-headed shot, hence the difficulty of selecting suitable ranges for comparison of respective derivations.

[2] That the *amount* of the *derivation* is probably influenced to some extent by the position of the centre of gravity would appear from the above statement; to establish this point, however, a number of shot of similar form, but having their centres of gravity in different positions, should be fired.

(2) That similar projectiles fired with *left-handed* rotation deflect to the *left*. (See Art. 15.)

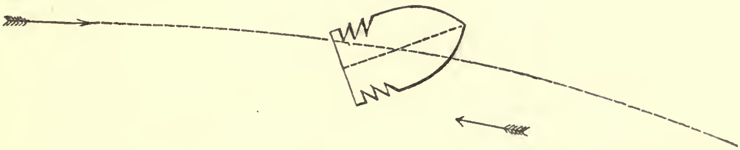
(3) That the *derivation* of cylindrical or flat-headed projectiles is in the opposite direction to that of projectiles with rounded or pointed heads, fired with similar rotation; for instance, if a cylindro-conoidal and a flat-headed shot be both fired with *right-handed* rotation, the *derivation* of the former will be to the *right* and the latter to the *left*.[3]

(4) That the *derivation* of ordinary service shot fired from the 40-pr. BL. R. gun is hardly sensible at 1,000 yds.; for it may be seen from Tables I. and II. that a slight breeze from right to left was sufficient to counteract the tendency of the shot to bear off to the right. It also appears from the tables that flat-headed shot require a very much higher velocity of rotation than cylindro-conoidal projectiles, and that the former lose their velocity very much sooner than the latter.

Professor Magnus first pointed out the effect of the resistance of the air upon a flat-headed or cylindrical shot, and after stating that their derivation would most probably be to the left, he says: 'I understand that experiments have already been instituted with such cylindrical projectiles, and their results have confirmed this conjecture.'[4]

[3] In order to overcome the *derivation*, and to keep the axis of the projectile tangential during the whole time of flight to the trajectory, M. Tamisier placed several grooves (cannelures) round the cylindrical part, so as to give a greater surface for the resistance of the air to act upon behind the centre of gravity of the bullet, and a tendency to bring down its point upon the curve of the trajectory; if the point falls below this curve, the resistance then acting above would tend to raise the point (Fig. 107).

Fig. 107.



These grooves were said to decrease but not to overcome the *derivation* of the bullet. *Reports of Experiments on Small Arms*, Appendix I., p. 13, by Officers of the U.S. Army.

[4] *Magnus on the Deviation of Projectiles*, second edition. Several of the remarks and diagrams in this Chapter have been taken from a small work, *On the Motion of Projectiles fired from Rifled Ordnance*, by the writer of this work.

CHAPTER VI.

THE PENETRATION OF PROJECTILES.

1. The penetration of a projectile depends upon a variety of circumstances, such as its velocity at the moment of impact, its weight, form, diameter, the material of which it is made, the nature of the object struck, and the relative position of this latter with regard to the trajectory of the projectile.

When a projectile strikes an object, it will penetrate until its *accumulated* or *stored-up work* is destroyed. This *work* will be expended not only in penetrating, fracturing, or producing vibration in the material of the object, but, when the latter offers great resistance, in breaking up or changing the form of the shot.[1] The terms *work* and *penetration* must not be confused; for instance, a cannon ball would easily penetrate a wall in which a battering ram, having the same amount of *work* as the ball, would only produce vibration.

2. The penetrations of spherical projectiles will first be considered. The area presented by a ball may be taken as equal to that of its great circle; if then $R=$ the mean resistance per square inch offered by the object throughout the penetration, $r=$ the radius of the shot, and $p=$ depth of penetration,

$$R\pi r^2 \times p = \text{total resistance to be overcome by shot.}$$

[1] The development of heat in both object and projectile, when a shot strikes an iron plate, is a question of great interest. See Tyndall's *Heat considered as a Mode of Motion*, p. 40.

The formula for *accumulated work* being

$$PS=\frac{wv}{2g},$$

where $P=R\pi r^2$,

and $S=p$, the space penetrated

$$R\pi r^2 p=\frac{wv^2}{2g},$$

$$\therefore p=\frac{wv^2}{2R\pi r^2 g}. \quad \ldots\ldots\ldots\ldots \quad (1).$$

Let δ = weight of a cubic inch of the material of the shot,

then $w=\frac{4}{3}\pi r^3\delta$,

$$\text{and } p=\frac{4}{3}\frac{\pi r^3\delta v^2}{2R\pi r^2 g}$$

$$=\frac{2}{3}\frac{r\delta v^2}{Rg}. \quad \ldots\ldots\ldots\ldots \quad (2).[2]$$

R, which will vary with the nature of the material fired at, whether wood, masonry, or other substance, must be found by experiment. When the resisting material is the same

P varies as $r\delta v^2$,

or the penetration is proportional to the diameter and density of the shot, and to the square of its velocity on impact. So that the larger the diameter of the ball, and the greater its density, the deeper will be the penetration, especially as the *final velocity* for the same *initial velocity* will be higher. For instance, a 68-pr. solid shot of 7·9 in. diameter fired with an initial velocity of 1,579 ft. will penetrate a clay butt at 1,060 yds. range to a depth of about 20 ft., but a 32-pr. solid shot of 6·1 in. diameter, and having an initial velocity of 1,618 ft., will only penetrate the same butt at an equal range to a depth of 13 ft.; again, if, instead of the shot weighing 66 lbs., a shell weighing 50 lbs. be fired from the 68-pr. with the same charge, and at the same butt and range, its penetration will be only

[2] This formula, although answering for low velocities (up to 300 feet), gives too great penetrations for high velocities; it is, however, sufficiently accurate for the deduction of the simple laws stated below it.

14 ft. 10 in., although its *initial* velocity is about 1,800 ft. per second. When shot of the same density are fired into the same material

$$P \text{ varies as } rv^2,$$

or with the diameter of the shot and the square of its velocity on impact.[3]

3. The penetration of an elongated projectile is greater than that of a ball of equal weight, when both are fired with the *same initial* velocity, for the former presents a *less area* to the resistance of the object, it can have a *pointed head*, and it will have a greater *final velocity*, being less retarded during flight. In general, however, an elongated projectile is fired with a lower initial velocity than a ball of equal weight from a smooth-bored gun, and therefore at a short distance the latter will most probably produce more effect as regards penetration than the former; but as the range is increased, so will the penetrating power of the elongated projectile be greater compared with that of the ball, for the former will maintain its velocity much longer than the ball. It is only at very short ranges, such as 500 or 600 yds., that the fire of a smooth-bored gun is sufficiently accurate to allow of a comparison of its results with those obtained from practice with a rifled gun; beyond such ranges the accuracy of a smooth-bored gun cannot be depended upon, and the total effect produced by a number of balls upon an object would most likely be inconsiderable; but with a rifled gun the blows of its elongated projectiles can be repeated on the same part of the object at much longer ranges, and a wall or side of a ship could therefore be battered with effect at ranges where balls would be practically useless.

It is difficult to obtain the results of practice from rifled and smooth-bored ordnance, which can be accurately compared, the circumstances (charge, weight of shot, nature of target, &c.) under which the experiments have been made usually differing so widely; but the above remarks are confirmed by the cases stated below. 12-pr. elongated shot fired with a

[3] Tables of the penetrations of projectiles, both spherical and elongated, into different substances are given in Chapter VIII. and in the Appendix.

charge of $\frac{1}{8}$th from a rifled gun (Armstrong) penetrate into solid oak—

40 in.	at	400	yds. range.
35 in.	„	1,200	„

Now 12-pr. balls fired with a charge of $\frac{1}{3}$rd from a SB. piece penetrate into similar material—

43 in.	at	109	yds. range.
32 in.	„	438	„
$14\frac{1}{2}$ in.	„	1,094	„

It may be observed, from these figures, that the penetration of balls fired from the SB. gun diminishes rapidly as the range increases, but the penetration of the elongated shot is only in this case decreased about $\frac{1}{8}$th when the range is trebled. At the Eastbourne experiment the penetrations of 40-pr. elongated shot varied from 3 ft. 11 in. to 5 ft. 5 in., while those of 68-pr. round shot fired at Bexhill under similar circumstances were only from 13 to 23 in.; several 68-pr. shells fired at the latter place penetrated 24 in.; and one blind shell as far as 35 in.; but this latter was evidently an exceptional instance.

An elongated 40-pr. solid shot, 4·75 in. in diameter, fired with a charge of 5 lbs., giving an initial velocity of 1,164 f. s., penetrates a clay butt, at a range of 1,060 yds., to a depth of 14 ft. 9 in.; a 68-pr. spherical shell, 7·925 in. in diameter, fired with a charge of 16 lbs., giving an initial velocity of 1,809 f. s., penetrates the same material at the same range to a depth of 14 ft. 10 in. Thus, although the former weighs 9 lbs. less than the shell, and is fired with a lower velocity by about 645 f. s., it penetrates to about the same distance as the spherical shot.[4]

[4] Respecting the very great penetrations obtained with the elongated projectiles, the late Ordnance Select Committee, in one of their Reports, made the following remarks: 'The increased penetration of the rifled projectiles is in a far higher ratio than theory would assign to them. It is plain, therefore, that we must look for some other cause than their superior *vis viva*, and this is furnished by their rotation on their longer axis. The 6-in. projectiles leave the muzzle of the gun spinning at the rate of about 63 turns per second. It is not probable that this rate diminishes as fast as the motion of translation. It will be very little reduced in 3 or 4 seconds, or at 1,032 yds., and must materially aid penetration.'—*Proceedings of R. A. Institution*, vol. ii. p. 407.

Even at short ranges (not at close quarters) the elongated projectile has necessarily a great advantage, both as regards the *energy* or *stored-up work* and the depth of penetration, when fired with equal or proportional charges. This is clearly shown in the following results of practice against iron plates at a range of 200 yds.

Gun	Projectile (steel)	Charge	Initial velocity	Effect against a *Warrior* target
	lbs.	lbs.	f. s.	
SB. 9-in. of 125 cwt.	104 (Spherical)	25	1,653	Penetrated the outside plate, but stuck in the backing
R. 7-in. of 134 cwt.	104 (Elongated)	25	1,625	Completely perforated the target

4. The theory of the penetration of elongated projectiles into solid substances has been treated in an elaborate mathematical memoir [5] by General Mayevski, a member of the Russian Artillery Committee. The complicated analytical investigations in this memoir would require too much space for insertion in these pages, nor do they come within the scope of a work intended, as stated in the preface, to deal simply with principles and the deductions from the more advanced mathematical problems; but some of the conclusions arrived at will be briefly noticed and compared with the results of practice.

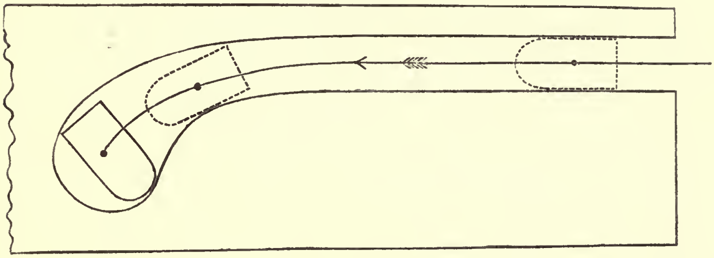
After examining the movements of translation and rotation while the projectile is penetrating a solid medium, General Mayevski gives a diagram to illustrate the respective positions of the shot at different parts of its passage, until it has gradually turned, so that the pointed head faces towards the entrance of the perforation made in the substance fired at.

The final position of the projectile will depend upon various circumstances, but for similar conditions of final velocity, form of head, and of substance, it would probably be about the same for a large number of rounds. This turning round of

[5] *De l'Influence du Mouvement de Rotation des Projectiles oblongs sur leur Trajectoire dans les milieux solides*, vol. v. *Revue de Technologie militaire*, 1865. A very able summary of this memoir, with explanatory remarks and illustrations from practice, was given in the *Engineer* of January 4, 11, 18, and 25, 1867, by Mr. R. Mallet, M.I.C.E., F.R.S., &c.

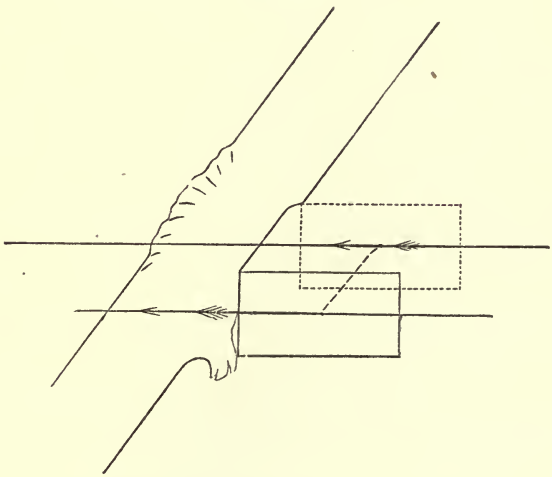
the head of a pointed [6] elongated projectile after penetrating earth or concrete, has been constantly observed at Woolwich, Shoeburyness, and other practice grounds, the axes of some projectiles having turned through an angle of 180°, others through 90° or less (Fig. 108).

Fig. 108.



The respective penetrations of flat and ogival headed projectiles into iron plates are examined both for direct and oblique impact, and the following practical conclusions arrived at:—

Fig. 109.



(1) That not only is the ogival form the best for penetrating armour plates when fired normally (direct), but that it is the best for oblique fire at any angle.

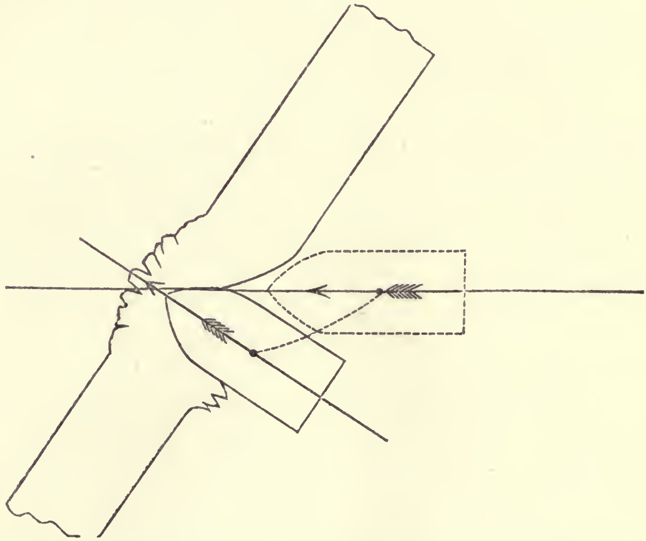
[6] The flat-headed projectiles used in proof do not turn round in the butt.

(2) That the ogival-pointed shot is much less likely to glance off in oblique fire.

(3) That ogival-pointed shot may penetrate and not glance, at angles of oblique fire more acute than half the vertex angle of the ogive; so oblique, indeed, that no spherical shot—much less any flat-ended cylinder—would have a chance of delivering anything more than a glancing blow.[7]

The respective motions of a flat and ogival headed shot after

Fig. 110.



striking an iron plate, inclined to the direction of the axis of the projectile, may be thus popularly explained:—

The flat-headed shot, on striking (Fig. 109), cuts out a portion of the face of the plate, which it carries along in front, thus increasing the thickness to be penetrated; and as the shot moves laterally, but remains nearly parallel to its original direction, the projectile has to pass through the plate obliquely, or through a greater thickness than if it struck direct with the axis perpendicular to the face of the plate.

Supposing, however, the projectile has an ogival head (Fig. 110), the point enters at first more deeply into the plate than the

[7] *Engineer*, January 25, 1867, p. 73.

flat head, and the centre of gravity moving forward, the projectile turns round more readily than with the latter, so that its axis becomes perpendicular, or nearly so, to the face of the plate, having then only the least thickness to penetrate.

Mr. Mallet points out that, if the angle of incidence be greater than half the angle of the ogival head, the shot 'at once digs its point into the iron and tends to turn. But it is to be also remarked, that a projectile whose angle of incidence may be equal, or even rather less, than half the angle of an axial section of the ogive, *may* turn, dig its point into the iron, and, although originally what may be called, from the obliquity of the line of fire, a glancing shot, may ultimately penetrate the plate.'[8]

5. That the penetration of an elongated projectile is influenced by the form of its head, has been shown by experiment, many different forms of head—flat, stepped, hemispherical, conoidal, and ogival—having been tried in this country since 1861. The flat head has been strongly advocated on two grounds—1st, because it is asserted to be a better form for *punching*[9] than any of the pointed heads; 2nd, because it is also asserted that it will *bite* into an iron plate at such an oblique angle as would cause a pointed head to merely *glance*. But the truth of these assertions has not been admitted by those who have carried on the experiments in this country against iron defences. In the Report of the Special Committee on Iron, 1861–64, it is stated 'that conical-ended shot are superior in accuracy and range over flat-ended projectiles, and that, except perhaps for oblique firing, they are also superior for penetration.'

A later report[1] contains the following remarks on this point :—

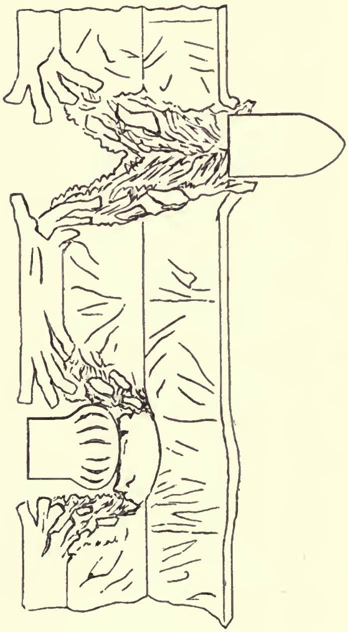
[8] *Engineer*, January 25, 1867, p. 73.

[9] Mr. Fairbairn, however, found by experiment 'that the indentation made by a round-ended punch is nearly three and a half times as great as that made with a flat-ended punch, and deduced that the work done is twice as great in the case of the round-ended shot as compared with those of the flat-ended.'—Paper on the Results of Experiments against Iron Armour, by Capt. Harrison, R.A., *Proceedings R. A. Institution*, vol. iv. p. 213.

[1] *Report on the Penetration of Iron Armour Plates*, by Capt. W. H. Noble, R.A., p. 16.

'The flat-headed or round-headed shot punches out a piece of the armour plate and drives it into the backing; the shot, however, has no means of ridding itself of this piece of armour plate, and consequently it has *to push it in front of it through the backing.* Thus in targets penetrated by flat-headed or round-headed shot we invariably find that *the piece of armour plate has passed through the target along with the shot.* It is needless to remark that this piece of jagged armour plate must greatly increase the resistance which the shot meets in passing through the backing. When, however, the shot is of the form of a pointed ogival, the results of its action are far different; this projectile cuts through the armour plate, or rather tears through, and the plate is bent back, and forced into the backing round the edge of the hole; the shot thus passes through the backing without carrying any jagged armour in front of it.' (See Fig. 111.)

Fig. 111.



There is another disadvantage which the blunt-headed form labours under, viz. the tendency to *set up* or bulge at the head, and this result is often very marked. A pointed head, on the contrary, does not *set up* to anything like the same extent, and almost all those which have been fired have preserved their points intact after passing through the plates.

On the whole, it may be said that in the case where the projectile ought to be capable of piercing the plate or target there is little difference between the effects of a flat head and a hemispherical head; but when the target is beyond the power of the shot the hemispherical head makes the deepest indent.

This is clearly shown in the case of the experiments with the wall piece at a 4·5-in. unbacked plate, and 12-pr. Armstrong and Whitworth guns at the Scott-Russell target. In every case where the target could not be penetrated the round gave a deeper indent than the flat head. The results of many other experiments might be quoted to show the inferiority of flat-headed projectiles for penetration when the fire is direct.

In an experiment with a 7-in. ML. R. gun firing steel projectiles of 115 lbs., and 22 lb. charges, against 6-in. plates backed by 18-in. of teak and a skin of two ½-in. plates, hemi-spherical-headed shot failed to penetrate, but the ogival head passed completely through the whole, 'with some remaining force left;' some chilled projectiles were also fired, the elliptical or blunt-headed shot failing to pierce the target when that with an ogival head penetrated completely.[2]

It is difficult to obtain for comparison the results of practice with flat and pointed-headed projectiles of the same material fired at targets inclined to the line of the range, the former having been so little used latterly either in this country or abroad, the form being so objectionable both as regards accuracy and velocity, as already pointed out.[3] Many experiments with Palliser projectiles have, however, shown that the ogival head will penetrate when the angle of incidence is 60° or less, and the tendency of such a form to turn after striking, so as to bring the axis of the shot nearly perpendicular to the face of the plate, as predicted by General Mayevski, has been observed after experiment.[4]

6. Projectiles intended for practice at objects composed of

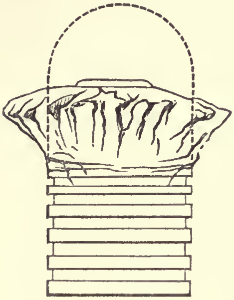
[2] Capt. W. H. Noble's *Report on Penetration of Iron Armour*, pp. 17, 18. Some chilled shot with the Belgian head (struck with radius of 1·47 diameter, and pointed in the shape of a cone) were also tried, but proved rather inferior to those with ogival points.

[3] P. 226. Mr. Mallet observes, in the *Engineer*, January 18, 1867, p. 53: 'It is quite true that Mr. Whitworth succeeded, in several instances, in punching holes with such flat-ended shot (prisms rather than cylinders) through obliquely presented plates, but this was only done by enormous velocity and disproportionate waste of power.' It must not be forgotten that the Whitworth projectiles are tapered in front, so that the flat head is of much smaller diameter than the body of the shot.

[4] See Report of experiment of September 25, 1867.

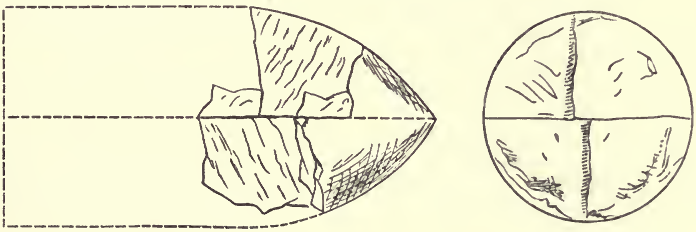
wood, masonry, or earth are made of cast iron; but, since the introduction of iron for the defence of ships and fortifications, a material possessing greater hardness than ordinary cast iron is required to overcome the resistance opposed by thick wrought-iron plates. Many experiments have been made with wrought-iron shot, which produce more effect upon iron plates than cast-iron projectiles; but wrought iron is too soft and ductile a metal, a large amount of the work which should be expended on the target being wasted on the shot, in flattening it out, or *setting it up*, as it is termed. (See Fig. 112.)

Fig. 112.



One of the best materials for projectiles intended for use against iron defences is well-tempered steel, but its great cost is a serious objection to its general employment. The Palliser projectiles were proposed to meet the difficulty, and such excellent results were obtained with them that they were adopted into the service. It has been already stated that the effect of these projectiles is due to the proper combination of material and form,[5] and that their cost is only about $\frac{1}{5}$th of that of similar steel projectiles.

Fig. 113.



It is found that chilled shot do not *set up* on impact, but the point retains its form[6]; the fracture is frequently in planes at right angles to each other, as in Fig. 113.

[5] *See* Part I., Chap. IX., § 11.

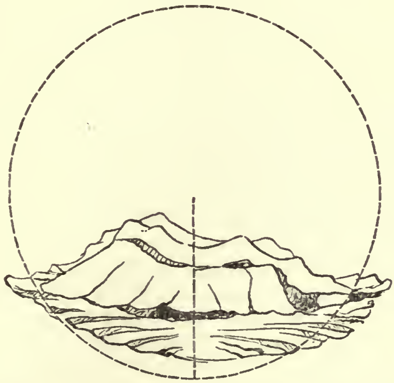
[6] When an ordinary cast-iron shot, either spherical or elongated, with a rounded

An experiment[7] on H.M.S. *Thunderer*, at Portsmouth, in 1866, clearly showed the superiority of the Palliser projectiles in direct fire, and of the 7-in. ML. R. Woolwich gun, which was lighter and fired a lighter projectile than the other pieces. The target was a 6-in. wrought-iron plate, backed by 42 in. of timber, and the range 10 yds.

Gun ML. R.	Weight of Gun	Projectile	Charge	Head of Projectile	Effect
	tons	lbs.	lbs.		in.
8-inch Shunt	7	150	30	Hemispherical (Steel)	8·25 indent
8-inch Polygonal	7	133½	20	Flat (Steel)	5·5 " 5·85 "
7-inch Woolwich	6½	114	12	Ogival (Palliser)	4·7 "
do.	do.	do.	14	do.	11 "
do.	do.	do.	22	do.	Penetrated through all

or pointed head, strikes a block of iron, a conical portion of metal is disengaged from the shot (see Fig. 114); the base of the cone is formed by the part which strikes the target first, and the axis is in the direction of the motion. Piobert thus describes the formation of this cone: 'The other parts (around and behind

Fig. 114.



the cone) of the projectile, in consequence of their inertiæ, tend to continue in motion, and if their velocity is sufficiently high to overcome their cohesion, they glide over the surface of the cone and stop when they meet the block of iron.'—*Cours d'Artillerie*, partie théorique, 1844, p. 25.

[7] *Extracts from Proceedings of the O. S. Committee*, vol. v. p. 112.

The following examples are taken from the results of experiments in August and September 1866:—[8]

Three steel and two Palliser ogival-headed shells were fired *direct* at a target of 8 in. of iron with a *Warrior* backing from a 9-in. ML. R. gun with a 43-lb. charge. The steel shell indented the target 4·5, 11·05, and 8·2 in. respectively, but both the Palliser shells penetrated the structure completely.

Two ogival-headed shot, one Palliser and the other steel, of 115 lbs. fired from a 7-in. ML. R. gun with a 20 lb. charge, at a *Warrior* target, the angle of incidence being 57°, made indentations—

The Palliser of 17 in., The steel of 6·5 in.;

and two similar projectiles, of about 180 lbs. each, fired from an 8-in. ML. R. gun, at 8-in. plates on a *Warrior* backing, the angle of incidence being 60°, made indentations—

The Palliser of 5·15 in., The steel of 2·05 in.;

and against this last target a Palliser shell from a 9-in. ML. R. gun penetrated 19·5 in., while a steel ogival-headed shot from the same gun gave an indent of only 8·25 in.[9]

7. The experiments made of late years, although numerous and costly, have not been carried out in such a manner as to afford the necessary data for establishing the laws of penetration;[1] but a few practical conclusions with respect to the pene-

[8] In these experiments the flat-headed *steel* gave deeper indentations than the ogival *steel* projectiles, but much inferior to the ogival Palliser, or the chilled shot with Belgian head, which also proved inferior to the Palliser shot.—*Extracts from Proceedings of the O. S. Committee*, vol. iv. pp. 370–376.

[9] Sir J. Whitworth has (in a Paper read before the British Association in 1869) given the results of experiments with a 3-pr. gun, to show the superiority of long shells of large capacity with flat heads over ogival-pointed service projectiles. No range is given, the ogival projectiles, unlike the service ones, are solid, and the long shells are considerably tapered, so that the flat-head, besides being rounded off, is of much less diameter than the body of the shell; but the experiments themselves disproved the statement that ogival-headed projectiles 'glance off from plane and convex surfaces when hitting diagonally,' for the two fired penetrated into the iron plate. The advantage of increased length of projectile would, however, appear from these experiments to be considerable.

[1] This has been owing to the desire to test special constructions and inventions, rather than by systematic experiments to obtain scientific results capable of general application.

tration of iron plates by elongated projectiles may be drawn from what has been done :—

(1) That the projectile should be made of *hard* material.

(2) That the *ogival* is one of the best forms of head for the perforation of iron plates.

(3) With hard projectiles the penetration is directly proportional to the *work* in the shot, and inversely proportional to the diameter of the projectile.[1]

(4) That if the plates be inclined, the effect produced upon them diminishes nearly in the proportion of *the sine of the angle of incidence to unity.*

(5) The resistance of wrought-iron plates, up to 5·5 inch, to complete penetration by solid steel shot, of similar form and equal diameter, varies as the square of their thickness, nearly.

In a paper *On the Resistance of Armour Plates*, Lieut. English, R.E., has calculated that the Palliser projectiles of the ML. R. 7, 9, and 12 (25 tons) inch guns can pierce wrought-iron plates of a thickness equal to the calibre of the gun, with a velocity of about 1,150 f. s.; those of the 10-in. gun with about 80 f. s. less. And, taking the final velocities from the Table in the Appendix, it would appear from his paper that the same projectiles of these guns can pierce plates thicker by rather more than 1 in. than the calibre of the gun at 200 yds., and rather thicker than the calibre at 1,000 yds.

8. It has been shown that the penetration of a shot depends more upon velocity than weight, and that the elongated is a better form than the spherical for mere penetration or *punching.* It must, however, be remembered that very heavy shot fired with velocities which might not enable them to penetrate or punch holes in iron armour, may still do great damage, especially if many are fired successively, by breaking bolts and shaking the whole fabric; also that a spherical shot, having a larger diameter than an elongated projectile, may often do more damage in cracking or shattering a plate than the latter in *punching* it, the *work* done by the ball being distributed

[1] See Capt. Noble's *Report on Penetration of Iron Armour*, pp. 7, 8, and 36. It is immaterial whether the *work* is made up of velocity or weight, within the usual limits which occur in practice.

over a larger area; the same argument will apply to the case of two elongated shot, having different diameters, striking a target with the same force, as measured by wv^2. Hence there were two methods of attempting the destruction of ironclad vessels when first introduced, termed respectively *racking* and *punching*.

For *racking*, heavy projectiles of large diameter are fired with low velocities, to destroy and shake off the armour by repeated shocks without penetration, and thus to expose the vessel to the effects of ordinary projectiles.

For *punching*, elongated projectiles of moderate weight are fired with high velocities, so as to perforate the armour, if near the water-line to sink the vessel, or at any other part to injure men or machinery, or explode the magazine within the vessel.

Racking was used chiefly by the Federals in the late American war, being especially adapted to their large SB. cast guns, with low charges and heavy spherical shot which lose their velocity rapidly. Some experiments were made in this country with heavy elongated projectiles and low charges, but the *racking* method was soon abandoned for *punching*, which causes more destruction, ensures greater accuracy of fire, and consequently requires a shorter time to effect the desired purpose.

9. In order to estimate the probable effect of a projectile upon an object, it is necessary to calculate the *stored-up work*, or *energy* as it has lately been termed, in the shot at the moment of impact. This may be done by the *Rule of Work:*

$$\textit{Work} \text{ or } PS = \frac{wv^2}{2g},$$

where w = weight of projectile,

v = final velocity,

g = accelerating force of gravity (32·2 f. s.).

The *punching* effects of projectiles fired at an iron target are usually compared, in this country, by calculating what is termed the *energy per inch of circumference* in *foot tons*, which is found by dividing the *total* work or energy by the number of inches in the circumference of the shot, and by 2,240 (the number of lbs. in a ton).

$$\text{Energy per inch of circumference} = \frac{wv^2}{2g \times 2\pi R \times 2240}$$

where R = radius of shot.

Example:—If a 9-in. Palliser shell fired with a battering charge at a vessel 200 yds. distant have a *final* velocity of 1,304 ft., what is the total *energy* or *work* on impact in foot tons, and the *energy per inch of circumference?*

Here,

$w = 250$ lbs., weight of projectile,

$R = \frac{8 \cdot 92}{2} = 4 \cdot 46$ inches, radius of do,

$g = 32 \cdot 2$ f. s.

$$\therefore \text{total } energy = \frac{250 \times \overline{1304}|^2}{64 \cdot 4 \times 2240}$$

$$= \underline{\underline{2946 \cdot 9}} \text{ foot tons.}$$

$$\text{and energy per inch of circumference} = \frac{2946 \cdot 9}{2 \times 3 \cdot 1416 \times 4 \cdot 46}$$

$$= \underline{\underline{105 \cdot 16}} \text{ foot tons.}$$

CHAPTER VII.

PRACTICE OF GUNNERY.

1. Different kinds of fire. Principles of Sighting: 2. Laying a gun.—3. Definitions.—4. Calculation of tangent scale. Sights for Ordnance: 5. Sights for S.B. guns.—6. Sights for BL. R. guns.—7. Sights for ML. R. guns.—8. Elevation by quadrants. Horizontal Fire: 9. General remarks.—10. Shell firing.—11. Influence of atmospheric pressure upon the burning of fuzes.—12. Rules for practice. Ricochet and Curved Fire: 13.—Ricochet fire.—14. Curved fire. Vertical Fire: 15. Laying mortars.—16. Rules for practice.—17. Time of flight.—18. Angle and velocity of descent.—19. Long ranges with vertical fire.

1. The practice of gunnery from ordnance may be divided into *horizontal* and *vertical* fire.[1] For *horizontal* fire, guns and howitzers are employed, the charges of gunpowder being generally fixed, and the ranges of the projectiles regulated by the elevation of the axis of the piece; this elevation, for any purpose, rarely exceeds 10°. Mortars are used for *vertical* fire, these pieces being usually fixed at a constant elevation of 45°, and the ranges regulated by increase or decrease of the charge. Howitzers and guns may, under certain circumstances, be employed for *vertical* fire.

The various kinds of horizontal fire may be classed as follows: *direct*, *oblique*, *cross*, *reverse*, *enfilade*, *ricochet*, and *curved*.

The four first of these terms convey their own meaning; it will only therefore be necessary to explain the others.

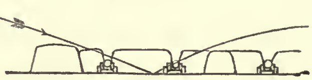
[1] These terms express the respective directions in which projectiles take effect; for instance, in either direct or ricochet fire, when it is required to strike guns, men, or works, the less curved (or more nearly horizontal) the trajectory of a projectile, the greater will be the effect produced; whereas in mortar firing vertical penetration is wanted, and consequently the shell should descend in a direction as nearly vertical as can be obtained.

In all horizontal firing, except in *ricochet* or *curved* fire, full service charges are used, as it is desirable to have a high *initial velocity*, in order that the trajectory of the shot or shell may be as nearly horizontal as possible, the chance of striking an uncovered object being then the greatest.

When a battery is placed perpendicularly to a line of troops or works, the shot from the guns raking the line, the fire is called *enfilade*, the guns being fired with full service charges.

Ricochet fire consists in placing a battery at right angles to the line of troops or works aimed at, as in *enfilade*, but, the shot having to clear a parapet which covers them, it is necessary to fire with a reduced charge and greater elevation, so as to give the shot a low velocity and a high curve, in order that it may be brought down immediately after clearing the crest of the parapet, and then, by rebounding along the face of the work, dismount the guns, or rake the line of troops under cover, as the case may be[2] (Fig. 115).

Fig. 115.



When a projectile is fired so as just to clear an interposing cover and then descend upon the object, the line of fire being perpendicular or nearly so to the front of troops or works to be destroyed, such practice is termed *curved*, or sometimes *indirect*, *fire* in order to distinguish it from *ricochet*; it must be evident that the direction of the fire with respect to the object is different from what it is in *ricochet*, and that no rebounding is necessary in *curved fire*, but that the projectile must produce the desired effect on striking the object. This kind of fire has been long employed to dislodge troops posted behind cover by firing common shells from guns or howitzers, but at the present

[2] Ricochet fire has been in use since 1572, when it was employed at the siege of Haarlem. It was reduced to method and rules made for its accomplishment, in 1688, by Vauban, but was not perfected till the siege of Ath, in 1697. The introduction of this kind of fire gave a great superiority to the attack over the defence of fortresses. The above definition of ricochet fire, thus laid down and understood for more than two centuries, has not been altered, but the modification rendered necessary by the substitution of shell for shot fire will be pointed out.

day it receives additional importance, for it would probably be the only effectual way of breaching many of the covered revetments of modern fortresses. Smaller charges and higher angles would (as in *ricochet*) be required than for ordinary direct fire.

Principles of Sighting Ordnance.

2. In order that a projectile fired from a gun or howitzer may strike a required object, it is necessary to, what is technically called, *lay* the gun ; this term includes two operations—viz., first (with smooth-bored ordnance) to bring the axis of the piece into the same vertical plane with the object ; and, secondly, unless the distance be within *point blank range*, to give the axis a certain elevation above the plane, passing through the object and the axis of the piece.

As the axis of the gun is not visible, it is necessary to make use of notches or *sights* on the exterior surface, to determine practically the position of the axis. The *line of metal* is a visual line, joining the notches cut on the highest points of the base ring and swell of the muzzle when the trunnions are perfectly horizontal. This line being in the same vertical plane as the axis, it is only requisite to bring the two notches and the object into the same line to ensure the piece being properly pointed ; in allowing for wind or other deflecting causes, these notches must be brought into line with some point right or left (as the case may require) of the object.

Should the carriage, however, stand on uneven ground, which may frequently happen in the field, one trunnion will be higher than the other, in which case, the external form of the gun being conical, the above notches will not be in the same vertical plane with the axis, but in a plane inclined to it, and the shot will be thrown to the side of the lowest trunnion.

This is shown in Fig. 116, where the piece is directed by the notches at A and C, on the object B. The shot will proceed in the line DE to the right of the object B, and at a long range this deflection BE would be considerable. In Fig. 117, where there is a *dispart patch*, making FC=DA, there will be no appreciable deflection at *point blank* range from the trunnions not being horizontal, the *lines of sight* and *fire* being parallel at a distance of merely an inch or two; but when the tangent scale is raised the lines of sight and fire will still cross, as in Fig. 116.

The charge of a gun or howitzer being fixed, and the initial velocity therefore being constant, the distance to which the

Fig. 116.

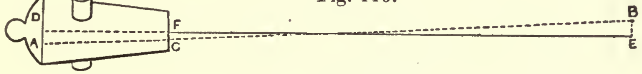
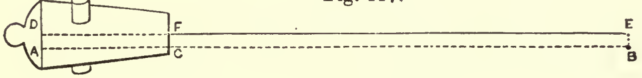


Fig. 117.



shot will range depends upon the inclination of the axis of the piece to the plane upon which the gun (on its carriage) is resting. From what has been previously said, it is evident that in firing at a given object, the axis of the gun must be directed upon a point at a sufficient vertical distance above the object to allow for the action of gravity, which causes the projectile continually to descend after leaving the bore of the piece.

The elevation of the axis of a gun is generally regulated by means of *sights*, the *tangent scales* of which are graduated in such a manner that the divisions correspond with the various ranges required from the gun. Before explaining the principle upon which the *tangent scale* is graduated it will be desirable to define a few of the terms used in practical gunnery.[3]

[3] The French have a much greater number of definitions than those in the text, but many are refinements quite useless in ordinary practice, although perhaps necessary for special scientific purposes. The following are some of the French definitions:—

Angle de mire, the same as our angle of elevation.

Angle de tir, the angle the axis of the gun makes with the horizon, as shown by the spirit level.

Angle de projection, the same as our angle of departure.

Angle de chute, the same as our angle of descent.

Angle d'incidence, the angle the tangent to the trajectory makes with the surface of the ground at the point of descent.

3. (1) The *line of fire* BD (Fig. 120) is the axis of the piece produced; it is evident that to strike the object C, the axis of the gun must be directed upon a point D, at a vertical distance above C corresponding to the time of flight required for the range, and at the end of which time the shot will be brought to C by the force of gravity.

(2) The *plane of fire* is the vertical plane passing through the axis of the gun.

(3) The *line of sight*, ABC (Fig. 120), is the line passing through the two sights (at any elevation) and the object.

(4) The *angle of elevation* of a gun is the angle which the *line of fire* makes with the *line of sight*; thus DBC (Fig. 120) is the angle of elevation.

(5) The *angle of departure* is the angle a tangent to the trajectory makes with the line of sight on the shot leaving the muzzle; this differs frequently from the angle of elevation in consequence of the muzzle being thrown up, and with windage, from the rebounding of the projectile from the top or bottom of the bore near the muzzle.

(6) The *angle of descent* is the angle made by a tangent to the trajectory with a horizontal plane, at the first graze, or at the point of impact on the object.

(7) 'The *range* is the distance from the muzzle of the gun to the second intersection of the *trajectory* with the *line of sight*. The range is not accurately the distance to the point at which the shot impinges on the plane, unless that is also the point aimed at, but the difference is practically of importance only at short distances.'[4] In practice the *range* is usually measured from the muzzle of the gun to the point of impact on the object, or to first graze of the projectile; it may be seen in Fig. 120 that the *trajectory* intersects the *line of sight* in B and C, the latter representing the centre of the object. The *range* depends upon the *initial velocity*, the *form* and

Angle d'arrivée, the angle a tangent to the trajectory makes with the horizon at the height of the crest of the parapet or object to be cleared.

[4] This definition is taken from a paper 'On the Determination of Range Tables for Rifled Ordnance,' by General Lefroy, F.R.S., *Proceedings of R. A. Institution*, vol. iii. p. 27.

density of the projectile, the *angle of elevation* of the gun, and the *difference of level* between the planes upon which the gun and object respectively stand.

(8) The *deflection* of a projectile is the perpendicular horizontal distance, right or left, of the first graze, or of the point of impact on the object, from the *plane of fire.*

(9) The *dispart* is generally defined as—half the difference between the diameters of the base ring and swell of the muzzle; however, most of the *dispart sights* or *patches* are not placed near the muzzle, but on the top of the gun a little in advance of the trunnions, or, as with the rifled guns, just above the trunnion. A better definition for dispart would then be,—*half the difference between the diameters of those parts of the gun upon which the sights are placed.* The ML. R. 9-prs. (bronze or iron) have a dispart patch on the muzzle.

(10) If a gun be laid upon an object by means of the *line of metal* (there being no *dispart patch*), it is evident, from the

Fig. 118.

conical form of the gun, that the prolongation of the axis will pass over the object aimed at (Fig. 118). The elevation thus obtained is called the *line of metal elevation,* and varies in different SB. guns.

In light bronze field guns it is . . .	1°
Medium do.	$1\frac{1}{4}$°
Ordinary cast-iron guns	$1\frac{1}{2}$°
Col. Dundas' 56-pr.	2°
Monk's guns	$2\frac{1}{4}$°

(11) Guns which have a dispart sight on the top of the piece near the trunnions have what is termed a *clearance angle.* This may be defined as the angle of elevation obtained when the *tops of the tangent scale and dispart sight, and the notch on the muzzle are in line* AEF (Fig. 121). If the scale be raised above this angle, the dispart sight falls below the line

joining the head of the scale and the muzzle, and the muzzle notch must then be taken as the second point of sight.[5]

The two following definitions are given as the terms are found in books, and the last (13) is the starting point in the Range Tables for SB. guns. (See Tables in Appendix.)

(12) A gun is said to be laid *point blank*, when the production of its axis will pass through the object aimed at; a gun may therefore be *point blank*, with reference to an object, and yet have several degrees of elevation or depression with regard to the horizon.

(13) The *point blank range* of a gun is represented in Fig. 119. The gun on its carriage is fired on a horizontal

Fig. 119.

plane, the axis of the gun being laid parallel to the plane. The distance to which the shot will range in this case, before it grazes the plane at D will evidently depend, first upon AC, the height of the muzzle of the gun above the plane; and, secondly, on the initial velocity of the shot, which varies with the charge. The resistance of the air, of course, depends upon the latter. We therefore obtain the following definition, viz.—

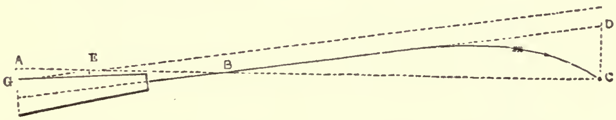
[5] The *clearance angles* of the cast-iron SB. ordnance most commonly employed for land service are as follows:—

Gun	Clearance angle
68-pr. of 112 cwt.	$4\frac{1}{2}°$
„ „ 95 „	5°
10-in. gun „ 86 „	5°
8-in. „ „ 65 „	$5\frac{1}{4}°$
„ „ 52 „	5°
32-pr. „ 58 „ } „ „ 56 „ }	4°
„ „ 50 „ (A)	5°
24-pr. „ 50 „ } „ „ 48 „ }	4°
18-pr. „ 42 „ } „ „ 38 „ }	4°

'The *point blank range*[6] of a gun is the range obtained at the first graze of the shot, when the piece placed on its carriage is fired, with the service charge, on a horizontal plane with no elevation; that is to say, when the axis of the gun is parallel to the plane.'

4. The length of tangent scale for any required elevation may be roughly calculated as follows:—

Fig. 120.



From the similar triangles AEG and DBC (Fig. 120),

AG : GE :: DC : CB.[7]

Now AG is the length of tangent scale required for the angle of elevation,[8] ∠ DBC = ∠ AEG,

and AG = GE × tan AEG.,

or

Length of scale = length between sights × tangent of the angle of elevation . . . . (1)

Should there be no dispart sight,[9]

Length of scale = length between sights × tangent of angle of elevation—dispart . . . . (2)

[6] The French definitions of point blank and point blank range are as follows: 'The second point at which the trajectory cuts the line of metal is called the "point blank" (*but en blanc*), and its distance from the piece the "point blank range;" from which it will be seen that their "point blank range" corresponds very nearly to our "line of metal elevation."' The term *point blank*, originated when it was imagined that a shot travelled for some distance in a straight line, is now of no practical use; however, both it and the term *point blank range* are given above, for, as they are constantly met with in books, it is necessary to understand their respective meanings. Gen. Lefroy, R.A., late President of the O. S. Committee, recommended that these terms should be disused. See a paper 'On the Determination of Range Tables,' *Proceedings of R. A. Institution*, vol. iii. p. 28.

[7] CB may be considered = the range, the distance BE which is very small compared to EC being neglected.

[8] See the definition of angle of elevation.

[9] When the tangent scale is not perpendicular to the axis of the piece, but

Sights for Ordnance.

5. Smooth-bored (LS.) cast-iron guns are provided with Millar's sights consisting of a *hind sight* (Fig. 122, 123) at the breech, and a *dispart or fore sight* (Fig. 124) in front of the second reinforce, the height of the latter being equal to the dispart at that part of the piece. The tangent scale (Fig. 122) of the hind sight is made of brass and fitted into a block (Fig. 123) of gun-metal, which is screwed on behind the base ring; this scale gives elevation up to the *clearance*

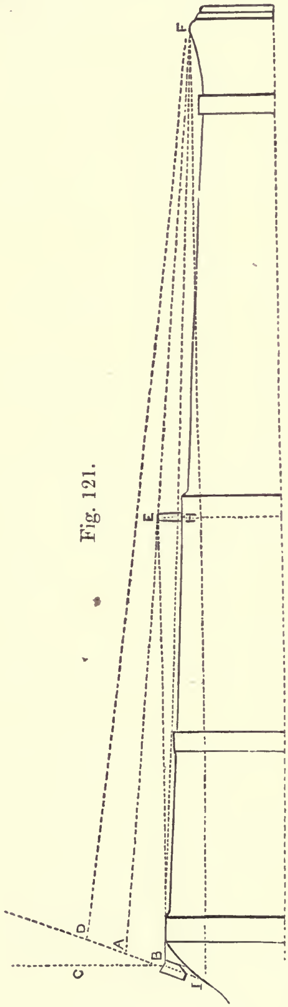


Fig. 121.

inclined to it like those of the cast-iron SB. guns (at an angle of about 76°), the length of scale may be found as follows (Fig. 121):—

Let a = angle of inclination of tangent scale,
b = given angle of elevation,
c = angle of dispart,
r = short radius,
R = long radius, or actual distance from tangent scale to muzzle sight,
x = length of tangent scale required.

Up to the *clearance angle*, that is, when b does not exceed the angle AEB,

$$x = r\frac{\sin b}{\sin\,(90 + a - b)} \qquad . \quad . \quad (3)$$

When the angle of elevation is greater than the *clearance angle*, that is when b is greater than AEB,

$$x = R\frac{\sin \text{DFB}}{\sin \text{BDF}}$$

$$= R\frac{\sin\,(b - c)}{\sin\,(90 + a - b)} \qquad . \quad . \quad (4)$$

$\text{BE} = r,$

$\text{BF} = R,$

$\text{DBC} = a.$

AEB is the *clearance angle*, which varies with the form of gun and position of *dispart sight*. When the tangent scale is raised to *clearance angle*, the top of scale A, that of dispart sight E, and muzzle notch F are in line.

angle of the gun and is graduated to the short radius, the second point of sight being the dispart sight.

The dispart or fore sight is of gun-metal, and its top is filed off to a sharp edge.

Fig. 122.

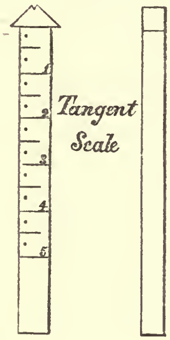


Fig. 123.

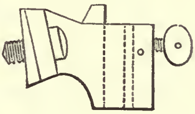
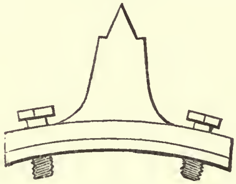


Fig. 124.



In addition to the brass tangent scale, wooden scales of two kinds are also supplied. No. 1, tangent scale is issued with Millar's sights, and is used generally for elevations exceeding the *clearance angle* of the gun. This scale is graduated up to 8°, and those divisions above the clearance angle are calculated to the long radius; for, as before stated, with elevations above the *clearance angle*, the dispart sight can no longer be seen, the notch on the muzzle being therefore taken as the second point of sight.

No. 2, wooden tangent scale is intended for those guns which are not fitted with Millar's sights, and which have therefore no dispart sight; they can be used only for elevations above the *line of metal elevation*.

The elevation as far as 3°, termed the *quarter-sights*, is cut on the sides of the base ring in SB. bronze field guns; in the 32-pr. and lower natures of SB. cast-iron guns, it commences from a notch, which, with another cut in the side of the swell of the muzzle, gives a line of sight parallel to the axis, but a little above it, so as to clear the capsquares of the trunnions.[1]

[1] Brass tangent scales of hexagonal form are used in the naval service; on the

6. All the Armstrong BL.R. guns except the 9-pr. were sighted so that the line of sight pointed to the right of the axis of the piece, in order to allow for the constant deviation (*derivation*) of the projectile to the right up to a range of about 1,200 yards. 8′ deflection was given in the sighting to the 6, 20, 40, and 110-pr. guns, and 12′ to the 12-pr.

The *left* deflection is not now given in the sighting, the sights being adjusted so that the vertical plane passing through them, when the tangent scale is down, is parallel to that through the axis of the bore; in order, however, to allow for the *derivation* of the projectile (up to 2,000 yds.) the tangent scale is inclined towards the left, at an angle of 2° 16′, and the deflection given in *laying* will therefore increase with the range.

Armstrong BL. rifled guns are provided with a *barrel-headed sight* (or new and simpler pattern) and a *trunnion sight* on each side of the piece; the former is held in either a *tangent ring* or a *socket*, according to the nature of the gun.

different faces, except one which has degrees marked on it, are the ranges in yards corresponding to different charges and projectiles, thus—

°	for degrees		
F.	„ yds.	Full.	Charges for shot.
D.	„ yds.	Distant	
R.	„ yds.	Reduced	
SF.	„ yds.	Full.	Charges for shell.
SR.	„ yds.	Reduced	

The scales are not all marked precisely in this manner, but on the same principle.

Long tangent scales of similar form made of brass are also used to give high elevations; all pivot guns are supplied with one set; but only one set, made of wood, is allowed to every six broadside guns.

A wooden tangent scale, called the *side tangent*, is used in the navy, and is held for the purpose of elevation on one of the steps of the gun-carriage; it can give 12° of elevation and 6° of depression.

The 150-pr. and 100-pr. built-up guns are provided with a barrel-headed and a trunnion sight on each side of the gun, like the 7-in. BL. rifled pieces; the tangent scale is not inclined to the left, but is vertical, there being no derivation with the projectiles of SB. ordnance. These two heavy guns are also each supplied with a hexagonal gun-metal centre sight and an iron fore sight on the top of the piece, by means of which 5° of elevation can be given.

A ship pendulum is used in the navy to ascertain the *heel* of a vessel, so that allowance may be made, in *laying* the gun, for the inclination of the deck; the pendulum vibrates through 25° on each side of the perpendicular. The angle of elevation given to a gun will vary with the *heel* as shown by the pendulum; for instance, if a gun requires 5° of elevation to reach an object and the *heel* of the ship is 8° towards the latter, 13° must be given to the piece.

All Armstrong BL.R. guns, except the 7-in., are supplied with a wrought-iron *tangent ring* (Fig. 125), which is screwed on to the end of the breech. On each side of the tangent ring is a socket, having a slot for the tangent scale, and a boss projects beyond the socket, through which a screw passes to clamp the tangent scale; the two slots are not vertical, for the *tangent ring* is adjusted[2] so that both are inclined to the left at an angle of 2° 16′, the tangent scales allowing therefore for the *derivation* of the shot as before explained. The clamping screws are made of copper.

The 7-in. guns have *sockets* instead of *tangent rings*. The socket, containing a slot for the tangent scale, fits into the side of the breech, and is prevented from turning by a projection which dovetails into the metal of the gun; the sight is provided with a separate movable clamp (see p. 290). The socket is kept down in its place by a small screw, which passes through it and into the metal of the gun.

The chief parts of the *barrel-headed sight* (Fig. 125) are the

Steel Bar.

Gun-metal { Elevating nut. / Cross head. / Two thumb-screws for moving leaf. / Leaf. }

The bar is made of steel, except for the 12-pr. and 7-in. gun of 72 cwt., which have a gun-metal bar.[4]

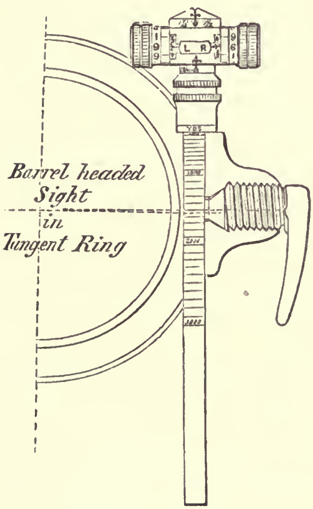
[2] Turned round from right to left, before being secured, until its horizontal and vertical axes are respectively inclined 2° 16′ to the horizontal and vertical axes of breech of gun; the sights on the right side will therefore be higher than those on the left side of the gun.

[4] These gun-metal bars are only retained because there are so many in the service. The following are the lengths of the bars for different guns:—

7-in. (both natures) .	Have 12-in. rectangular bar, graduated according to the nature of gun.
64-pr. (wedge) . .	
40-pr. „ . .	
Light 7-in. gun has a gun-metal hexagonal bar.	
20-pr. LS. . . .	10-in. special rectangular bar.
20-pr. SS. (both natures)	8½-in. rectangular bar, graduated according to the nature of gun.
9-pr. (both natures) .	
6-pr. „ . .	
12-pr.	8½-in. special gun-metal hexagonal bar.

One side of the bar is graduated to degrees, the other to yards. The degrees are divided into six parts of 10′ each; and any number of minutes up to 10′ can be obtained by turning round a graduated elevating nut on the top of the bar, which works an internal screw and so raises the head of the scale. For instance, if 2° 25′ be the elevation required, 2° 20′ is given by raising the scale in the usual way, and the additional 5′ by turning round[5] the elevating nut from 0 to 5. The tangent scale or bar is, as before explained, inclined to the left to allow for *derivation*, but it is also fitted with a horizontal scale or cross head, graduated to give ½° of deflection either to the right or left, and this ½° on both sides is subdivided into three parts of 10′ each; at each end of this slide is a graduated nut divided into minutes up to 10′, and these nuts are connected by a screw which crosses the bar at right angles. A leaf with the sight-notch slides along the scale, and can be moved right or left by either nut.

Fig. 125.



Trunnion sights are of two kinds, termed respectively *drop-sights* and *screwed-in sights*. The light 7-in. 12-pr. LS. and SS., 9-pr. and 6-pr., are supplied with the latter, and other natures of guns with the former.[6]

[5] There is a stop inside the nut to prevent its being turned completely round, for otherwise the head of the scale might be raised off the bar.

[6] One pattern *drop-sight* with hog-backed steel leaf for . .	7-in. gun 64-pr. (wedge). 40-pr. O. P. „ G.P. 20-pr. LS. „ SS.
One pattern screwed-in sight of steel with hog-backed leaf, for the .	Light 7-in. gun.
One pattern screwed-in sight of steel with hog-backed leaf, for . .	12-prs. LS. and SS.
One do. do. . .	9 and 6-pr. gun.

The *drop-sight* consists of four parts:—

Gun-metal	Socket. Collar. Pillar.
Steel . .	Leaf.

The socket fits into the gun, the collar locks into the socket, and the pillar, at the top of which the leaf is screwed, fits into the collar. The arrangement for securing the sight is a kind of bayonet joint; by lifting the collar, and making a quarter-turn from left to right with the pillar, the collar and pillar are drawn out; but without raising the collar the pillar is immovable in any direction, and must be exactly in its place. The pillar cannot be separated from the collar while the leaf is fixed.

Fig. 126.

The *screwed-in sight*, which is made of steel and has a steel leaf, dovetailed into its top, is screwed into a hole above the trunnion (Fig. 126). The leaf is hog-backed in shape, and its rear face is roughened to prevent the reflection of the light interfering with the *laying* of the gun.

7. The ML. rifled guns are provided with a *breech tangent* and *trunnion* or *fore* (*drop*) *sight* on each side of the gun, and also with a *hexagonal tangent scale* graduated to 5° and a *dispart* or *fore* (*drop*) *sight* on the top of the piece; the breech tangent sights fit into sockets let into the sides of the breech, and they are inclined to the left like those of a BL. rifled gun, but at different angles, the inclination of the sight for the 7-in. gun (both natures) being 3°, for the 8-in. 23′, for the 9-in. 44′, and for the 10-in. 1° 10′.

No more *barrel-headed* tangent sights are to be manufactured, but the existing store is to be used up. Tangent sights of the following simpler construction are now made:—

The tangent sight has the same steel bar as the barrel-headed sight; it is graduated in the same way, and inclined at the same, angle but instead of the barrel head it has a simple cross head with sliding leaf and clamping screw, which is used to move the leaf to the right or left. The cross head is graduated like that of the barrel head to give $\frac{1}{2}°$ on each side, each $\frac{1}{2}°$ being divided into three spaces of 10′. The LS. tangent sight for the 40-pr. has the graduated elevating nut.[7]

The SS. tangent sight has no elevating nut.[8]

The tangent sights of all built-up guns above the 20-pr., both BL. and ML., are in future to be furnished with separate movable clamps, which prevent the liability of their slipping down, and will admit of their being lifted out of the gun, and taken to the light for adjustment.[9]

The 64-pr. (wedge) gun has, in addition to the side sights, a *hexagonal brass sight* (tangent scale) graduated to 5° and a *dispart* or *fore* (*drop*) *sight*; the former on the top of the breech, and the latter on the top of the trunnion ring.

The ML. R. 64-pr. and 80-pr. Palliser converted guns are provided with a breech and trunnion sight on each side of the gun, but have no top sights. The breech sights are supported by sockets let into the metal of the piece as with other ML. R. guns; the scale is inclined at 2° 16′ with all the 64-pr. guns, and at 19′ with the 80-pr. The trunnion sights are drop sights; the socket is set down into a boss, projecting from a

[7] The LS. tangent sight had the graduated elevating nut, but this nut was recently abolished in sights for the 64-pr. and higher calibres. (See *List of Changes* § 2,198.)

[8] A wooden scale (for SS.) is now made for the heavy ML. R. guns to replace he side tangent scale. The scale is square in section and is placed vertically on the platform behind the gun, and against the rear face of the cascable. The different faces are graduated thus (for the 7-in. guns):—

A. Degrees.
B. Yards, shot or shell, 22 lbs. battering charge.
C. „ double shell, 14 lbs. full charge.
D. „ shot or shell, 14 lbs. full charge.

The rear face of the cascable is graduated to $3\frac{1}{2}°$ above and below zero, which is in the plane of the axis of the gun, and the scale is thus used:—

'The heel of the ship being observed, a chalk mark is made on the cascable at the degree corresponding to the heel above or below zero, as the heel is from or towards the object; the scale being then placed on the platform and applied to the cascable, the breech is raised or lowered until the chalk mark coincides with the required tabular elevation or range marked on the wood scale.'

The scales are cut to the length required for the gun with which they are used. Two are to be supplied for each revolving gun used at beam ports, one on each side. (*Changes in Patterns*, § 1,306.)

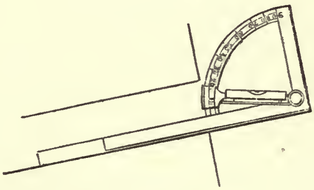
[9] *Changes in Patterns*, § 1,144.

gun-metal bracket attached to the side of the gun by two screws. A wood (side) scale is also supplied to these guns.

The ML. R. 16-pr. is sighted on both sides; each of the breech sights is graduated in yards, lengths of fuze, and degrees; each has an elevating nut, fits into a socket with a copper screw handle to secure it, and is inclined at an angle of 1° 50′; the trunnion sights are screwed in. The ML. R. 9-pr. is sighted *centrally*, that is with only one set on the top of the gun. The head of the tangent scale is protected from injury by being let into a recess in the breech, and the fore-sight by being screwed into a recess in a dispart patch on the muzzle; it has two tangent scales, one giving 6°, and the other from 6° to 12°; the inclination of the scale is 1° 30′.

8. Angles of elevation or depression may be given to ordnance, without using the sights, by means of either the *spirit level quadrant*, or the *gunner's quadrant*.

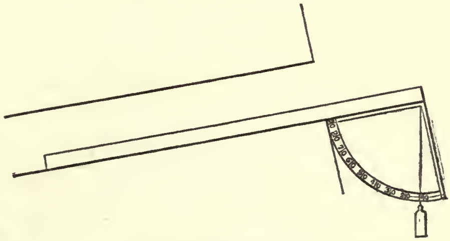
Fig. 127.



Spirit Level Quadrant.

In order to give elevation by the *spirit level quadrant* (Fig. 127), the long limb must be inserted into the bore, the spirit level attached to the graduated arc being set to the required angle, and the piece elevated until the spirit level becomes horizontal, which will appear by the bubble resting in the centre of the glass tube.

Fig. 128.



Gunner's Quadrant.

A new pattern (II.) quadrant differs from the above in being stronger, the bar has been reduced to 12 inches in length, the base is broader and is fitted with a stop to prevent its slipping into the chamber.[1]

With the *gunner's quadrant* (Fig. 128), the muzzle of the

[1] *Changes in Patterns*, § 1,439.

gun must be raised until the plumb-line cuts the required angle on the graduated arc.

These instruments only give the elevation above the horizon, but by laying the gun *point blank* at the object, and determining its elevation above the horizon, the required elevation may afterwards be given. Angles of depression may be taken by reversing the position of the quadrant, and placing it against the face of the piece.

Horizontal Fire.

9. In horizontal fire the ranges are, as before stated, regulated by alteration in the elevation of the axis of the piece, a fixed (termed a *service*) charge being generally used with each nature of gun; this charge is the largest the piece is capable of firing (except the battering charge for a heavy gun), so as to give a very high velocity to the projectile, and consequently a low trajectory, upon which accuracy of fire and the extent of ground effectively covered by the shot mainly depend.

In order to secure good practice, it is essential to have tables of the ranges of the different natures of ordnance, with their corresponding angles of elevation, charges, &c. It is with great difficulty that tables are constructed for SB. guns, from the results of the most careful experiments, owing to the very different ranges and deflections obtained in firing projectiles even from the same gun, with similar charges and elevations. The employment of good rifled ordnance decreases this difficulty, but it must be remembered that any practice table will only serve as a *general guide*, and that small alterations in elevation or deflection are required according to the force and direction of the wind, the position of the battery with respect to the object, the quality of the gunpowder, and several other circumstances. In the instruction of men in gun practice, the inutility of constantly altering the elevation to correct small errors in range should be pointed out, and the necessity of observing the results of several rounds without making any change, so as to allow for the necessary probable errors, should be strongly inculcated. Table XXI., Appendix, shows clearly the unavoidable inaccuracy of fire from SB. guns. In the Tables of Practice[2] for SB. guns the old custom of commencing from the *point blank* range is followed; but those for R. guns commence with the elevation required for 100 yds., the ranges being taken, not to the *graze* on the ground, but to the *second intersection* of the *trajectory* with the *line of sight*.

In making out Range Tables, it is necessary to eliminate as far as possible the differences in the ranges due to the various circumstances affecting them when fired under like conditions, and this is done by constructing a *Range Curve*. If the ranges be merely put down from the recorded results of practice on various days without the requisite comparison and adjustment, errors or even apparent impossibilities may sometimes be found.[3]

The ranges corresponding to the angles and minutes of elevation given in Tables are determined by means of a *Range Curve*, which is constructed as follows from the results of practice:—Draw 2 lines OX, OY at right angles to each other (Fig. 129); set off on OX from any convenient scale of equal parts the points A, B, C, representing the mean ranges from O, as found by experiment at the angles of elevation *a*, *b*, *c*, respectively. On OY set off, to any scale, divisions for the elevations *a*, *b*, *c*, from which draw lines parallel to OX; then the intersections of these lines with others drawn from A, B, C

[2] In Appendix.

[3] For instance: In a table for Armstrong 12-pr. 6 cwt. *Manual of Artillery Exercises*, 1860, p. 300.

Range	Time of flight
900 ft.	1 second
1,950 „	2 „
2,799 „	3 „
3,675 „	4 „
4,425 „	5 „
5,325 „	6 „

From which it would appear that the distances passed over by the projectile in successive seconds might be—

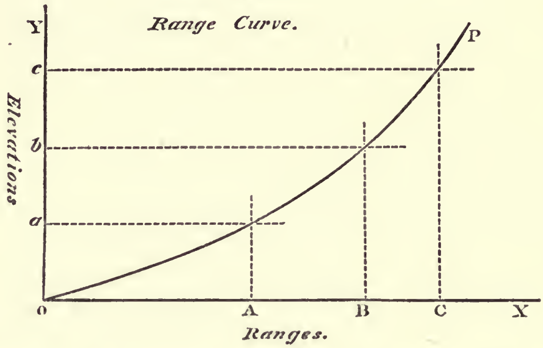
In 1st second	900 ft.
„ 2nd „	1,050 „
„ 3rd „	849 „
„ 4th „	876 „
„ 5th „	750 „
„ 6th „	900 „

That is, the projectile moves faster during the 2nd than the 1st second; and during the 6th faster than in the 5th, 4th, or 3rd, and as fast as in the 1st.

perpendicular to OX will give 3 points through which the *Range Curve* OP must be traced.

A series of ranges for intermediate angles and minutes may now be easily found by drawing lines from the requisite divisions on OY parallel to OX to meet the *Range Curve* OP,

Fig. 129.



and dropping perpendiculars from the intersections with the curve on to OX.

Should a gun have to be *laid* upon an object situated on an ascending or descending plane, and if the inclination of the plane to the horizon be but slight, little or no alteration in the elevation, from that used for the same range on a horizontal plane, will be necessary. If, however, the difference in level between the gun and object be considerable, a greater or less amount of elevation will be requisite, according as the object is above or below the gun; this is evident, for in the case of firing upwards gravity will act as a retarding force, while in firing downwards it will act as an accelerating force.

10. In firing shells with time fuzes it is necessary to know the time of flight in order to regulate the burning of the fuze composition for the range required. The time of flight can be found with sufficient accuracy for such purposes by means of instruments such as the *stop clock* or the *water clock*, but they may be calculated with the help of the Tables in the Appendix.

Example.—Find the time of flight of a common shell fired from a ML. R. 7-in. gun of 7 tons with a 14 lbs. charge at 1,000 yds.; also, the length of fuze required.

By Table IX. the initial velocity of the shell = 1,258 f. s. Look out in Table XV. the velocity equal, or nearest to, this initial velocity, which will be found to be 1,258·7 opposite the distance 5,100 ft.

By adding 3,000 ft. (the given range) to 5,100, we obtain 8,100; and the velocity 1,076, opposite the latter, will be the *final velocity.*

$$\frac{V+v}{2}=\frac{1258+1076}{2}=1167=\text{mean velocity};$$

$$\text{and, time of flight}=\frac{\text{range}}{\text{mean vel.}},$$
$$=\frac{3000}{1167},$$
$$=\underline{\underline{2\cdot57}} \text{ seconds.}$$

From Table on page 299 the 9-seconds fuze burns at the average rate of 1 inch in 4·2 seconds in the shell of the 7-in. gun;

$$\overset{\text{sec.}}{4\cdot2} : \overset{\text{sec.}}{2\cdot57} :: \overset{\text{in.}}{1} : \overset{\text{in.}}{\underline{\cdot61}}$$

The times of flight found by the above formula are, however, too short, the resistance of the air retarding the projectiles in their descent. Fired against troops (Fig. 130), a time

Fig. 130.

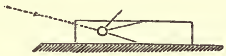
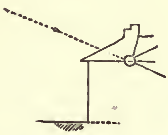


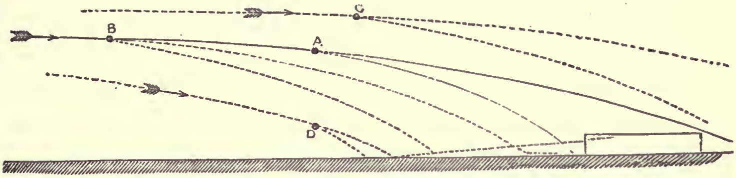
Fig. 131.



fuze should be regulated so that the shells may explode immediately before reaching the ground, and among the troops; against houses, earthworks, &c., the fuzes should be rather long (Fig. 131).

With shrapnel the effect produced by the bullets will chiefly depend upon the bursting of the shell at exactly the required instant; no precise rule can be absolutely laid down as to the distance short of the object at which the shell ought to burst, as so much will depend upon the velocity of the shell just before it opens, and other circumstances. It is generally considered that shrapnel shell should, if possible, be made to burst from 20 to 80 yds. short of the object; or in practice the artillerist should endeavour to regulate the fuze so that the shell may explode when about 50 yds. (the mean between 20 and 80) short of the object fired at. The bursting of a shrapnel shell at the proper distance from the object fired at is

Fig. 132.



Shrapnel Shell Firing.

A	represents the bursting of shell when the fuze is good and elevation correct.				
B	,,	,,	short	,,	,,
C	,,	,,	good but	,,	high.
D	,,	,,	,,	,,	low.

of the very greatest importance; if the shell bursts too soon (the fuze being *short*), the whole or greater part of the balls will strike the ground before reaching the object, the velocity and penetrating power being greatly diminished in consequence; should the fuze be *long*, that is, if the shell pass the object without exploding, the effect of the shell as a shrapnel will be entirely lost (Fig. 132).

With a good *percussion* fuze common shell practice is simplified and rendered more effective, the fuze requiring no preparation, and the action not being dependent upon its proper manipulation by a gunner.

The following results of experiment will however show clearly the destructive power of shells fired from some of the best rifled guns now in use. The practice was carried on, in October and November 1871, at Shoeburyness, with—

			lb.	oz.
Prussian BL. R.	4-pr. (=9-pr.),	charge	1	1·6
British ML.R.	9-pr. . . .	do.	1	12
	16-pr. . . .	do.	3	0

There were 4 rows of targets 20 yds. apart, giving a depth of

60 yds.; each row consisted of six 9 × 9 targets, giving a frontage of 54 ft. 10 rounds fired from each gun at both ranges.

			Total Hits at 2,500 yds.	Total Hits at 3,000 yds.
Prussian 4-pr.	common shell,	percussion fuze	144	21
British 9-pr.	do. ,,	do. ,,	107	38
	shrapnel ,,	do. ,,	125	26
	do. ,,	wood time ,,	312	158
British 16-pr.[4]	common ,,	percussion ,,	90	72
	shrapnel ,,	do. ,,	356	167
	do. ,,	wood time ,,	532	420

The Prussian common shell thus proved superior as far as total hits to either of the other common shell at 2,500 yds., and practically equal to the 9-pr. shrapnel with *percussion fuze*; but at 3,000 yds. the 9-pr. and 16-pr. shrapnel with *time fuzes* were alone thoroughly effective, their superiority being very marked. The committee appointed to carry on the experiments estimated the probable casualties (men disabled) *per round* with the 4-pr. and 9-pr. thus:—[5]

	2,500 yds.		3,000 yds.	
	Cavalry	Infantry	Cavalry	Infantry
Prussian 4-pr. com. shell, percussion fuze	3 8	5·3	1·1	0·6
British 9-pr. do. ,, do. ,,	3·8	5·6	1·7	2·3
British 9-pr. shrap. ,, do. ,,	2·9	5·8	1·1	1·5
British 9-pr. do. ,, time ,,	7·0	10·4	5·1	7·8

11. It has been found by experiment that diminished atmospheric pressure increases the time of burning of a *time* fuze. Quartermaster Mitchell, finding, from experiments made at various altitudes in the Himalayas, that the fuzes of shells burnt longer at elevated stations than at the level of the sea,

[4] At the nearer range, one common shell and two shrapnel with time fuzes, and at further range three shrapnel with time fuzes, were blind after grazing.

[5] The superiority of the German shell is owing to its construction being adapted to allow of its bursting into a large number of pieces. In an experiment made in the Royal Laboratory, the average fragments into which the shells broke up were—4-pr. 58, 9-pr. 35, and 16-pr. 39. The fragments were larger with the British shells, and as an incendiary shell, the 4-pr. is inferior to the 9-pr., the respective bursting charges being 6½ and 8 oz. The 16-pr. common shell holds 1 lb. (*Report of Committee on German 4-Prs., and Proceedings of the Department of Director of Artillery*, vol. ix. p. 299.)

first drew attention to this fact. Dr. Frankland, F.R.S., afterwards carried on experiments with 6-in. fuzes burnt in artificially rarefied air, and comparing his results with those of Mr. Mitchell, embodied them in the following law:—

The increments in time are proportional to the decrements in pressure.

And he stated that 'for all practical purposes' the following rule might be adopted:—

Each diminution of one inch of barometrical pressure causes a retardation of one second in a thirty-seconds fuze, or each diminution of atmospheric pressure to the extent of one mercurial inch increases the time of burning by one-thirtieth.

Dr. Frankland also made the following suggestive remarks: 'This retardation in the burning of time fuzes by the reduction of atmospheric pressure will probably merit the attention of artillery officers. Up to the present moment these fuzes have been carefully prepared, so as to burn, at Woolwich, a certain number of seconds; but such time of combustion at the sea-level is no longer maintained when the fuzes are used in more elevated localities. Even the ordinary fluctuations of the barometer in our latitude must render the time of the combustion of these fuzes liable to a variation of about ten per cent. Thus a fuze driven to burn 30 seconds when the barometer stands at 31 in., would burn 33 seconds if the barometer fell to 28 in. Even the height to which a shell attains in its flight must exert an appreciable influence upon the burning of its time fuze; to a still greater extent, however, must the time of combustion be effected by the position of the fuze during the flight of the shell. If it precede the shell, the time of burning must obviously be considerably shorter than if it follow in the comparatively vacuous space behind the shell.'[6]

M. Dufour afterwards made experiments, but in the open air at different altitudes on the Alps, and the agreement of his results with those of Dr. Frankland was remarkable, considering that the size, form, and time of burning of the fuzes were

[6] *Proceedings of R. A. Institution*, vol. iii. p. 15.

in the two cases different. M. Dufour also ascertained that the increase in the time of burning when the density of the air is less is not due to the decrease of oxygen, but is a purely mechanical effect.[7]

It must, then, be evident that the burning of a time fuze varies constantly throughout the flight of the shell, and that when, as in elongated shells fired from rifled guns the fuze is presented to the enormous pressure of the air, the time of burning would be considerably decreased; it is therefore to protect the burning composition from exposure to direct pressure that the heads of the 9 and 20-seconds ML. time fuzes, which are used for the shells of rifled guns, are closed by a metal plug.[8] In spherical shells the old rule of 1 *in.* in 5 *seconds* is a fair approximation; for, as these shells have no definite rotation given by the gun, the fuze during flight is constantly changing its position, so that it is at one point subject to increased and at another to decreased pressure.

The following average times of burning 1 in. have been collected from the results of practice:—[9]

Fuze	Piece of Ordnance	Initial velocity of shell	Time of burning 1 in.
		f. s.	seconds
Common or Diaphragm time	8-in. gun.	1,465	5·19
	68-pr.	1,791	5·21
	32-pr.	1,912	4·94
9 and 20-seconds BL. R. time	7-in. BL. R.	1,015	4·84
	64-pr. „	1,120	4·71
	40-pr. „	1,200	5·06
9 and 20-seconds ML. time	9-in. ML. R.	1,160	4·49
	8-in. „	1,180	4·56
	7-in. „	1,220	4·20
	64-pr. „	1,120	4·55
Mortar fuze	13-in. mortar.	300 to 800	5·75
	10-in. „	200 to 500	5·50
	8-in. „	„	5·70

The table shows, notwithstanding some anomalies, that in mortar shells, which have low velocities and consequent small comparative pressures on their fuzes, the time of burning is

[7] *Proceedings of R. A. Institution*, vol. iii. p. 262.

[8] The *detonator* effects the same purpose in the BL. 9 and 20-seconds time fuzes.

[9] *Short Notes on Professional Subjects* (7), issued with *Proceedings of R. A. Institution.*

longer than 1 in. in 5 seconds; that for the spherical shells of SB. guns the rule is sufficiently good for practical purposes; but that in the shells of R. guns, which have lower initial velocities than the spherical shells, the rate of burning is more rapid than the old rule would allow.

12. Empirical rules are sometimes useful if practice tables be not at hand; the following, which will be found to give fair approximations, are therefore inserted:—[1]

With SB. cast-iron shell guns, which have *point blank* ranges of about 400 yds.—

$\frac{1}{4}°$ gives 100 yds. range, from *PB.* to 1,200 yds.
,, 75 yds. ,, 1,200 to 2,000 ,,

With SB. cast-iron shell guns which have *point blank* ranges of about 300 yds.—

$\frac{1}{4}°$ gives 75 yds. range, from *PB.* to 1,200 yds.
,, 50 yds. ,, 1,200 to 2,000 ,,

For the shell guns, *twice the number of degrees* of elevation + 1 will give about the number of tenths of fuze required.

For the service rifled guns—

Each minute gives 10 yds. range, up to 500 yds
,, 7 ,, from 500 to 1,000 yds
,, 6 ,, ,, 1,000 ,, 3,000 ,,

and each minute of deflection on the sight gives a difference of an inch in every 100 yds. range.

With the 9 and 20-seconds time fuzes, $\frac{2}{3}$ *range in hundreds* gives the *number of tenths* of fuze for common shell; the fuze must be bored one-tenth shorter for shrapnel.

With the Armstrong BL. rifled guns the *number of hundreds of yards in range* divided by 3 gives roughly the time of flight, and divided by 6 the length of composition of E time fuze required; thus for 1,800 yds. range this rule gives 6 sec. for the time of flight and 3 in. for the length of fuze. The E time fuze is now, however, withdrawn from the Land Service.

Projectiles from rifled and smooth-bored guns, with full

[1] The rule for SB. guns were deduced from the Practice Tables.

charges, as a general rule pass over the undermentioned distances on the sands at Shoeburyness before coming to rest.[2]

		1°	5°	10°
Rifled Guns:—		yds.	yds.	yds.
ML.	7-in.	5,000 to 6,000 with battering charges.	6,000	5,500
	8-in.			
	9-in.			
	13-in.			
BL.	12-pr.	3,500	4,000	4,500
	40-pr.	4,000	4,500	5,000
	7-in.			
	64-pr.			
Smooth Bore:—				
	18-pr.	3,000	4,000	3,500
	24-pr.			
	32-pr.			
	8-in.			
	68-pr.	3,000	3,300	4,000
	10-in.	3,000	3,500	3,500

Projectiles fired from rifled guns with a right-hand twist ricochet to the right, the final graze being from 400 to 500 yards right of the line on which they are fired.

Projectiles are more irregular in their ricochet on water than on the sand, and more again in rough weather than in calm.

Ricochet and Curved Fire.

13. As *ricochet* and *curved fire* differ in many respects from the ordinary kinds of horizontal fire, it will be better to consider them separately. In *ricochet fire* the object is to fire the projectile at such an angle that it may descend very near to the parapet after just clearing it. The object to be attained in *ricochet fire* has been explained in Art. 1.; the gun is laid at the crest of the epaulment, the angle of elevation given varying, with the charge, from 5° to 10°. No greater elevation than is absolutely necessary should, however, be given to the gun, as the shot would either rebound at too high an angle to be effective, or it would penetrate into the ground; whilst the smaller the angle at which the shot reaches the ground, the more horizontal will be its subsequent course, and the greater the velocity it will retain, both of which are

[2] From the *Range Regulations, Shoeburyness.*

essential points in this species of firing. Should the range be unknown, a good plan to be adopted is, to commence firing short of the parapet, and gradually increase the elevation until the shot strikes as near the crest of the parapet as possible; the least increase of elevation will then attain the object.

The rebounding of shot moving with low velocities produces but trifling effect compared to the devastation caused by the explosions of large shells full of powder, and the latter projectiles would now be employed against a work which would formerly have been ricocheted with shot. Shot fired so as to ricochet will rarely dismount heavy ordnance, and they will often pass through or lodge in a carriage without rendering it unserviceable; also, but little ground is covered by the shot before and after the graze. Large shells falling close to a gun and then bursting will generally render the platform or carriage unserviceable, and should one explode underneath a gun, the piece may be dismounted. Shells produce a much greater effect than shot upon the traverses and parapets, as well as upon men; and if the fuze is bored long, a shell may ricochet and then burst, but the rebounding will sometimes extinguish the fuze. Should, however, shells be fired so as to clear the covering parapet, and fall into the battery at different distances from it, the fuzes being regulated so that the shells may burst on grazing, as great effect will most probably be produced as by firing in any other way.

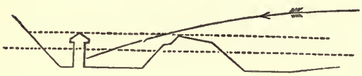
A ricochet battery should be placed so that one gun may be directly on the prolongation of the face enfiladed. The SB. ordnance most suitable for the modified ricochet fire of the present day are the 8-in. guns of 52 or 50 cwt., but any rifled gun throwing an elongated projectile, which is capable of holding a large bursting charge, might also be used to drop shells into the battery so as to burst on grazing; the path of an elongated projectile is so eccentric after grazing as to render it unfit for *ricochet fire* strictly speaking, but, as before observed, more effect would probably be obtained by the bursting of a large shell after grazing than by the rebounding of a shot.[3]

[3] The O. S. Committee report that the projectiles of the BL. Armstrong guns

It was found by experiment in ricochet firing, carried on at Woolwich in 1821, that at a range of 400 yds., with a charge of powder $\frac{1}{32}$ the weight of the shot, about two-thirds of the number of rounds took effect. At 600 yds., with a charge of from $\frac{1}{32}$ to $\frac{1}{20}$ the weight of the ball, about one-half to one-third took effect. At 800 yds., with a charge of from $\frac{1}{24}$ to $\frac{1}{12}$, not more than from one-third to two-fifths of the rounds took effect. From this it would appear that ricochet batteries should, if possible, be placed at a distance of from 400 to 600 yds. from the enemy's works.[8]

14. As before stated, *curved* or *indirect fire* has been long employed to dislodge troops posted behind cover, by firing common shells from SB. guns and howitzers; and it was found by experiment in Plumstead Marshes, in 1824, that masonry as proposed by Carnot (Fig. 133) could be breached by firing at it with small charges and elevations of from 10° to 15°. The batteries were from 400 to 500 yds. distant; eight 68-pr. carronades, three 8-in., and three 10-in. howitzers were placed in them; and, after each firing 110 rounds in six hours, a practicable breach was made 14 ft. wide. The howitzers fired live shells filled with powder, the bursters being, however, reduced during the experiment on account of the splinters from the shells inconveniencing the men in the breaching battery at 400 yds.; the carronades fired solid shot.

Fig. 133.



The earthen counterguard of regular thickness and equal

'are not so well adapted as round shot for what is commonly intended by ricochet fire, namely, to proceed through a work by short bounds, making more than one graze in it. The second graze is almost invariably too far distant from the first to be in any way relied on; it is however tolerably regular both in direction and distance.'—*Report of Ordnance Select Committee, Proceedings of R. A. Institution*, vol. iii. p. 250.

[4] The Prussians used to employ a kind of ricochet fire from field guns against large masses of troops at very long ranges. For this purpose the axis of the gun was laid horizontally, and the shot when fired, after striking the ground three or four times, proceeded on in short rebounds, not rising above the height of a man; the ground must be open, flat, and hard for this kind of ricochet, or it may be used on calm water. This fire, depending as it must do, so much on chance, would probably cause little damage, and it would, generally speaking, be far more judicious to reserve the fire of your guns till the enemy's troops were within effective range.

height with the wall was at its crest 20 yds. from the top of the wall. A full account of this experiment is given in Sir H. Douglas' *Observations on Modern Systems of Fortification.*

Some very important experiments were made on a large scale at Julich in Prussia, in 1860, to ascertain the suitability of rifled guns for breaching revetments either by *direct* or *curved fire.* The results showed conclusively the great superiority of rifled over smooth-bored guns for these purposes. The chief points to be decided were—the accuracy of rifled pieces when fired with reduced charges and high angles at considerable ranges, and the effects produced upon masonry by elongated shells fired under such circumstances. The conclusions drawn from these experiments are given at the end of the remarks on Breaching Revetments in Chap. VII. Part III.

Experiments were made in Plumstead Marshes, in October and November, 1861, by the late O. S. Committee, to test the efficiency of the Armstrong rifled guns for enfilading a work armed with 10 guns separated by 4 traverses, and protected by a screen of earth 10 ft. high and 30 ft. long at the angle of the nearest flank. The pieces employed were—

BL.R. { 40-Pr. / 20-Pr. / 12-Pr. }   S.B. { 32-Pr. (of 25 cwt.) / 8 in. (of 65 cwt.) }

and the range to the nearest angle of the work was 950 yds., a distance chosen as being beyond the risk of annoyance from the fire of riflemen. Although made chiefly with the view of ascertaining whether the fire of the rifled guns would be accurate with the reduced charges and high angles required for enfilading the work, the results were valuable as showing that rifled pieces could be depended upon for striking sunken revetments, the object in curved fire. The Report states that the committee were fully satisfied 'that Armstrong projectiles may be fired with greatly reduced charges, so as to have a high descending angle, and still retain precision of direction and uniformity of range. This adapts them well for silencing guns covered by traverses, or for breaching caponnières and sunken defences.'[5]

[5] *Proceedings of R. A. Institution,* vol. iii. p. 250. A table of elevations and charges for curved fire with BL. R. guns is given in the Appendix.

An instructive paper on 'Breaching by Indirect (Curved) Fire,' by Col. H. H.

Vertical Fire.

15. The *laying* of a mortar so as to ensure a correct direction to the shell is generally accomplished by means of a plummet, which is held in the hand immediately behind the mortar, and the string made to coincide with two pickets or rods placed upon the parapet and directed upon the object. The pickets are first lined upon the object, the plummet is made to coincide with them, and the mortar is then traversed until the line of the plummet covers the centre line on the mortar, which is denoted by a notch in the muzzle, and another behind the vent, a chalk line being generally drawn on the exterior surface of the mortar between these notches. Should the bed, upon which the mortar rests, be level, this line will be in the same vertical plane as the axis of the piece.

If the platform be in good order and level, the mortar may be laid by means of a line chalked on the platform on each side of the bed, or by a batten of wood nailed to the platform, and touching one side of the bed when the mortar is accurately laid; this latter expedient is very useful in night firing.

16. The following rules are generally given for mortar firing; it will, however, be found in practice that the charges of powder required for the same ranges will constantly differ, owing to the varying strength of the powder, according to the state of the atmosphere, and other circumstances.

The 13-in., with a charge of 3 lbs. of powder, gives a range of 850 yds., and every additional ½ lb. increases the range about 180 yds.

The 10-in., with half the charge of the 13-in., will give about the same range.

Maxwell, R.A., may be found in the *Proceedings of the R. A. Institution*, vol. vii. In it are described the methods followed in Prussia and Russia to obtain tables giving the ranges, angles of elevation, deflections, and angles of descent for each gun, with different charges. Such tables proved of great use to the Prussians at the siege of Strasburg, in 1870, where breaches had to be made by *curved* fire; and it would be very desirable to have, as Col. Maxwell points out in this paper, and Col. S. E. Gordon, R.A., in a recent 'Note on Curved Fire,' in vol. viii. of the *Proceedings*, similar tables made out for our siege pieces.

The 8-in., with about one-third of the charge of the 13-in., will also give about the same range.

The elevation of the mortar for the above must be 45°. At 15° the range is rather more than half that at 45°; at 10° rather less than half, the charges being equal.

17. For ranges to which the parabolic theory is applicable the time of flight may be found by the formula,

$$t = \frac{1}{4}\sqrt{\text{range in ft.}}$$

when the elevation of the mortar is 45° (Equation 5, p. 209); on reference to the tables usually given for mortar practice, as in Table XXVI., Appendix, it may be seen that the times of flight (for the length of fuze) have been calculated from this formula. At long ranges the times of flight calculated by this formula will be too short, for the velocities being comparatively high, and increasing with the range, the trajectories will differ very sensibly from parabolic curves. On reference to Tables of Mortar Practice, it will be seen that at a range of 1,000 yds. and beyond, the times of flight are greater than those calculated by the above formula, and that as the shell is smaller, so the time of flight is longer for equal ranges, at least in comparing the 8-in. with either of the others, and the 10-in. with the 13-in. at 2,000 yds. and over. At short ranges, such as those on Woolwich Common, the times of flight, as calculated by the formula above, are generally said to be too long, but on service the fuzes of shells for heavy mortars are always required to be *long*, so as to give the shells time to penetrate, and that they may not burst on striking, for the usual effect would be thereby almost entirely lost.

The large mortar shells, 13, 10, and 8-in., are generally used in bombarding towns and works, and for these purposes it is desirable that the shell should penetrate and then burst, the fuze being therefore bored, as it is technically termed, *long* (Fig. 134); these shells are most useful in destroying and setting fire to buildings and magazines, levelling earthworks, &c. The small mortar shells (common shells fired from the $4\frac{2}{5}$-in. and $5\frac{1}{2}$-in. bronze mortars) are generally fired against troops posted behind cover, and they should therefore be made to explode at the instant they reach the ground; if they penetrate into the ground, and then explode, the splinters will have little lateral range, and the destructive effect of the shells will be greatly decreased (Fig. 135).

Fig. 134.

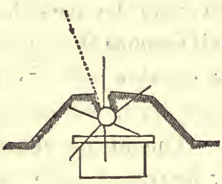
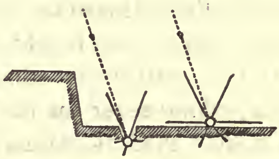
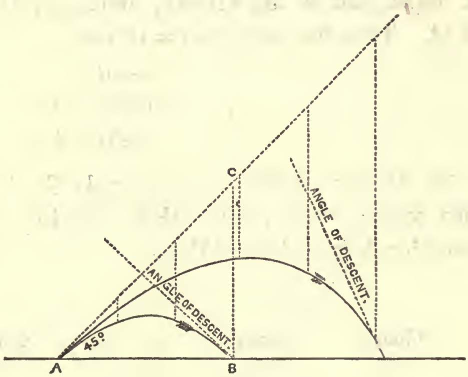


Fig. 135.



18. The *angle of descent* of a mortar shell increases with the range, which of course depends upon the charge; for as the velocity increases, so will the greater resistance of the air cause the trajectory to differ more from a parabolic curve, the descent of the shell being consequently more nearly vertical, as shown in Fig. 136. The *angles of descent* are seldom observed, but the following are taken from the experimental practice carried on in 1857 with Mallet's 36-in. mortar, which was fired with an elevation of 45°:—

Fig. 136.



At a range of	800 yds.	the angle of descent	=	45°
„	1,650	„	„	70°
„	2,600	„	„	80°.

The shells generally used being so much smaller than the above, they are more retarded by the resistance of the atmosphere, and their angles of descent for corresponding ranges are therefore most probably greater.[6]

[6] By the employment of very large SB. mortars, throwing shells of greater dia-

x 2

The penetration of a mortar shell depends upon the vertical (or downward) component of the velocity at the moment of striking the ground, and this will of course be due to the fall of the shell from the highest point of its trajectory. As the range increases, the shell descends more vertically, so that at long ranges the velocity of projection may be considered as practically destroyed by the time the shell reaches the ground; and the greater the height reached, the greater will be the penetration until the terminal velocity is attained, which, however, is perhaps never the case in practice. The falling velocity of a mortar shell at ordinary ranges may be found with sufficient accuracy for practical purposes as follows:—The shell may be assumed to be rising during half the time of flight, and falling during the other half; therefore, if t be the time of flight, and v the velocity required, the latter will be due to $\frac{1}{2}t$. Thus for 500 yds. $t=10$ sec.,

$$v=gt;$$

$$\therefore \quad v=32\times 5$$

$$=160 \text{ f. s.}$$

19. Mortar shells are constantly fired at very long ranges into towns, works, &c.; the following are the charges, the elevation being about 45°:—

13-in., SS.

Charge lbs.	Range yds.
10	2,800
12	3,150
14	3,500
16	3,800
18	4,100
20	4,400

10-in., SS.

Charge lbs.	Range yds.
5	2,800
8	3,400
10	3,600

meter than those now in use, the accuracy of vertical fire might be greatly increased, as such projectiles would be less liable to deflection and irregularities in range; their momentum and penetration with equal velocities, and the bursting charge, would also increase in a much higher ratio than the calibre. The chief obstacles to the use of very large mortars are, the practical difficulties experienced in the manufacture of the mortars and in the transport of both mortar and ammunition, which latter would necessarily be of great weight, and occupy much space. Rifled mortars are, however, now being gradually adopted.

Guns are sometimes used for vertical fire to throw projectiles at long ranges into towns, works, or camps, but the results are necessarily very uncertain. 32- and 18-pr. guns sunk in the sand were thus employed by the English at the great siege of Gibraltar to alarm and annoy the Spaniards; and in the Crimean War both the allies and the Russians used damaged guns in the same way, but with no very great success.

The following are the charges necessary for the 24-pr. SB. gun of $9\frac{1}{2}$ ft., at 45° elevation :—

Charge lbs.	Range yds.
6	4,500
8	4,800.

CHAPTER VIII.

PRACTICE OF GUNNERY—*continued.*

Effect of Artillery Fire upon Objects: 1. French experiments with SB. guns against different materials.—2. Recent English experiments against masonry and earth.—3. Effects of projectiles on iron defences.—4. Experiments against wrought-iron shields for land defences.—5. Effects of shells against wrought-iron defences.—6. Experiments against iron armour for vessels of war.—7. Experiments on ships' decks.—8. Penetration of projectiles through water.

Effect of Artillery Fire upon Objects.

1. The French have made many experiments in penetration with SB. guns; those carried on at Metz in 1834 were made on rough hewn stone of good quality. In these experiments the holes formed in the masonry by balls fired perpendicularly to it, and at short distances, were in the shape of a funnel externally, whose mean diameter was about five times that of the shot; internally, the form of the hollow was nearly cylindrical. The shape of the internal portion appears to have been produced by the reaction of the masonry, of which some pieces were projected to a distance of from 40 to 50 mètres. Round the opening, a cracking or rending of the masonry took place, which separated the stones, and which was about half as large again in diameter as the opening, viz.—

1·15	mètres for the	24-pr.
·9	„	16-pr.
·8	„	12-pr.

Nearly all the balls were broken, being fired with a charge of one-fourth their weight. The effect of shells against masonry was scarcely perceptible. They broke at the moment of impact; or when fired with small charges made but feeble impression. From experiments made at the same period with regard to the penetration of shot into iron, it was found that masses of cast iron above 1 yd. square and 13 in. thick do not resist the shock of balls fired against them, with even moderate velocities, having been fractured, not only at the point of impact, but also at points considerably removed from them.[1]

2. The comparative penetrations of elongated and spherical projectiles respectively, into brickwork of the best quality at a range of 1,032 yds., taken from the results of experiments against a Martello tower at Eastbourne in 1860, and against a similar tower at Bexhill in 1861,[2] are shown in the following Table:—

TABLE I.

Elongated (Armstrong)				Spherical			
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	„ shell	51	16	1 9
„ shell .	77	9	4 3	32-pr. shot	32	10	1 4
40-pr. shot } „ shell }	41	5	4 1	„ shell	23½	10	1 4

Experiments were made in 1863, at Newhaven, to determine the relative penetrations of projectiles fired from SB. and rifled (BL.) guns into natural and artificial earthwork. A few of the results are given in Table II.

TABLE II.

Range 1060 yds.

Gun		Charge	Projectile			Clay (artificial)	Natural concrete[3]	Hard gravel
			Nature	Weight	Diameter			
		lbs.		lbs.	in.	ft. in.	ft. in.	ft. in.
BL. rifled (Armstrong)	7-in.	12	Shot .	111·0	7·04	21 3	9 2	—
	„	„	Shell .	104·7	7·04	18 3	7 9	—
	40-pr.	5	Shot .	41·2	4·8	14 9	—	7 8
	„	„	Shell .	40·4	4·8	11 8	—	6 1
	20-pr.	2½	Shot .	20·4	3·8	10 10	—	4 7
	„	„	Shell .	21·2	3·8	10 3	—	—
	12-pr.	1½	Seg. shell	10·6	3·04	4 0	—	—
SB. cast-iron	10-in.	12	Shell .	83·9	9·84	11 0	3 10	—
	8-in.	8	Shell .	50·3	7·85	11 5	—	3 6
	68-pr.	16	Shot .	65·9	7·91	20 0	—	—
	„	„	Shell .	50·3	7·85	14 10	—	4 0
	32-pr.	8	Shot .	31·2	6·17	13 0	—	2 8
	„	8	Shell .	23·6	6·17	9 5	—	2 8

Note.—The shot were solid, and the shells were common shells, filled with sand and plugged, except the 12-pr. segment shells.

[1] The results of these experiments will be found in Tables XXXI., XXXII. Appendix.

[2] *Proceedings of R. A. Institution*, vol. ii. p. 406.

[3] Hard flints bound with stiff gravelly clay.

3. It would require too much space to describe the numerous experiments made during later years, both in this country and abroad, to test the respective values of the many different constructions and combinations of materials, supported in various ways, proposed as armour for vessels or land defences to resist the formidable projectiles now fired from heavy rifled ordnance; it will be sufficient to point out a few of the more important results of these experiments, in order to show clearly what has been accomplished, and therefore the effects that may be fairly anticipated to be produced by the fire of heavy rifled guns in actual warfare. Sir H. Douglas gave the following results of experiments carried on at Portsmouth in 1854:—'During the months of September and October 1854 some experiments were carried on at Portsmouth, in order to try the capability of wrought-iron slabs to resist the impact of solid and hollow shot, and the following are the results:—The target was a section of a frigate covered with wrought-iron plates 4½ in. thick, and the projectiles employed were 32-pr. and 68-pr. solid shots, and 8-in. and 10-in. hollow shots. At 400 yds. the 32-pr. solid shot, and the 10-in. and 8-in. hollow shot, merely indented the target to the depths respectively of 1½, 2½, and 1 in.; but the 68-pr. solid shot, being fired with 16 lbs. of powder, penetrated the plates. These were always split at the bolt-holes, which were about 1 ft. asunder; and, in consequence, it was recommended that they should be bored as far apart as possible. The conclusion drawn from the experiment was, that 4½-in. iron plates, applied as a covering to ships, would give protection during an action against 8-in. and 10-in. hollow shot, and against 32-pr. solid shot, but very little against solid shot of 68 lbs.'[4]

Experiments were carried on at Woolwich, in 1858, in order to ascertain the resistance which blocks of cast iron 2½ ft. thick, and plates of wrought iron 8 in. thick, would offer to projectiles fired from the service 68-pr., it being supposed that land batteries might be strengthened with such masses of iron.

[4] The iron plates now made are, however, of much better quality than those tried in the early experiments, and they consequently offer far more resistance to the fire of ordnance.

The results of these experiments were generally considered unfavourable to the employment of iron, either cast or wrought, for strengthening batteries.

In May 1861, experiments were made at Shoeburyness to ascertain what protection would be afforded to masonry by wrought-iron plates 2, 2½, 3, and 3½ in. in thickness. The results were—

'That masonry covered with 2-in. iron plates will effectually resist a 12-pr. Armstrong shot at 600 yds.

'Covered with 2½-in. plates, it will effectually resist a 25-pr. Armstrong shot at 600 yds.

'Covered with 3-in. plates, it will effectually resist a 40-pr. Armstrong shot at 600 yds.

'But the 3½-in. plates are not sufficient to resist the heavier natures of projectiles.'[5]

'Granite faced with 4-in. iron plates is seriously injured by 68-pr. cast-iron shot, fired with the service charge, at 100 yds. range. In an experiment at Shoeburyness it was found that blocks of granite 3 ft. thick, faced with an iron plate 4 in. thick, were cracked through and split by the impact of a single shot fired under these conditions. The plates were of excellent quality, and were only slightly indented.'[6]

'In order to test the various effects of different sorts of backing, some 2½-in. wrought-iron plates were fastened respectively to blocks of cast iron 3 ft. thick, to solid granite, to a mass of oak made up of timbers 10 in. by 10 in., and to a mass made of alternate layers of fir and cork and bitumen cork.

'The results proved the immense superiority of a massive rigid over an elastic backing, both as regards the plates themselves and also as regards the fastenings.[7] 40-pr. service shot

[5] Paper on 'Iron Defences,' by Capt. (now Major) H. C. S. Dyer, R.A., *Proceedings of R. A. Institution*, vol. iii. p. 37. Live shells were fired from the 68-pr. and 110-pr. rifled Armstrong gun, but produced little effect on the plates until they had been damaged by shot and blind shells filled with sand.

[6] Capt. Harrison's paper on 'Experiments against Iron Armour,' *Proceedings of R. A. Institution*, vol. iv. p. 201.

[7] When the target was taken to pieces, it was found that the bolts had suffered most in the plates with rigid backing.

at 200 yds. did little or no damage to the plates backed by granite and cast iron, but went clean through the plates backed by oak and fir, and did great damage to it. A 110-pr. cracked a plate backed by cast iron, and the cast iron also, but did little damage.' [8]

Two shields,[9] of 6 in. and 10 in. thickness respectively, composed of a number of thin wrought-iron plates (from $\frac{5}{8}$ in. to 2 in. thick) bolted together, were tried in 1861, at Shoeburyness; they offered but small resistance compared to a solid target of similar weight. At 200 yds. the 6-in. shield was punched through by the fire of the 68-pr. SB. and the 110-pr. rifled (Armstrong) gun; the 10-in. shield was much bulged by the same fire, and some of the plates were also broken.

4. A large number of shields for embrasures of different constructions have been tried, but as more powerful ordnance have been gradually introduced, so have many of these shields been sooner or later disposed of as inadequate for the requisite protection against their fire. In 1860, an embrasure of Thorneycroft's rolled iron bars, 10 in. × 4 in., resisted successfully the fire of projectiles from the SB. 68-pr. and the R. 80 and 40-pr. guns; but two similar shields afterwards succumbed to the fire of the SB. 68-pr. and the R. 110 and 120-pr. guns. In 1863, a shield, proposed by Captain Inglis, R.E., consisting of horizontal and vertical planks supported by framework, was not seriously damaged by the fire of 100, 130, and 300-pr. rifled guns; but the introduction of heavier guns, firing larger charges, necessitated the employment of larger and thicker masses of iron. It has latterly become a disputed point whether two or more plates of moderate thickness, or a single very thick plate, is the best protection for an embrasure.[1] It doubtless would require greater force to penetrate a solid plate than a target of the same thickness composed of two or more plates bolted together, supposing both targets to be equally

[8] Paper on 'The Application of Iron to Defensive Works,' by Capt. Inglis, R.E.

[9] Proposed by Mr. Hawkshaw.

[1] The building up of a target with two or three plates of moderate thickness must not be confused with the *laminated system*, consisting of a large number of very thin plates, which, as already pointed out, offer but feeble resistance compared to a solid plate.

sound; but the difficulty in practice is to obtain very large and thick masses in great numbers of uniformly good quality and at a moderate cost. Plates of much greater thickness and soundness than those made a few years ago can now be manufactured, but necessarily at a high cost; and many of these exhibit a tendency, when struck, to separate into different layers. With targets made up of several plates, the chief difficulty has been to contrive bolts of suitable form, and to dispose them so that the strength of the target is not quickly impaired by the *shearing* of the bolts from the vibration of the separate plates, or by their fracture on being struck by shot. It has been asserted, as the plate is thinner, so is a perforation in it more liable to extend into cracks or fissures; but this does not appear to be borne out by the results of experiments.

The Gibraltar shield, consisting of $5\frac{1}{2}$-in. front plates, backed by 5-in. plates and an iron skin of $1\frac{1}{2}$ in., making a total thickness of 12 in., was, after several trials in 1867, reported as 'not strong enough to sustain a severe fire from the heaviest rifled guns, although it would probably afford good protection against lighter guns, or against casual fire;' and that a Palliser shell, fired with a charge of 43 lbs. from a ML. R. 9-in. gun at 70 yds., could perforate the weaker portion of it completely.[2]

Important experiments were made in 1868 against a much stronger target, viz., a structure representing the Plymouth Breakwater Fort, consisting of three 5-in. plates, supported by sets of vertical iron planks, with oak between them; an additional 5-in. plate was bolted to the west side, to show how the structure might be strengthened if necessary. Twenty rounds were fired from the ML. R. 9-in., 10-in., and 12-in., and the SB. 15-in. (Rodman) guns, with battering charges, besides 8 rounds from the ML. R. 10-in. and 12-in. guns, with reduced charges to give the final velocities at 1,000 yds. range; during which very severe test the structure was penetrated when struck direct between the vertical struts by a 12-in. and a 10-in. shell fired with battering charges at 200 yds. range, and nearly penetrated, in a like place, by a 12-in. shell with the charge for 1,000 yds.[3]

[2] *Proceedings of O. S. Committee*, vol. vi. p. 71.

[3] Palliser shot and shell were fired from the ML. R. guns.

It was stated that a mantlet would be necessary to protect the gunners from the fragments of iron, bolt-heads, rivets, &c.

In order to compare the resistance of solid unbacked 15-in. plates with the Plymouth structure, a 15-in. rolled and another 15-in. hammered plate were fired at with battering charges at 200 yds. range. Five rounds, from the ML. R. 10-in. and 12-in. and the SB. 15-in. guns, were fired at the first, the result being that, although not perforated, the plate was cracked through at each round, and at the last broken into three pieces. The second plate was broken into three pieces by two rounds from the ML. R. 12-in. gun. The resistance of the three 5-in. plates compared favourably with that of the solid 15-in. plates, and the latter were not recommended, 'the effect of repeated blows on the solid structure being to produce a more complete destruction than that which takes place in the case of the compound structure.'[4]

The Millwall shield, tried in 1868, proved capable of resisting well the fire of the most powerful rifled ordnance. This construction consisted of two large front plates, the upper 6 in. and the lower 9 in. thick, supported behind by hollow rails or *stringers*, fitted between with timber, and riveted to a double skin of $\frac{3}{4}$-in. plates. It was first tested by the fire of ML. R. 9-in. and 10-in. and SB. 15-in. (Rodman) guns, with reduced charges, to give velocities for 400 yds. range, at 70 yds. distance, and reported to be 'in a perfectly serviceable condition, and no

[4] *Extract of Reports of O. S. C.* vol. vi. p. 298.

From experiments made in 1867 to ascertain the comparative resistances of solid and built-up targets the following results were obtained:—

Target	Charge required to penetrate target	Energy per inch of shot's circumference
	lbs.	foot tons
Solid 7-in. plate	$15\frac{1}{2}$	61
Two plates each $3\frac{1}{2}$ in. thick . .	14	57
Three plates each $2\frac{1}{3}$ in. thick .	13	52

From a more recent experiment with two solid 10-in. plates and a target of two 5-in. plates the conclusion was drawn that a solid 10-in plate offered probably little more resistance than two 5-in. plates bolted together; but a complete series of experiments would be required to determine the law of resistance in such cases. The tendency of the 10-in. plates to separate into two 5-in. plates when struck was observed in the experiment.—See *Short Notes on Professional Subjects*, pp. 57, 58.

penetration had been effected.'[5] It was afterwards tried more severely by the fire of Palliser shot from the ML. R. 12-in. gun, with a charge of 74½ lbs. of pellet powder, to give the velocity of the full charge of 76 lbs. at 200 yds. range, at a distance of 70 yds.; and, although penetrated through the 6-in. plate, the resistance of the shield was reported to be satisfactory.[6]

It will only be necessary to notice one more shield, designed by the Royal Engineers, which the projectiles of the most powerful rifled ordnance failed to pierce. The shield was composed of three large 5-in. plates, with intervals of 5 in. between them filled with iron concrete,[7] and having an embrasure cut through it; the front and second plate were bolted together, the second and third to the supports behind, no fastenings appearing at the back of the shield, and iron frames were placed at the embrasure to prevent the concrete being forced out.[8] The guns fired at it in March 1870 were the ML. R. 12-in. and 10-in., and the Whitworth 9-in., the projectiles failing to penetrate, but making indentations of from 20 to 24½ in. The 12-in. and 10-in. guns fired four Palliser projectiles each, and the 9-in. gun three shells of what Sir J. Whitworth terms *yellow metal*, one of which broke up on leaving the gun.[9]

It would thus appear that great difficulty has been experienced in constructing shields capable of resisting the fire of the heavy rifled guns now made; but still there is no doubt that land defences can be made practically impregnable, there being no limit but *cost* to their being strengthened to meet increased power in ordnance; and the same may be said of floating batteries for harbour defence. But sea-going vessels

[5] *Extracts of Reports of O. S. C.* vol. vi. p. 312.

[6] *Ib.* p. 440.

[7] Iron filings and asphalt.

[8] This liability of the concrete to be forced out has been exhibited in the previous experiments with it, and again in a more recent experiment with a target of 4½-in. plate, backed by 6-in. of concrete, supported by an 8-in. plate. By increasing the thickness of the front plate and leaving out the concrete a stronger target might probably be obtained with a less thickness of shield at the embrasure, an advantage as far as training of the gun is concerned.

[9] The first of the Whitworth shells was flat-headed, and, being inaccurate in flight, struck too close to the port; the second had an ogival head and produced good effect; the third, a flat-headed shell, broke up.

can only carry a certain weight of armour, in order that they may fulfil the requisite conditions of service; and hence the necessity of arming coast batteries with powerful guns, which may fairly be expected to sink or otherwise seriously injure any such vessel that may venture to attack them.

5. Before giving the results of experiments on armour for vessels of war, the employment of shells against iron plates must be noticed. The general impression was that it would be useless to fire shells against wrought-iron plates; cast-iron shells invariably broke up against the plates, merely indenting and slightly cracking them. In September 1862, however, Mr. Whitworth proved conclusively that steel shells *without any fuze* could be fired so as to penetrate the plate and then explode. A 70-pr. rifled gun was fired with a flat-headed steel shell, having its bursting charge confined in a flannel bag, at a wooden box protected in front by a 4-in. iron plate, and at the back by a 2-in. plate. The shell penetrated the box, punching a hole 5·6 in. × 5·4 in. in the 4-in. plate, and exploded on the rear plate, blowing out the sides of the box and forcing the front and rear plates outwards; the rear plate was indented 2·6 in.; the shell broke into large pieces.[1]

The probable cause of the ignition of the bursting charge *without a fuze* may be thus explained:—When the gun is fired, the powder is, in consequence of its inertia, *set up* or condensed into a solid mass, in which state it occupies a less space than when loose, and therefore does not fill the shell; on impact against the hard metal plate, the solid cake of powder, continuing to move when the motion of the shell is suddenly checked, comes in violent contact with the inner surface of the shell, sufficient heat being thereby generated to ignite the powder.

Sir W. Armstrong afterwards tried a shell which differed in some respects from the Whitworth shell. The latter had a solid flat head, and the charge was inserted at the base, which was closed by a screwed cup. The Armstrong shell was solid at the base, and was made of steel, with the exception of a small cast-iron hollow head of hemispherical form; before the

[1] Account of experiment, *Proceedings of R. A. Institution*, vol. iii. p. 171.

head was screwed in, the charge was inserted and *stemmed* into the shell by means of a setter and a maul; the flash from the breaking up of the cast-iron head on impact against the plate probably ignited the bursting charge.

The Whitworth shell being solid in front, the cup at the base was sometimes blown out, and the force of the explosion, acting in a backward direction, produced but little effect; but when the base was solid and the head open, as in the Armstrong shell, the charge exploded forwards into the structure fired at, and so greatly increased the destruction caused by the projectile.[2] These shells did not break up, like those of cast iron, into a number of destructive fragments, for it was thought necessary to make them of very tenacious metal to enable them to penetrate the iron plates; by using gun-cotton for the bursting charge a greatly increased shattering effect would probably be produced, but the explosion of this substance is so rapid that it would perhaps fail to ignite any timber in the object. The Palliser shells used in the service break up in passing through an iron target, and the charge is exploded by the heat and flash produced during the penetration, the fragments of the shell, if the structure be completely penetrated, acting as langridge behind it.[3]

6. In Table III. the respective effects produced on the same description of ship target, the *Warrior*, by various projectiles, fired with different charges and at several ranges, are given. The results were all determined by actual experiment at the ranges stated. The target consists of $4\frac{1}{2}$-in. iron plates, on an 18-in. teak backing, and with a $\frac{5}{8}$-in. iron skin, an excellent arrangement of the material for resistance to the fire of artillery.

The various circumstances which influence the destructive effects produced by projectiles on objects must be considered, in drawing comparisons between the results of practice at a given iron target. Instances may be taken from Table

[2] Sometimes setting fire to the wood backing.

[3] With respect to the relative effects produced by Palliser cored shot and Palliser shell, it has appeared from experiments that the shot effect the most damage against armour protection beyond the power of the gun, and the shells are most destructive against armour not exceeding the power of the gun. (*Proceedings of Department of Director of Artillery*, vol. ix. p. 92.)

TABLE III.

Gun: Nature	Gun: Weight	Gun: Calibre	Projectile: Nature	Projectile: Weight	Charge	Velocity: Initial	Velocity: Final	Range	Effect on Target
	cwt.	in.	CAST-IRON:—	lbs.	lbs.	f. s.	f. s.	yds.	
SB. 68-pr.	95	8	Spherical shot	66½	16	—	1400	200	Depth of indent 2·5″.
Rifled BL. 110-pr. (A)	81	7	Elongated "	111	14	—	1140	"	" 1·6″.
Rifled " "	"	"	" "	200	10	—	—	"	Indent too small to be measured.
Rifled ML. 120-pr. "			" "	140	20	—	—	"	Depth of indent 3·1″.
SB. Horsfall	tons 24	13	Spherical "	279½	74¼	1630	—	"	*Through target*; hole in plate 28″ × 25″, and in skin 3 ft. square.
"	"	"	" "	284	"	"	1290	800	Hole in plate 2′ × 1′·11″; penetrated to 12″.
			CHILLED CAST-IRON:—						
Rifled ML. 7-in. (A).	cwt. 134	7	Elongated RH. shot	104	25	1516	—	200	Hole in plate 8·5″ × 7·5″; penetrated to a depth of 9″.
Rifled "	"	"	" EH. "	101	"	1558	—	"	*Through target*; hole in plate 8″ × 7·5″, hole in skin 18″ × 14″.
			STEEL:—						
R. 70-pr. (W)	76	5	Elongated FH. "	71	12	1275	—	"	Through plate, and 3″ into backing.
SB. 68-pr.	95	8	Spherical "	74	16	—	—	"	Total indent 4½″ "
SB. 100-pr. (A)	125	9	" "	105	25	1653	—	"	Hole in plate 9″ × 9″, depth to shot 6·5″, skin cracked.
R. ML. 7-in. "	134	7	Elongated RH. "	104	25	1625	—	"	*Through target*; hole in plate 8″ × 7·5′, hole in skin 18″ × 12″.
R. ML. 130-pr. (W) [4]	148¾	6·4	" FH. shell	130	25	—	1268	600	*Through target*; hole in plate 8·5″ × 7·5″, and in skin 13″, fragments inside target.
"	"	"	" FH. shot	130	27	—	1204	800	*Through target*; hole in plate 8″ × 8·3″.
"	"	"	" FH. shell	151	27	—	1175	"	*Through target*; hole in plate 7·5″, and in skin 10″, fragments inside target.

SB. smooth-bored. R. rifled. (A) Armstrong. (W) Whitworth.
EH. elliptical head. Bursting charge of Whitworth's 130 lb. shell . . . . 3½ lbs.
FH. flat head. " " " 151-lb. " . . . . 5 "
RH. round head " " Armstrong's 610-lb. " . . . . 24 "

III. which will serve to illustrate the remarks made on the penetrations of projectiles in Chapter VI., Part II.

The advantage of high velocity, combined with better material for the projectile, is shown by comparing the effect produced by the 7-in. cast-iron shot of 111 lbs. fired with only 14 lbs. of powder, and that of the steel 7-in. shot of nearly equal weight, 104 lbs., fired with a 25-lb. charge, giving a very high velocity. The immense cast-iron ball of the monster Horsfall gun failed to penetrate the target at 800 yds., but a Whitworth steel projectile of less than half the weight, and fired with less than half the charge, punched the target with ease at the same range, the increased effect being due to the elongated form of the latter shot, and to its being made of a better material. The advantage of the elongated form, with projectiles of the same material, is clearly shown by comparing the respective effects of the 105-lb. ball and the 104-lb. elongated shot, both having been fired with 25 lbs. of powder. The trifling result produced by a heavy shot and a very small charge ($\frac{1}{20}$ weight of shot) may be observed by referring to the case of the 200-lb. shot fired with 10 lbs. of powder.

The following are some of the results of more recent experiments against wrought-iron targets:—

To perforate wrought-iron unbacked plates up to about 5·5 in. thick the same *energy* is required, whether hemispherical-headed steel or ogival-headed Palliser shot are used; if, however, the plates be backed, the latter has an advantage in the proportion of 10 to 9.

If the fire be *direct*, an *energy* of about 60 foot-tons per inch of shot's circumference is necessary to penetrate completely the *Warrior* target with a hemispherical-headed steel shot, but only about 54 foot-tons with a Palliser shot. Should the target be inclined at an angle of 60°, the steel shot would require about 81 foot-tons, and the Palliser shot 73 foot-tons per inch.

A Palliser shot, 250 lbs., fired from the 9-in. ML. R. gun with a charge of 43 lbs. has completely perforated a target consisting of an 8-in. plate on the *Warrior* backing when fired *direct* at a range of 200 yds. Striking obliquely at 60°, it failed to penetrate. When the charge was reduced to 23 lbs., the same projectile perforated an ordinary *Warrior* target at 200 yds.

A Palliser shell of 115 lbs. fired *direct* from the 7-in. ML. R. gun, with a reduced charge of 13 lbs., completely penetrated the *Warrior* target; when the target was inclined at 60°, the same projectile failed to penetrate with an increased charge of 20 lbs.; with 22 lbs. charge the Palliser shot perforated the target at the same angle.

The conclusion has also been drawn from other experiments 'that Palliser projectiles can easily perforate (unbacked) plates thicker than their own diameter with battering charges.'[5]

In an experiment against the *Hercules* target, in 1865, with 10·5-in., 10-in., 9·22-in., and 13-in. ML. R. guns, the latter firing chilled shot weighing as much as 578 lbs., with 100 lbs. charges, it was found that the structure was practically impenetrable; the 13-in. gun was fired at 700 yds., and the other pieces at 200 yds. range.[6]

[5] *Short Notes on Professional Subjects*, p. 57.

[6] An account of this experiment is given in the *Proceedings of R. A. Institution*, vol. v. p. 107. The following targets represent the different modifications made from time to time in the construction of ship armour, to enable it to withstand the constantly increasing power of heavy rifled ordnance as shown in the numerous experiments carried on during the last few years at Shoeburyness and Portsmouth.

The *Hercules*, constructed in 1865, consists of 8 or 9-in. iron plates, backed by 12 in. of wood, having $\frac{3}{4}$-in. horizontal iron girders 2 ft. apart, and behind this two $\frac{3}{4}$-in. plates, 28 in. of wood, and a $\frac{3}{4}$-in. iron skin. This was the strongest ship target then constructed, but was not intended as a covering for the whole of a ship's side, but merely to serve as a belt to protect the water-line.

The *Lord Warden*, made in 1863, is a $4\frac{1}{2}$-in. iron plate backed by 10 in. of wood, a $1\frac{1}{2}$-in. plate, and behind this $20\frac{1}{2}$ in. of wood.

The *Bellerophon*, constructed in 1863, is made of a 6-in. iron plate, 10 in. of wood with horizontal $\frac{1}{2}$-in. plates 2 ft. apart, and two $\frac{3}{4}$-in. plates.

The *Minotaur*, made in 1862, is a $5\frac{1}{2}$-in. plate backed by 9 in. of wood, and a $\frac{5}{8}$-in. skin.

The *Warrior*, constructed in 1861, consists of a $4\frac{1}{2}$-in. plate, backed with 18 in. of wood, and a $\frac{5}{8}$-in. skin.

The respective weights, per square foot, of these different targets are—

	lbs.
Hercules (with 8-in. plate)	652
,, (with 9-in. plate)	689
Lord Warden	483
Bellerophon	393
Minotaur	349
Warrior	341

[Stronger

A so-called *Hercules* shield was, during an experiment in Russia in 1870, completely penetrated by a steel shell[7] from an 11-in. *Krupp* gun; but it has been pointed out that 'the Russian target consisted of a backing of 39 in., protected by 9-in. and 6-in. armour plates, whereas the English target had a backing of 43·75 in., and was protected by 9-in. and 8-in. plates.'[8]

In 1871 a target, No. 33, consisting of:—

8-in. iron plate,
6-in. teak backing,
5-in. iron plate,
6-in. teak backing,
1½-in. iron skin;

that is, 13 inches of iron plate supported by 12 inches of wood backing and 1½-in. skin, was penetrated by the Palliser cored shot of both 10 and 11-in. ML. R. guns at 200 yds. range,[9] and by the shot of the 11-in. gun, fired with a charge of only 75 lbs., so as to give a final velocity equal to that at 1200 yds. with a battering charge.

But in 1871, two turret targets, No. 34 and 35, consisting of:—

No. 34.	No. 35.
14-in. iron plate,	8-in. iron plate,
9-in. vertical oak balks,	9-in. vertical oak balks,
6-in. horizontal do,	6-in. iron plate,
Two ⅝-in. plates (iron skin);	6-in. horizontal oak balks,
	Two ⅝-in. plates (iron skin);

Stronger armour than that of the *Hercules* has now been made; a description of that of the *Glatton* is given on page 324.

[7] The projectiles for Krupp's guns are usually coated with lead attached mechanically by undercut grooves, but on those intended for penetration the lead coating is very thin and attached by zinc.

[8] Extracts from *Proceedings of Director-General of Ordnance*, vol. viii. p. 55. The *Hercules* target is somewhat similar in construction to the *Chalmers* target, which was so favourably reported on by the Iron Plate Committee in 1864. Mr. Chalmers' principle was to lessen the thickness of the front plate, and put the metal saved into a second plate in the backing, and into very thin horizontal plates, to support and confine the timber between them. Two of the Chalmers targets were, however, in February 1869, completely penetrated by Palliser projectiles from a 9-in. gun, when similar projectiles failed to pass through an 8-in. plate on a *Warrior* backing.

[9] *Proceedings of Department of Director of Artillery*, vol. ix. pp. 181, 247.

both having the iron plates bent to a radius of 15 ft. 7½ in., and a total thickness of 30¼ in., including 14 in. of iron plate, successfully resisted the fire of the ML. R. 10, 11, and 12-in. guns with Palliser projectiles and battering charges (pebble powder) at 200 yds. range, although they afforded but little margin of protection. Both targets gave practically the same protection. The Committee, under whose directions the experiments were made, expressed a preference for the latter construction, on the following grounds—that the double plate system admits of the employment in turrets of armour plates of a breadth equal to the height of the turret;[1] that through joints can thus be dispensed with; that the bolting and securing of the structure is facilitated; that thin plates can be made of better and more uniform quality than thick plates; that the cost is less; and that the resistance does not appear to be practically affected.[2]

There appeared to be but little practical difference in the perforating powers of the 12 and 11-in. 25-ton guns fired with the same charges (85 lbs. P.), the total work done by the 12-in. being, however, greater than that done by the 11-in. gun.

As these experiments gave no information in several important points of turret construction—such as the effect of the shock of heavy blows upon the turning machinery, the result of shot striking near the junction of the deck and turret, &c.—the *Glatton*, one of the strongest vessels recently constructed for coast defence, was subjected, in July 1872, at Portland, to the fire of the 12-in. (25-ton) ML. R. gun with Palliser shot and battering charges; the gun was on board the *Hotspur*, which was moored 200 yds. from the *Glatton*.

The hull and part of the turret of the *Glatton* are protected by 12-in. plates on wood backing, but the port side of the turret, against which the fire was directed, has 14-in. curved plates, 17 in. of teak backing, and a skin of two ⅝-in. plates; this is supported by strong horizontal and vertical girders, and an inner lining over all of ¼-in. plate. The structure is therefore slightly stronger than No. 34 target.

[1] 14-in. plates of such breadth would be difficult to obtain.

[2] *Proceedings of Department of Director of Artillery*, vol. ix. p. 187. The details of these experiments are given at pp. 94 to 101, and 184 to 186.

Three shot struck the turret—(1) at the top, cutting away two stanchions: (2) near the horizontal joint of the 14-in. plates, forcing them 3 in. apart; the point of the shot penetrated through the 14-in. plate, making a vertical split through it; the inner lining was stripped off behind three vertical ribs, which were bent, and one broken; the double skin was distorted and cracked; a heavy bolt-head was driven through the skin, and a large number of rivet-heads were forced off into the interior of the turret: (3) the glacis plate, and rebounded on to the lower armour plate, which it penetrated to a depth of 13½ in.

The general deduction from the experiment seems to have been that the structure is capable of resisting successfully the fire of the 12-in. gun, for although one struck on a weak place, and another at a part where serious damage might have caused the turret to jam, none of the projectiles made their way into the interior of the turret, nor were the gun-carriage or turning gear of the turret injured. It must, however, be remembered that had two of the shot struck the strongest portion of the armour nearly in the same place, one would doubtless have passed through into the turret; and that the 12-in. armour of the other part of the turret or of the hull could be easily pierced by 10, 11, or 12-in. guns.

It has been stated[3] that 12-in. solid plates, with 18 or 26 in. of wood backing, and a skin of ⅝ or 1 in. thick, have recently been pierced by projectiles from German (Krupp) 10-in. and 11-in. guns. Lieut.-Col. E. Reilly, R.A., has, however, given[4] details of experiments carried on at Tegel, in August, 1872; from these it appears that the projectile, weighing 414 lbs., of the 26 *c.m* (10¼-in.) gun, fired with a charge of 70·5 lbs., pierced completely 10 inches of iron, 18 inches of oak backing, and a ⅝-inch iron skin at a range of 164 yds., but failed with

[3] See *Guns* versus *Armour*, in the *Times* of Oct. 30, 1872; and the *Pall Mall Gazette* of Oct. 28, 1872.

[4] In *Notes on a Visit to Berlin, Dec.*, 1872. Lieut.-Col. Reilly, in these *Notes*, compares the British ML.R. 7, 8, 9, 10, and 11-in. guns with the German BL.R. 17, 21, 24, 26, and 28 *c.m* guns, and shows that although the *muzzle energy* of the German projectile is rather greater than that of the British projectile, taking the guns in pairs, the former does less work in penetration than the latter; and he points out that this inferiority is said to be due to the additional resistance caused by the lead coating of the German projectile in its passage through the target.

a charge of 72·7 lbs. to pierce 12 inches of iron on the same backing; also, that the projectile, weighing 513 lbs., of the 28 *c.m* (11-in.) gun penetrated completely the same 12-inch target, with a surplus of unexpended power. These projectiles (Grüsen's) are chilled in casting, and have lead coating and ogival head; their performances are inferior to those of our 10, 11, and 12-in. projectiles against No. 33 target. More powerful guns than these are, however, now in our service. The 12-in. gun of 35 tons was fired, on 20th June, 1872, at Shoeburyness, with large-cored Palliser shot of 699 lbs. and 110 lbs. charges, against No. 33 target strengthened with a 4-in. plate secured on the front, thus giving a total thickness of 18½ in. of iron and 12 in. of wood backing; the range was 70 yds. The target was driven back, and completely penetrated by the head of the shot.

Lieut. English, R.E., has given[5] a diagram to show the greatest calculated thicknesses of armour plate which can be perforated by Palliser shot; and if this be compared with the velocities given in Table X., Appendix, it would appear that, at 200 yds. range, our heavy ML. R. guns can with Palliser shot pierce wrought-iron plates thicker by rather over 1 in. than the calibre of the gun; and at 1000 yds., plates rather thicker than the calibre.

7. Ironclad vessels, by keeping at a considerable range, would not be liable to serious injury from the fire of even powerful rifled guns; but they might be much annoyed by vertical fire from heavy mortars, which, notwithstanding its inaccuracy (to be decreased by the introduction of rifled mortars), might occasionally produce the most destructive effects by falling upon and piercing through the deck of a ship. To ascertain the penetration of 13-in. mortar shells through decks protected by iron plates, the following experiment was made in April 1870:—

The target consisted of iron deck-beams, covered half with 1-in. iron plating and 5 in. of wood, and half with 1½-in. iron plating and 4½ in. of wood. Two rounds were fired with 7 lbs., to give the *terminal velocity* with a 20-lb. charge—one at the 1-in. plating, and the other at the 1½-in. plating; both

[5] In a Paper 'On the Resistance of Armour Plates,' in *Professional Papers of Corps of Royal Engineers*, vol. ix.

being perforated, the timber behind being much cut up and the shells broken into large fragments. Two rounds were then fired with a charge of 3½ lbs.; one cracked the 1½-in. plating, and the other penetrated the 1-in. plating, the shells not being broken. In the experiment the shells were filled with sand, but with bursting charges between decks the destruction would no doubt be very great.

Experiments have also recently been made against a similar target (No. 32) representing a protected ship's deck with the ML. R. 9-in. gun fired with Palliser shell and battering charges. The target rested on piles on the sands at Shoeburyness, the angles of incidence of the projectiles being varied by raising or lowering one end.[6]

At 15° the shell did not explode, but a large hole was made through the deck, partly in one section and partly in the other. At 8° the shells deflected without exploding, but the iron skins were rent by the grazes. At 10° the shells burst on striking the iron, made a hole through, ripped up the planking, damaged the deck beams below, and covered the ground under the target with the fragments of shell and target. The target, therefore, failed to resist the fire, but it was said not to represent improved constructions.

8. In 1848 experiments were made to try the penetration of shot into water, when fired with small angles of depression towards its surface. Upon the results of these experiments Sir Howard Douglas made the following remark:—'In consequence of the loss of force which the balls in all these experiments sustained, it has been inferred that if a shot be fired with such a depression as a ship's gun will bear, it will not penetrate into water more than 2 ft.; and, consequently, that it will be impossible to injure a ship by firing at her under water. The correctness of this inference we must, however, be permitted to doubt till further experiments have been made. It is highly probable that conoidal shot would penetrate to a certain depth into the water, and strike the ship below the water-line.'[7]

[6] *Proceedings of Department of Director of Artillery*, vol. ix. p. 93.

[7] *Naval Gunnery*, p. 117.

This opinion of Sir H. Douglas has been borne out by later experiments. An elongated projectile fired from a Whitworth gun passed through 33 ft. of water, and then penetrated into the side of a ship through 12 or 14 in. of oak beams and planking.[8] Sir J. Whitworth, in a paper read before the British Association in 1868, gives the results of an experiment made by himself to ascertain the best form of projectile for penetration through water. He fired 3 forms—(1) with flat, (2) with hemispherical, and (3) with ogival head, from a 1-pr., at 7° 7′ depression, against an iron plate immersed in water. He stated that (1) passed through the water without deflection and struck the plate; (2) were deflected upwards, but struck the plate below water; (3) were deflected up so as to quickly rise from the water, and struck the plate some inches above it.

Experiments were made at Shoeburyness, at the end of 1871 and beginning of 1872, with the ML. R. 9-in. gun at angles of depression from 6° to 12° against targets under water at a range of 106 ft. Out of seven service Palliser projectiles, two ricocheted to long distances, the other five being found lying on the mud 48 yds. from the gun, and two of these five rose slightly from the water. Ten flat-headed shot were also fired; all ricocheted from one to four times except three, which were found in the mud from 45 to 64 yds. from the gun.[9]

[8] *Naval Gunnery*, p. 424.

[9] *Proceedings of Department of Director of Artillery*, vol. x. p. 26. Mr. R. Mallet pointed out in the *Engineer* of Jan. 25, 1867, that 'ogival' shot, and in a less degree the square-ended, as well as the spherical, all describe a curve in the water, hollow on its uppermost side, and *ricochet* out of the water again.

CHAPTER IX.

ACCURACY AND RAPIDITY OF FIRE.

1. Difficulty of estimating accuracy of fire.—2. Accuracy dependent upon size, density, and velocity of projectile.—3. Mean errors in range and deflection.—4. Captain A. Noble's comparison by rectangles.—5. Figure of merit.—6. Accuracy of fire of rifled ordnance.—7. Vertical fire from SB. mortars and R. howitzers.—8. Circumstances upon which rapidity of fire depend.—9. Rates of firing different guns.—10. Rate of firing at moving objects.

1. IN order to estimate the comparative efficiency of ordnance, it is very desirable to ascertain their relative precision of fire. To determine a satisfactory method, by which the results of practice from two guns may be compared, as regards accuracy of fire, is however a problem of some difficulty. If the object fired at be wide, but of small depth, deflections, unless very great, will be of small importance, so long as the ranges are regular; should the object be deep, and only present a narrow front, uniformity in range will be of little use, when the deflections vary considerably.

2. From what has been said in the Chapters on Gunnery, it must be obvious that the *larger* and *denser* the projectile (the same form being preserved), the greater will be the accuracy of fire; also, that the practice will be more accurate as the charge is increased;[1] for the *higher the velocity* the *less the angle* required for a *given range*, and consequently the greater the chance of the object intercepting the shot, and also the *longer the extent of ground covered by the shot* (or *splinters of shell*) both before and after the graze.[2]

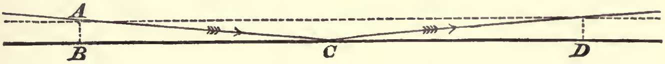
If AC in Fig. 137 represent the trajectory of a shot before

[1] Not in vertical fire with a constant elevation.

[2] In Piobert's *Traité d'Artillerie* are a number of tables giving the respective percentages of projectiles, fired from SB. guns of various natures, which at different ranges will strike a mark of certain size.

grazing at C, which at a low angle will not differ sensibly from a straight line, ABC is the *angle of descent* (a), and BC the ex-

Fig. 137.



tent of ground covered before the graze at a height AB above the plane.

$$\text{Then BC} = \frac{\text{AB}}{\tan a.}$$

As the angle of ricochet would be less than the angle of descent, in consequence of the projectile striking the ground, a comparatively non-elastic substance, more than BC would probably be covered after the graze, supposing the ground to be level, so that, for about twice BC, the shot would pass within a height of AB from the plane. It is then evident that the higher the initial velocity, and therefore the lower the angle of elevation, the flatter will be the trajectory, and the greater will be the extent of ground rendered dangerous to an enemy.

3. The *range* and *deflection* of a projectile have been already defined, but in considering the accuracy of fire of ordnance it is necessary to understand the following terms, which refer to a number of shot fired under the same circumstances, that is, with the same charge and at the same angle of elevation:—

The *mean range* is found by adding all the ranges together, and dividing the sum by the number of shot fired.

The *mean difference of range*, or the *mean error in range*, is thus found:—Take the difference between each range and the mean range; add the differences together, divide by the number of shot fired, and the quotient will be the *mean difference of range.*

To find the *mean deflection*:—Add together separately all the *right* deflections, and all the *left* deflections; subtract the smaller sum from the larger, and divide the difference by the number of shot fired.

The *mean reduced deflection*, or the *mean error in direction*, is found as follows:—Find the distance of each deflection from a line passing through the *mean deflection*; add these distances termed *reduced deflections* together, and divide by the number of shot fired for the *mean reduced* deflection.

Example:—Five shot, fired under the same circumstances, give the following ranges and deflection:—

Ranges yds.	Deflections yds.
1,010	4 Right,
1,060	1 ,,
1,040	2 Left,
1,020	5 ,,
1,030	3 Right.

$$\frac{\text{Sum of ranges}}{\text{number of shot fired}} = \frac{5{,}160}{5} = 1{,}032 \text{ yds.} = \textit{mean range.}$$

The differences between each range and the mean range are 22, 28, 8, 12, and 2, $=72$ yds.

and $\frac{72}{5} = 14{\cdot}4$ yds. *mean difference of range.*

Sum of right deflections $= 8$ yds.
,, left ,, $= \underline{7}$,,
1

$$\frac{1}{5} = {\cdot}2 \text{ yds. right} = \textit{mean deflection.}$$

Deflections from line through *mean deflection* are 3·8, ·8, 2·2, 5·2, and 2·8=14·8;

$$\frac{14{\cdot}8}{5} = 2{\cdot}96 \text{ yds.} = \textit{mean reduced deflection.}$$

The accuracy of fire of a gun must obviously be judged by the mean difference of range and the mean reduced deflection, and not by the mean range and mean deflection.

4. In order to ascertain the relative precision of fire of different ordnance in a more satisfactory manner than can be done by a mere inspection of tables of practice, Capt. A. Noble (late R.A.) proposed to apply the Theory of Probabilities to the calculation of an area or rectangle for each particular gun, so that a comparison of the respective areas would at once show the relative accuracy of fire of the several guns under trial. The area, being derived from the results of practice with the gun, represents a space within which there would be

an equal chance of any shot fired from the gun striking; or, if a given number of shot were fired, half of the number might be expected to fall within the area.[3]

If a be the length, and b the width of the area or rectangle required,

$$a = 3{\cdot}12 \times {\cdot}8453 \; \frac{\text{sum of differences of ranges}}{\text{one less than number of ranges}},$$

$$b = 3{\cdot}12 \times {\cdot}8453 \; \frac{\text{sum of reduced deflections}}{\text{one less than number of deflections}}.$$

5. The relative precision of small arms is decided by what is termed the *figure of merit*, or *the mean radial distance* of the shots from the centre of the group on the target. The method of determining the *figure of merit* is as follows:—

The horizontal distance of each shot upon the target from a fixed vertical line or axis (as one side of the target) is first found, and a mean horizontal distance obtained, by dividing the sum of the distances by the number of shot; the same process is followed to obtain a mean vertical distance from a fixed horizontal line or axis (as the bottom of the target). The intersection of two lines drawn parallel to the bases respectively, and at distances equal to the horizontal and vertical mean distances already found, gives what is termed the *point of mean impact*. The absolute distance of each shot from the *point of mean impact* is then measured; these distances are added together, and the sum, divided by the number of shot on the target, gives the *figure of merit*. Half a diagonal is allowed for every shot that does not strike the target.

This method might be applied to the fire of ordnance, by reducing the grazes to an imaginary vertical target, the angles of descent being assumed equal for all shot fired with the same elevation.

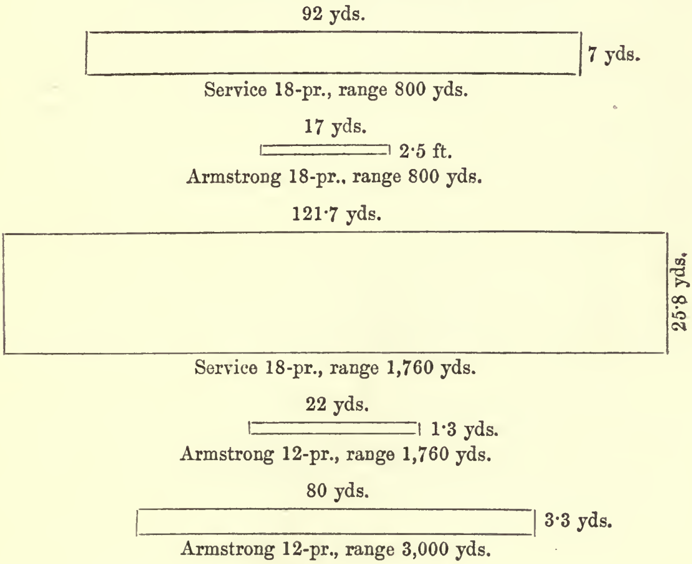
6. We have only to consult the Reports of Practice from

[3] 'The Application of the Theory of Probabilities to Artillery Practice,' by Capt. A. Noble (late R.A.), F.R.A.S., in the *Occasional Papers of the R. A. Institution*, vol. i. p. 173. It has been objected that this method of comparison does not allow for vertical errors; also that equal areas may be constructed from different errors in ranges and deflections: thus, an area 18 yds. long and 1 yd. wide = area of 9 yds. long and 2 yds. wide, and it would in many cases be difficult to decide which area represented the most accurate practice.

rifled guns, and compare them with those from smooth-bored pieces, to observe what an immense advantage has been gained in *accuracy of fire* by the adoption of the former. As good practice can now be made at 3,000 yds. with rifled guns as could formerly have been obtained at a range of 1,500 yds. with smooth-bored ordnance; and, with projectiles from the former, a 9-ft. target may, when 1,000 or 1,100 yds. distant from the gun, be struck nearly every time.[4] That these statements are not mere opinions may be seen from the following *probable rectangles*.

The following areas, or *Probable Rectangles*, as they are termed, were calculated by Captain A. Noble from the results of practice at Shoeburyness:—

Diagrams of Comparative Error.



The comparison given below, of the mean errors in range and direction of the projectiles fired from the best shooting SB. and rifled guns respectively, also shows plainly the great superiority of the rifled guns in precision of fire.[5]

[4] About 90 per cent.

[5] Tables showing the errors in range and direction of projectiles fired from the

Range	Nature of gun	Mean error in range	Mean error in direction
yds.		yds.	yds.
1000	SB.	43	4.0
,,	Rifled.	19	·3
2000	SB.	60	10·0
,,	Rifled.	21	·7

In order, however, to secure great accuracy of fire, supposing the powder to be of uniform quality, the gun must be fired under the following favourable circumstances, viz. :—

(1) The gun-carriage must stand upon a level and sound platform.

(2) The distance of the object must be known.

(3) There must be sufficient time to allow of the gun being *laid* with care.

(4) The air must be still, there being little or no wind,

(5) There must be neither mist nor smoke, the latter, in general actions or bombardments, being often very dense.

At very short ranges, up to 300 or 400 yds., especially in rapid firing, the smooth-bored guns make as accurate practice as the rifled pieces. If the distance be unknown, a *range-finder* should be used to ascertain it, for no shot should be thrown away.

Projectiles fired from rifled guns deviate very considerably after grazing, the deflection varying with the velocity of rotation, the nature of the ground, &c.; and, therefore, in certain

French rifled field guns, also the number of shot out of a certain number of rounds which strike various targets at different ranges, are given in the *Aide-mémoire portatif*, 1864; the results are, however, in some cases very discordant. The ranges and accuracy of the German BL. R. 4-pr., and the British ML. R. 9-pr., were found to be as follows:—

Gun	Elevation	Mean range	Mean error in range	Mean error in direction
	°	yds.	yds.	yds.
BL. 4-pr.	2	1043	13·8	0·6
,,	5	1934	18·9	1·3
,,	10	3049	19·9	1·5
ML. 9-pr.	2	1131	19·0	0·8
,,	5	2171	26·9	1·8
,,	10	3480	31·7	3·6

(*Report of Committee on German* 4-prs., p. 4.)

cases, as for instance in firing at an object of little breadth, this deflection will evidently impair the accuracy of fire; for if a shot strikes short it will, most probably, ricochet wide of the object. With regard to this point, Sir H. Douglas remarked 'that the effect of ricochet with elongated projectiles is lost, or cannot be relied upon, either by land or by sea, in general actions; and, consequently, that efficient use of rifled cannon ceases at the first graze, and, therefore, that good secondary effects can only be obtained by the projectile being enabled to act as a shell when it is no longer efficient as a shot.'[6]

Shell-fire having now become general for almost all artillery purposes, the deflection of elongated projectiles after grazing is comparatively unimportant.

7. Vertical fire is of all practice from ordnance the most uncertain as regards precision. The chief causes of the inaccuracy of vertical fire are—that the shells, having comparatively low velocities but long *times of flight*, are peculiarly liable to considerable deviations from wind and other disturbing causes, that the angles of descent of mortar shells, fired at the usual angle of 45°, are so great that, unless the object be of some extent, an error in range of a few yards might render the shell useless, whereas when a projectile is fired at a low angle of elevation, so much ground is covered by it before and after grazing, that an error of some yards *under* or *over* would not generally be of much consequence; also, that it is difficult in practice to ensure the requisite care in weighing out the charges. In vertical fire, as the object cannot be seen and the piece is generally short, it is very difficult to *lay* the mortar exactly in the same line for a number of rounds; but if the *laying* could be performed with the greatest accuracy, irregularities must always occur in practice with projectiles fired at high angles and with low velocities.

Piobert[7] makes the following remarks relative to the accuracy of vertical fire:—

'Firing mortars on the practice ground is generally carried on at the angle of 45°; the object against which it is directed

[6] *Naval Gunnery*, Article 243, p. 231.

[7] *Traité d'Artillerie*, p. 275, partie élémentaire et pratique.

is a cask raised eight or ten yards above the ground, and supported by a vertical pole, the foot of which forms the centre of two circles of four and eight yards in diameter. The numbers given in the following table are the result of a very large number of shells fired.

'In firing at a powder magazine 38 ft. long, $16\frac{1}{2}$ ft. wide, and 14 ft. high, at the distance of 656 yds. from the battery, the 12·6-in. mortars struck it $4\frac{2}{3}$ times out of 100 rounds at 45° elevation, and $1\frac{3}{4}$ times at 60°; the 10·63-in. mortars struck it $5\frac{1}{2}$ times at 45° elevation, and $3\frac{3}{4}$ at 60°.

Probability of Fire of Mortar Shells.

	Calibre of the mortars	Distance of the object	Percentage of shells which struck the mark				
			Cask	Pole	Small circle	Large circle	Total
	in.	yds.					
Practice during 30 years	12·6	656	0·07	0·18	1·24	2·71	4·20
		547	0·09	0·24	1·55	3·50	5·38
		437	0·10	0·29	4·03	0	4·42
	10·63	656	0·06	0·17	1·18	2·60	4·01
		547	0·07	0·21	1·40	3·12	4·80
		437	0·08	0·26	3·52	0	3·86
	8·661	656	0·03	0·08	0·53	1·16	1·80
		547	0·04	0·11	0·70	1·49	2·34
		437	0·05	0·16	2·44	0	2·65
Practice during 8 years	5·905	547	0·04	0·14	0·72	1·86	2·76
		437	0·07	0·32	2·27	0	2·66
		382	0·15	0·49	2·96	0	3·60
		328	0·16	0·50	3·02	0	3·68
		272	0·24	0·77	4·67	0	5·68
		218	0·25	0·88	4·96	0	6·09
		163	0·29	0·94	5·67	0	6·90
		109	0·51	1·54	9·23	0	11·28
		65	0·75	2·45	14·76	0	17·96
		33	0·98	3·17	19·01	0	23·16

'In firing at the epaulment and terreplein of a battery of three pieces, at distances varying from 629 to 700 yds., out of 100 rounds the 12·6-in. mortars struck it from seven to eight times, the 10·63-in. from seven to fourteen times, and the 8·66-in. five or six times.'

The following table will show the advantage gained as regards accuracy by the use of a rifled piece for vertical fire.

The practice was carried on towards the end of 1871, at Shoeburyness, from the ML. R. 8-in. howitzer.[8]

Charge	Elevation		Time of Flight	Mean Range	Mean Error in range	Mean Error in direction
lbs.	°	′	secs.	yds.	yds.	yds.
1	40	41	9·3	491	6·0	2·1
2	40	19	13·6	1033	3·0	2·4
4	40	9	19·3	2116	40·3	1·1
6	40	6	24·7	3469	45·6	5·2
8	40	5	27·4	4283	45·0	10·4
10	40	5	30·1	5134	21·5	5·0

8. The rate at which ordnance can be efficiently served, that is, loaded and *laid* with care, depends upon a variety of circumstances; such as, the proficiency of the gunners in drill, the description of carriage or platform, the state of the weather, the range, the nature and amount of the enemy's fire upon the battery, &c. At practice for instruction the numbers are constantly changed, so as to give each gunner of the detachment a knowledge of the respective duties of all the numbers; but such changes are not made in action, as they would be prejudicial to the effects produced by the fire of the battery, the rapidity and accuracy of which depend chiefly upon the efficiency of No. 1.

9. The following are the average rates of firing different ordnance with well-drilled gunners, when the piece is *laid* at each round:—[9]

		Rounds	Minutes
SB. Guns.	Heavy guns, on dwarf platforms . .	10 in	15
	do. casemate . .	do. „	13
	do. {standing carriages on ground platforms}	do. „	20 to 30
	Siege guns, on Clerk's platforms . .	do. „	10
	Field guns	do. „	5
BL. Rifled.	7-in. on traversing platform	do. „	11½
	40-pr. (screw) on Clerk's platform .	do. „	7½
	do. (wedge) do. . .	do. „	6
	12-pr.	do. „	5

[8] *Proceedings of Department of Director of Artillery*, vol. ix. p. 276.

[9] These rates are taken from the results of practice at Shoeburyness, given me by the late Capt. F. Lyons, R.A., and by Lieut.-Col. R. Curtis, R.A.

Without *laying* the guns can of course be served with much greater rapidity; thus

			Rounds	′	″
	SB. 68-pr.	on traversing platform	10 in	6	0
BL. Rifled.	7-in.	do.	do. „	5	50
BL. Rifled.	do.	on naval slide	do. „	7	20
BL. Rifled.	64-pr.	on traversing platform	do. „	4	55
BL. Rifled.	12-pr.	. . . .	do. „	2	0

In the trial of the 9-pr. (bronze) for Indian service, fifty rounds were fired in thirteen minutes, making twenty-seven hits on a 9-ft. target at 1,000 yds. Such practice is, however, very exceptional even under the most favourable circumstances; thus at Shoeburyness, in July 1871, at a similar target and range, the German 4-pr. took 10 mins. 18 secs. to fire twenty-rounds, and made thirteen hits; the service ML. R. 9-pr. took 8 mins. 20 secs. for the same number of rounds, and made twelve hits. In September 1871, at Shoeburyness, twenty rounds were fired in the time and with the effect stated below, the range being 1,800 yds. and the target 9 × 9 ft.[1]

		Mins	Hits
BL. R.	12 pr.	10·4	1
ML. R.	9 pr.	10·9	1
ML. R.	16 pr.	13·6	6

In firing plugged common shell, as rapidly as case shot, the German 4-pr. fired eight rounds, and a ninth in the gun, in 3 minutes; the ML. R. 9-pr. eleven rounds in the same time.[2]

Shells cannot be fired so quickly as shot, for the fuzes require preparation and adjustment; with *percussion* fuzes, the latter only being required, more rapid practice can be made than with *time fuzes*. In an experiment in 1870, seven rounds were fired in three minutes from both a 12-pr. BL. R. and a 9-pr. ML. R. gun, with segment shell and percussion fuzes; with shrapnel and time fuzes, the fire was slower, four rounds being fired from the BL. 12-pr. and $5\frac{2}{3}$ from the ML. 9-pr. in three minutes.

[1] *Proceedings of Department of Director of Artillery*, vol. ix. p. 295.

[2] *Report of Committee on German 4-prs.* p. 4.

10. The rate of firing at moving objects with heavy guns is shown by the following experiments. A ML. R. 9-in. gun on a casemate slide was fired at a 5-ft. target, moving at the rate of $3\frac{1}{2}$ miles an hour,[3] the range was 1,000 yds., and the racers allowed of the gun traversing, so that the target was under fire for a distance of 750 yds.

Five rounds were fired in 4′ 52″, the third shot hitting the target.

When the target moved at the rate of seven to eight miles an hour, five rounds were fired in 3′ 22″, the fourth shot hitting the target.

The gun was traversed with tackles, and it was observed that every shot would have hit a gunboat or even a man-of-war launch.

A ML. R. 12-in. gun on a turntable was fired five rounds through a port representing the embrasure of a fort, and was laid carefully at every round at a target at 1,000 yds. range; the time was 7′ 39″, or about $1\frac{1}{2}$ minute for each round.[4]

It must, however, always be remembered that accuracy of fire should never be sacrificed to rapidity.

[3] The target is drawn by horses with a rope 150 yds. long.

[4] *Short Notes on Professional Subjects*, p. 49.

PART III.

ORGANISATION AND USE OF ARTILLERY IN WARFARE.

CHAPTER I.

PROGRESS OF ARTILLERY IN THE SIXTEENTH, SEVENTEENTH, AND EIGHTEENTH CENTURIES.

1. Different branches of artillery.—2. Improvements in artillery *matériel* dependent upon progress in mechanical arts. Sixteenth Century: 3. Artillery *matériel* at the beginning of the century.—4. First use of cannon.—5. Gunnery considered a mechanical art.—6. Artillery train.—7. Employment of artillery in the field.—8. Progress made during the century. Seventeenth Century: 9. Introduction of light artillery by Gustavus Adolphus.—10. Artillery tactics of Gustavus.—11. Improvements in *matériel* towards the end of the century. —12. First creation of a distinct artillery regiment, Eighteenth Century: 13. Condition of artillery prior to Seven Years' War.—14. Artillery in the Seven Years' War.—15. Use of battalion guns.—16. Improved organisation of field artillery.—17. Reconstruction and simplification of artillery *matériel* by Gribeauval.—18. Reorganisation of artillery service by Gribeauval.—19. Suppression of battalion guns and formation of horse and field batteries.—20. Sieges and maritime expeditions.—21. Establishment of artillery schools.

1. In the following remarks there will be no attempt to give a history of artillery, which, to be complete, should include a full account of three distinct branches, viz.—

(1) Artillery *matériel*.

(2) Science of gunnery.

(3) Application of artillery as an arm.

The development of the second has been sketched in the first and second Chapters of Part II., while the results of recent gunnery investigations have been given in their proper places in subsequent Chapters of the same Part.

To go thoroughly into the first and third branches would require a separate treatise, and although those portions of the early history of artillery relating to the discovery of gunpowder or the first employment of ordnance are most interesting,[1] they are of less practical importance to an artillerist of the present day than a brief account of the progress made in the construction of *matériel* and the methods of organising and employing artillery during the last two or three centuries. In the following remarks upon the first and third branches, which will not, then, go farther back than the sixteenth century, an endeavour will be made to give a clear general idea of the amount of ingenuity, skill, and experience that have been required during a long period to bring modern artillery to its present efficient state as a separate and powerful arm of the service.

2. On inquiry into the circumstances which have influenced the development of artillery as a separate arm, it will be found that the more extended action and employment of ordnance in the field depended necessarily on the improvement of *matériel*. Until the guns were made of suitable size and weight, were mounted on carriages capable of being moved with ease, and were provided with the means of transport for a sufficient quantity of ammunition and stores, artillery could not be organised so as to manœuvre with troops of other arms. The many improvements in *matériel*, which have served to increase the effect of artillery fire and the mobility of the guns, have been chiefly due to the progress of physical science and advance in the mechanical arts, as well as to the more extended knowledge of the principles of gunnery.

Sixteenth Century.

3. It would appear that in the times of the Tudors the

[1] Two papers on 'Ancient Cannon in Europe,' written with great care and research by Lieut. (now Capt.) H. Brackenbury, R.A., will be found in the *Proceedings of the R. A. Institution*, vols. iv. and v. One of the most valuable and interesting works on the history of artillery is that written by the late Emperor Napoleon III., entitled *Études sur le Passé et l'Avenir de l'Artillerie.* Vols. iii. and iv. were continued by Col. Favé of the French artillery. In the *Proceedings of the R.A. Institution*, vol. ii. p. 155, a 'List and Description of old Guns and Mortars, English and Foreign, in the Royal Military Repository and in the Royal Arsenal, Woolwich, and in the Tower of London,' was given by Lieut. Edgar, R.A., M.A.

calibres of guns were much the same as those of the cast SB. ordnance of the present day; the pieces were generally made of bronze, they were much ornamented, and many had peculiar names, being called after birds or serpents.[2]

Some of the guns at this time were very long, as the powder was not grained. The carriages were heavy and unwieldy, and had no limbers. The projectiles were balls of lead, iron, or stone, and some of an incendiary nature. Shells (hollow spheres filled with powder), although employed for mortars, had not come into general use as projectiles for ordnance in the sixteenth century; hand grenades had been adopted.

On account of the weights of the guns and the unwieldy construction of the carriages, artillery was of little use in the field. Hence the introduction of *hand cannons*, which were fired from a rest, and could be served and carried by two men; also of *ribaudequins* or *organ guns*, consisting of a number of tubes placed in a row like those of an organ, forerunners of the modern *mitrailleuses*.

4. Artillery was at first used principally in the attacks on castles or towns. Mention is made of its employment in the field on various occasions, when it is probable that the moral effect produced by the noise of discharge was of almost as much importance as the slow and inaccurate fire of the guns.

When artillery came afterwards to be employed in the open country, it was necessary to assign it a place in the order of battle, but, as the pieces, of different weights and calibres, and mounted on clumsy carriages, all marched together under the orders of a chief of artillery and his lieutenant, the movements were slow and the tactics limited. Artillery was in fact a mere adjunct and not a component part of an army. The multiplicity of calibres and the defective supply of ammunition made the train of artillery little suited to field operations.

5. The service of cannon was for a long time considered merely a mechanical art. Men were apprenticed to the art by serving different pieces and firing at a target, after which they obtained a certificate, and were then in a condition to

[2] As the *falcon*, the *saker* (a kind of falcon), the *culverin* (from colubrine, a species of serpent), and the *basilisk* (from the serpent of that name).

offer their services to princes of different States. They were well paid and professed to keep their art secret. Charles V. issued an ordinance, in 1519, forbidding cannoniers and artificers to teach without permission.[3] Princes seldom maintained as many cannoniers as were necessary for a campaign: they borrowed them from foreign princes or towns.

6. From the works of Tartaglia and other authors, it appears that at this period the *heavier* pieces, the Cannon Royal, Serpentine, Culverin, &c., were generally used for *siege* or *garrison service*; the lighter *guns*, the Falcons, Falconets, and Sakers, for field service; but there was no attempt at distinct organisation or equipment.

The guns which accompanied an army were *assembled* into an *Artillery Train*, containing pieces of different weights and calibres, to meet the various requirements of a campaign; and a certain number of men with officers were attached to the train, some to serve the guns, others to move and mount them and effect repairs. In order to transport the train or move guns into position, horses or bullocks, and drivers, were hired in the country in which the operations were being conducted.

When an army encamped, a particular situation was assigned for the train, which, besides the guns, included a number of wagons, loaded with projectiles, ammunition, and implements, the whole forming the artillery park.

On the march the train was, according to Grewenitz, preceded by an advanced guard of light cavalry to protect it. The first portion of this troop carried hatchets and saws; the second, instruments and implements for the construction of machines; the third, sledge-hammers, iron wedges, and pickaxes; finally, the last were provided with pioneers' implements. After these came carriages loaded with gyns, capstans, levers, and other like machines; they were followed by the light pieces, by the heavy siege guns, by ammunition wagons, by pontoons and the necessary men for them, by the artillery artificers, and lastly by the baggage.[4]

[3] Cannoniers served the guns; artificers conducted vertical fire and made up warlike stores.—*Traité de l'Organisation et de la Tactique de l'Artillerie*, par le major De Grewenitz, traduit de l'Allemand par R. de Peretsdorf, p. 37.

[4] *Grewenitz*, p. 48. Lieut.-Col. F. Miller, R.A., gives an account of the different

7. On the field of battle, artillery tactics consisted simply in deploying the guns, usually in advance of the line of troops, when they fired a few rounds, but could rarely follow any movement of the army. In a retrograde movement, the guns were always liable to capture, as they could retire but slowly.

The following extract from the Ordinances of War[5] of the Margrave Albert I. of Brandenbourg will serve to illustrate the method of employing artillery in the sixteenth century:—'All possible means should be employed to bring the cannon into action quickly, and to assure their effects; when this is done the battle is soon gained. It is necessary above all things to place the large pieces between the masses of troops up to the moment of engagement, taking care to hide them from the enemy as much as possible, so that he may not be able to guard against their effect; for, thus disposed, they can be unyoked with as much facility as rapidity, and the gunners have sufficient time to fire one or several shots; after that they must be yoked again and made to advance. It is not doubtful but that these pieces, directed upon the true point of attack, well served and aimed, will procure the victory.'[6]

The principle of masking guns, and of placing them so that their fire is made the most of, was thus fully recognized; it is however evident that but few rounds could be fired.[7]

8. During the long wars at the end of this century, carried on in the Netherlands to throw off the Spanish yoke, little was done to develop the use of field artillery; but in the attack and defence of fortresses large numbers of heavy guns were required, vertical fire was much practised, and the fabrication of laboratory stores was considerably improved.

The proportion of guns to men in an army was laid down by tacticians of this period at 1 piece to 1,000 men.[8] Uffano, however, gives less—viz., 24 heavy and 6 light guns to an army of 34,000 infantry and 6,000 cavalry.

branches composing an English artillery train in the sixteenth and seventeenth centuries in an essay on the *Early Establishments of Artillerymen in England.*

[5] Of 1555.—*Grewenitz*, pp. 33, 34.

[6] *Grewenitz*, p. 34.

[7] The Margrave gave forty-two figures to represent different orders of battle, in which he never failed to indicate the place of artillery.

[8] *Grewenitz*, p. 43.

Seventeenth Century.

9. The introduction of small pieces, mounted on light carriages, and horsed so as to be capable of rapid movement, was the first step towards the division of the rude and unwieldy trains of former days into distinct classes of artillery, each having an organisation and equipment adapted to the peculiar service for which it is intended.

The first successful attempt to form a distinct field artillery—that is, one capable of co-operating with troops in their movements—was made by Gustavus Adolphus, who, early in the seventeenth century, in his wars with Denmark, Russia, and Poland, displayed great talents in the organisation of his forces. Comprehending the advantages to be derived from the employment of guns capable of *moving rapidly* and firing quickly, he took into Poland some light pieces made of copper, strengthened with leather and coiled rope; but before entering on his famous German campaigns, these were replaced by iron 4-prs., two of which were attached to each regiment and placed under the orders of the colonel.[9] The 4-prs. weighed 650 lbs., were drawn by two horses, and could be fired three rounds while the musket fired but one; the rapidity of fire was obtained by the use of cartridges, the ordinary method of loading being to insert the charge as loose powder by means of a ladle.[1] These pieces were at first intended to fire case, which were before only employed in flanks of fortified places and for naval warfare; but they soon came to be fired with balls. These light guns are said to have been of great service to Gustavus, especially at the battle of Leipsic,[2] September 7, 1631.

This, then, was the origin of the employment of battalion or regimental guns, which were gradually introduced into other armies, and held their place until they were superseded by the more powerful and complete organisation of the *battery*.

[9] *Grewenitz*, p. 50.

[1] Ladles were still used by the Austrians at the battle of Mollwitz, in 1741.

[2] Harte, in his *Life of Gustavus Adolphus*, says (p. 28, vol. ii.) that 'the victory was principally owing to the easy shifting and quick discharge of the newly invented leather cannon.' The leather cannon had, however, as stated above, been discarded at this time.

10. Besides the adoption of lighter and more efficient field guns, Gustavus introduced a new method of distributing his artillery: instead of ranging them along the front of the army according to the usual custom, he, in the battle of Lützen, in 1630, placed strong batteries of guns on the wings and in the centre of his line, an arrangement which has since been generally practised, and, being developed, has given rise to the division of field artillery into *brigades* and *batteries*.

Gustavus well understood the power of artillery, and accordingly increased greatly the number of his guns. In 1630 he had 80 guns for an army of 12,000 infantry and 85 squadrons of cavalry; before Frankfort he had 200 pieces; he forced the passage of the Lech in 1632 under the protection of 172 guns; and he took no less than 70 in his rapid march on Nuremberg.

11. Towards the end of the seventeenth century considerable and important changes were effected in artillery *matériel*. Both bronze and iron guns were cast in great numbers, especially in France; much attention was given during the reign of Louis XIV. to the improvement of the metals, and to the effect of varying the lengths and weights of pieces, and the form of chamber at the bottom of the bore; the calibres of the French guns were reduced in number, made uniform in size, and those adopted—viz., 33, 24, 18, 16, 12, 8, 6, and 4—have remained unaltered to the present day for French SB. ordnance, some of which have been rifled. The construction of the carriages was better adapted to the nature of the service for which they were intended. Siege and field carriages had heavy bracket trails, but were provided with limbers having a straight pintail at the top, like our old service siege limber; platform wagons were used to relieve the gun-carriages, and it is curious to find that wrought-iron field carriages and travelling mortar carriages were used by the French. For coast batteries a carriage similar to the present garrison standing carriage was employed.[3]

[3] An account of the artillery *matériel* used at this time, taken from Saint-Rémy's *Mémoires d'Artillerie*, published in 1697, is given in chap. x. vol. iv. of the *Études sur le Passé et l'Avenir de l'Artillerie*: it is illustrated with numerous excellent drawings.

The English and Dutch brought howitzers into the field; mortars were extensively used in sieges, but the manner of firing shells from them was primitive, one soldier lighting the fuze of the shell and another firing the mortar. Hand grenades were supplied to infantry, and it may be said that explosive projectiles commenced to take part in all operations of war. Canvas cartridges were pretty generally used for the charges of ordnance, and both case and grape shot were employed in the French service.[4]

12. To Louis XIV. artillery owes the creation of the first corps consecrated specially to its service. He raised, in 1671, a regiment of Royal Fusiliers destined for artillery service, composed of gunners and of workmen, regulations being made for the ranks and duties of the officers.[5] In Germany and other countries at the end of the seventeenth century cannoniers and artificers were generally united in companies, but did not yet form a special corps, being distributed in garrisons during peace time. Grewenitz observes that at this time artillery was considered in France as an arm and a science, although still looked upon elsewhere as a mere mechanical art; and as evidence of this he points to the formation of the special artillery force, and to the establishment of schools of instruction;[6] there had, however, been artillery schools in Italy and Spain long before this period.

Eighteenth Century.

13. The experience gained in the great wars of this century —viz., in that waged by the Duke of Marlborough and Prince Eugène against the French, in the Seven Years' War, and the

[4] Grewenitz states that two important inventions were made during this period—the elevating screw in 1650, and a tin tube for firing guns in 1697, which was used at the siege of Brussels in the same year.—*Traité*, p. 59.

[5] *Études*, vol. iv. p. 65; *Grewenitz*, p. 63. Two companies of artillery were first raised in England in 1716, but there had been permanent establishments of gunners (train) in the sixteenth century.—Lieut.-Col. Miller's *Essay on Early Establishments*. See also the *History of the Royal Regiment of Artillery*, vol. i. by Capt. F. Duncan, M.A. D.C.L. R.A. p. 81. An interesting account of the state of artillery in this country about the middle of the seventeenth century is given in a paper on the *Field Artillery of the Great Rebellion*, by Lieut. H. W. L. Hime, R.A.

[6] No trace of schools in Germany till 1740.—*Grewenitz*, p. 64.

wars of the French Revolution—led to the rapid growth of artillery in all its branches. The *matériel* was simplified and much improved, both as regards principles of construction and methods of manufacture; schools of instruction were established, and the organisation and equipment were gradually modified until the adoption of the modern system, which rendered possible the great results achieved with artillery by Napoleon and others during the present century.

In Marlborough's campaigns large numbers of guns were used on both sides, and in some instances with considerable skill. At Blenheim a strong battery placed on the right wing of the allied army enfiladed the French, greatly contributing to the victory; and at Malplaquet a battery of forty pieces was advanced in the centre by Marlborough. The greater mobility attained by artillery was shown in this action; for, although the French artillery continued its fire up to the moment of the assault on the entrenchments, only eight or ten guns were taken by the allies.

In 1732 important changes were made in the French artillery by Valière. The dimensions and charges of guns were determined on better principles, both field guns and carriages were lightened, and the different calibres in a train of guns were separated into brigades. Previous, however to the Seven Years' War field artillery was still too heavy and immovable, the pieces being dragged by the gunners on the field, the horses being kept under cover near them. Artillery was at this time separated into—

Regimental or Battalion Guns.
Artillery of Position.
Garrison or Siege Artillery.

The first were attached to infantry, at the rate of two guns to a battalion; the position artillery was usually distributed in several large batteries, in favourable positions, on the wings or in front of the line; and the siege guns were formed into a train, as at the present day.

14. It was during the Seven Years' War that artillery came to be recognised, both in Austria and Russia, as a *special arm*

deserving of a distinct and careful organisation. After the Austrian artillery had suffered severely in the first campaigns, it was re-organised by Prince Liechtenstein, who was appointed chief of artillery, and invested with rank and authority proportioned to the dignity of the arm.[7]

In France artillery was at this time in a deplorable state, in consequence of financial difficulties and official neglect; and in Prussia its condition was not probably better at the commencement of the war; for, as Decker observes, the sword and bayonet were the favourite weapons, and Frederic could not be expected to have a predilection for an arm which he considered but as an obstacle to his brilliant plans of attack, deranging as it did the mathematical regularity of his evolutions.[8] He appears however to have thrown off his dislike to artillery after the battle of Rosbach, in 1757, where it performed such good service; and it is to him the service is indebted for the first formation of horse artillery in 1759. The light battery, as it was termed, consisted of ten light 6-prs.; and although twice destroyed, at Künersdorf and Maxen, the king was not discouraged, but created it a third time. Prince Henry also formed a light battery which rendered him great services at the battles of Pretsch in 1759, and of Reichenbach in 1762.[9] The Russians, who have always considered artillery as a principal arm, employed large numbers of guns,[1] and each of their dragoon regiments had three *licornes*, or howitzers, attached to it, the gunners being mounted.

The pieces generally used for field service at this time were 3, 6, and 12-pr. guns, and 7, 10, and 25-pr. howitzers.[2] Frederic

[7] Decker, in his *Batailles et Principaux Combats de la Guerre de Sept Ans*, p. 7, says, with regard to this appointment, that 'in raising him to this post Austria made a giant's stride and advanced beyond Prussia by more than fifty years.' And on p. 8 he states that Prussia had no proper chief of artillery during the whole war.

[8] Decker's *Batailles et Combats*, p. 7.

[9] The Prussian light artillery nevertheless remained for a long time in a state of wretched mediocrity, there being no one who knew how to profit by the king's partiality for it. Decker says that it was for long a *bugbear* to the artillery commanders.—*Batailles et Combats*, p. 20.

[1] In their army of invasion in 1758 they had 425 guns to 104,000 men.

[2] These designations of howitzers were taken from the weights of stone balls which would respectively fit their bores; their shells weighed 15, 20, and 50 lbs.

was very partial to howitzers, and frequently endeavoured with his long 12-prs. to overmatch the enemy by weight of metal.

15. The tactics of the regimental or battalion guns have been described as follows:—The direction of the two pieces was entrusted to a corporal, who was obliged to obey implicitly the orders of the commander of the battalion; the latter was too much occupied with his men to think of the cannon. The consequence was that the two pieces marched peaceably behind the battalion, but upon arriving within 500 paces from the enemy they unlimbered and continued to advance, dragged by the men. It is very doubtful whether the corporal had any particular instructions; we only know that he had orders not to fire case until within 350 paces, and always to keep himself fifty paces in advance of the battalion, which, if beaten, usually entailed the loss of the guns from want of time to limber up.[3]

It is, however, satisfactory to find that the English artillery, even under such discouraging circumstances, succeeded in distinguishing itself. At the battle of Minden, in 1759, the British Field Artillery played an important part. It was more heavily armed than usual, a portion of it was divided into brigades of nine or ten pieces, and the rest served as battalion guns; the captains commanding the brigades of guns acted with independence and boldness.[4] Decker says: 'The English artillery was distinguished by its lightness (3-prs.), its elegance, and, above all, by the good quality of its materials. Its administration was never degraded by sordid economy. In the battle of Marbourg (July 31, 1760), although the English artillery was not horsed, it followed Lord Granby's cavalry at a trot, and was always ready to engage. When the French in retreat endeavoured to take up a position on the right bank of

[3] *Batailles et Combats*, p. 9.

[4] The brigades were as follows:—

Capt. Macbean's brigade (heavy)—10 medium 12-prs.

Capt.-Lt. Drummond's brigade—2 light 12-prs., 3 light 6-prs., and 4 howitzers.

Capt.-Lt. Foy's brigade— 4 „ 3 2 „

There were also 12 light 6-prs. with the six British battalions. Capt. Duncan's *History of the Royal Artillery*, vol. i. p. 212. In the previous campaigns of this century, 6 and 3-prs. were generally used for field-guns.

the Diemel, it was this artillery that stopped it. The English artillery, says Tempelhof, could not have been better served; it followed the enemy with such vivacity, and maintained its fire so well, that it was impossible for the latter to re-form.'[5]

16. From the experience of the Seven Years' War were derived three important steps in the organisation of field artillery:—

(1) The separation of position guns into batteries,[6] which were distributed among the brigades of infantry.

(2) The union of howitzers in separate batteries.

(3) The formation of light or horse artillery.

The Austrians do not appear to have distributed their position guns in batteries, but into four divisions, called *reserves*—one for the right wing, another for the left wing, a third for the centre, and the fourth as a *grand reserve*;[7] thus keeping a strong reserve of different calibres to meet the various exigencies of service. Their artillery possessed, however, a great advantage in having been always commanded by one officer of rank and influence, who knew its wants and capabilities, and not, like that of other Powers, often, as Decker remarks, entrusted to an ignorant and absolute stranger.

17. We now come to one of the greatest reformers of modern artillery, Gribeauval, who, having been wisely placed by France at the disposal of Austria, and entrusted with the command of artillery under Prince Liechtenstein, returned home possessed of a thorough knowledge of all improvements made in foreign artilleries. Being ordered by the Duc de Choiseul to reconstitute the French artillery, he proceeded, with the help of some officers, selected for their special knowledge, to elaborate a complete system, his leading idea being to create a distinct *matériel* for each service—field, siege, garrison, and coast.

For field service he had lighter pieces—12, 8, and 4-pr.

[5] *Batailles et Combats*, p. 23.

[6] The Prussian batteries consisted of ten, the Russian of five, and the British of nine or ten pieces.

[7] *Études*, vol. iv. p. 98.

guns, and 6-in. howitzers cast solid,[8] suppressing ornaments and bouching them with copper. To field carriages he gave greater mobility by the introduction of iron axletrees and higher wheels for the limbers; both field and siege carriages had bracket trails, and straight pintails on the top of the limbers, and the former had poles for draught. To facilitate the service of the gun, cross-headed elevating screws, tangent scales, and fixed ammunition were adopted, as also the *bricole* (collar with a rope and hook), for moving the carriage by hand, and the *prolong*, to unite the trail and limber when retreating slowly.

For siege and garrison service the 12 and 16-pr. guns, the 8-in. howitzer, and the 10-in. mortar[9] were adopted. The siege carriages were of nearly similar construction to the field carriages, but had shafts for draught; the garrison carriages had two wheels in front and a large truck in rear; and for coast batteries a traversing platform, with a bolt in front and a truck in rear to run upon a circular racer, was contrived. To obtain uniformity and precision, and to facilitate the repairs of stores, tables of dimensions were sent to the arsenals to be strictly adhered to, and everything was made interchangeable—felloes, naves, transoms, bolts, &c.

18. Besides the simplification and reconstruction of the *matériel*, Gribeauval entirely re-organised the *personnel* of the French artillery. By an ordinance of August 13, 1765, the following organisation was adopted:—

The guns of an army in the field were divided into two parts—one distributed as *regimental guns* among the battalions of infantry; the other formed in *two or three reserves* on the right, centre, or left of the infantry.

[8] Guns at this period were cast hollow by means of a core, which was kept suspended in the centre of the mould while the metal was being run in. Owing, however, to the great difficulty experienced in keeping this core in a perfectly true position, several artillerists deliberated whether guns cast hollow or solid had the preference, and investigations took place as to the possibility of boring the latter; the result of which was that Maritz, who had a foundry at Geneva, informed the Court of France, in 1739, that he had discovered a method of boring guns and mortars which had been cast solid. He was at once invited to France, and, first at Lyons, afterwards at Strasbourg, secretly worked at boring pieces of ordnance, which on trial proved perfectly satisfactory.—*M. S. S. Course of R. M. Academy.*

[9] Gribeauval adopted the 12, 10, and 8-in. gomer mortars in 1785.

The *reserve* artillery was separated into *divisions of eight pieces* of the same calibre, and a company of artillery was attached for the campaign to each.

Two guns were still distributed to each battalion, but a company of artillery was attached to each brigade of four battalions for the service of the pieces.

We thus find the company organisation, which has merged into that of the *battery*, and the establishment of the *artillery unit* by Gribeauval, as pointed out by Colonel Favé :—'Thus Gribeauval made the gun, munitions, and gunners an inseparable whole, which becomes the unit of field artillery. The realisation of this principle has been completed in our time by the addition to this unit of the horses and drivers requisite for the mobility of the piece.'[1]

The extensive changes studied and proposed by Gribeauval, and adopted in 1765, met with great opposition from many able officers eminent for their services, more than twenty publications investigating the large question in all its aspects. The consequence was that the system was abolished in 1772, but again submitted, in 1774, to the judgment of four French marshals, and, on their recommendation, definitely adopted the same year.[2]

19. The divisional organisation of the French army, adopted in 1793, adding to the mobility of troops, the battalion guns became more embarrassing, and the system of thus employing them was abandoned without official authorisation. Bonaparte, in his Italian campaign of 1796, entirely suppressed battalion pieces, and distributed all his guns among the infantry divisions.

Horse artillery was introduced into the French service in 1792, and the *divisions* were shortly after reduced from eight to six pieces—in the horse artillery first—as eight were found

[1] *Études*, vol. iv. p. 160.

[2] Gribeauval was made Inspector-General of Artillery in 1776, an appointment he kept till his death, in 1789, during which time he effected such improvements in the arsenals that artillery constructions were said to be in advance of those of industry. A full account of his system, and the discussion upon it, will be found in the *Études*, vol. iv.

too many for a company of men well horsed, and supplied with the most skilful drivers furnished by contractors.[3]

General Lespinasse showed in his writings the insufficiency of the organisation of contract transport. 'The artillery equipages could not be worse maintained than by the companies in whose charge they were in the different armies, since everywhere the carters were continually without bread, pay, clothes, and their horses without forage, shoes, and harness. Such, and worse still, was the condition of the artillery equipages of the army of (for the invasion of) England.' 'In this state of things the only means of having in armies artillery equipages which can be relied on was that the Republic acquired horses, and took carters and employés into pay as special troops attached to this service.'[4]

The necessity of providing soldier-drivers having been thus urged, an *artillery train* (or driver corps) was organised by an order of the Consuls on January 3, 1800, five companies being formed, and the best (*d'élite*) attached to the horse artillery.[5]

In the English service, previous to the establishment of the battery system, all the artillery of an army was formed into a field train including field and siege guns; the former were nominally divided into brigades of twelve pieces, with a company of 100 gunners, but they were distributed for fighting among the infantry at the rate of two per battalion. The horses were purchased or hired, and entrusted to conductors temporarily employed. So late as 1799 there were only two 6-prs., with one ammunition wagon, to a brigade of infantry; each piece was drawn by three horses in single draught and conducted by a driver on foot with a wagoner's whip. Horse artillery was, however, introduced in 1793, and driver corps in 1794; but the battalion guns were retained until 1802, when field batteries of six guns each were established, but called *brigades*, the term *troop* being applied to horse artillery batteries.[6]

[3] *Études*, vol. iv. pp. 182–186. [4] *Ib.* p. 188.

[5] The gradual improvement of field artillery as regards *mobility* has been fully treated by Capt. Hime, R.A. in a series of papers, which may be found in the *Proceedings of the R. A. Institution*.

[6] See *Equipment of Artillery*, by Major F. Miller, R.A., V.C., pp. 16, 17. The

20. The progress made in the organisation and equipment of field artillery during the eighteenth century having been traced, it will now be necessary to refer to the many occasions on which garrison artillery was employed in siege and maritime expeditions, which gave opportunities for the display, not only of the gallantry and endurance of the artillery companies engaged in them, but of skill and ingenuity in the mounting, transport, and service of heavy ordnance with their numerous stores and appliances.

The siege of Lille, the strongest place in French Flanders, in 1708, was an enterprise of the greatest danger and difficulty, owing to the large train of ordnance having to be transported by land over a distance of twenty-three leagues, with a powerful army threatening the flank. Prince Eugène was entrusted with the conduct of the siege, while the Duke of Marlborough commanded the covering army. The train consisted of 120 heavy guns, 40 mortars, 20 howitzers, and 400 ammunition wagons; it extended over fifteen miles on the line of march, and required 16,000 horses for its transport. The fortress, commanded by Marshal Boufflers, held out for sixty days, thirty of which were open trenches, and the citadel for six weeks longer. The losses were very great, especially on the side of the besiegers.[7]

Several maritime expeditions, in which the British artillery played an important part, such as the siege of Louisbourg in 1758, and that of Belleisle in 1761, are well described in Captain Duncan's 'History of the Royal Artillery.'

The siege of Gibraltar, which lasted more than three and a half years, from June 21, 1779 to February 2, 1782, was the most remarkable artillery operation of the time. The armament at the end of the siege, which was as follows, will give an idea of the natures of ordnance then employed in sieges:—

different troops formed the Royal Horse Brigade. In 1859 the term brigade was substituted for battalion, and battery for troops or companies, throughout the service. The term field battery was adopted from the Continent in 1826.

[7] Alison's *Life of the Duke of Marlborough*, vol. i. p. 407.

452 guns of 32, 26, 24, 18, 12, 9, 6, 4, and 3-pr. calibres,
70 mortars of 13, 10, 8, $5\frac{1}{2}$, and $4\frac{2}{5}$-in. calibres,
28 howitzers of 10 and 8-in. calibres.

Total 550 pieces.[8]

There being only five companies of artillery to serve this large number of ordnance, a small force of infantry was told off to assist the gunners. At the grand attack, the Spaniards had 47 sail of the line and 10 battering ships armed with 212 guns, besides 200 heavy pieces on the land side, and of these 300 pieces came into play; the garrison defended themselves against the combined naval and land bombardment with the fire of 80 guns, 7 mortars, and 9 howitzers, which expended over 8,300 rounds (more than half hot shot) and 716 barrels of powder. The total expenditure of ammunition during the siege was as follows:—

British		Spanish	
Shot . . .	57,163	Shot .	175,741
Shells . . .	129,151	Shells	68,363
Grape . . .	12,681		244,104 (of heavy natures)
Carcasses . .	926		14,283
Light Balls .	679	Total	258,387
	200,600	Exclusive of Battering Ships.	
Gun Boats	4,728		
	205,328		

The account of this siege, written by Captain Drinkwater, who took part in it, is of the greatest interest to an artilleryman, as it not only describes the various incidents in the trying life endured so long by the besieged, but gives all necessary details respecting the daily expenditure of ammunition, the experiments tried with guns, carriages, and projectiles, the contrivances for shelter for guns and men from the enemy's fire, and the losses inflicted. It will be sufficient to mention a few instances. The large number of shells fired by the British

[8] See Capt. Duncan's *History of the Royal Artillery*, and Capt. Drinkwater's *Siege of Gibraltar*.

is accounted for by the adoption of *horizontal shell fire*, as it was found that shot did little harm to the enemy's working parties, and the shells fired at high angles sank so deep into the sand that the splinters seldom rose to the surface; the horizontal fire of small shells ($5\frac{1}{2}$-in. or 12-pr.) proved very effective, and were sometimes made to burst over the working parties, at others to ricochet along the track by which the Spaniards brought stores in carts or on mules. The plan was also adopted of sinking a 13-in. mortar, five 32-pr. guns, and one 18-pr. gun, and securing them with timber, the mortar at 45°, the guns at 42° elevation, in order to fire shells into the Spanish camp and artillery park.

The artillery of the fortress set the Spanish batteries on fire and burnt large portions of them on many occasions by means of carcasses, or carcasses and red-hot shot. The effect of the hot shot was however said to be most valuable at the grand attack against the battering ships, most of which were set on fire and several blown up by them. It is however probable that some of these conflagrations were due to shells and carcasses, although all are usually attributed to hot shot. The battering ships were strengthened on the larboard side with shields 6 or 7 ft. thick, consisting of green timber bolted with iron, cork, junk, and raw hides; and the decks were protected with bomb-proof roofs inclined so that the shells might slide off.

Experiments were made with light balls and a depression carriage, the latter a valuable contrivance for a fortress like Gibraltar; also with stone shells for the 13-in. mortars, which however did not answer. A supply of carcasses was provided by boring three holes in the enemy's shells and filling them with composition. Captain Drinkwater thus speaks of the services performed by the artillery: 'The exertions and activity of the brave artillery, in this well-fought contest, deserve the highest commendations. To their skill, perseverance, and courage, with the zealous assistance of the Line (particularly the corps in town, the 39th and 72nd regiments), was Gibraltar indebted for its safety against the combined powers, by sea and land, of France and Spain.'[9]

[9] Drinkwater's *Siege of Gibraltar*, p. 290.

In these sieges, in some of which British artillery was employed for attack and in others for defence, much valuable experience in moving and serving heavy ordnance, and in the use of various kinds of projectiles and stores, was obtained, and the necessity was shown of improving the construction of artillery *matériel*, and of examining the principles of gunnery. The way was thus prepared for the experiments and investigations of Robins and Hutton, who, as before pointed out, laid the foundations of the science of gunnery.

21. As artillery thus increased in importance and in the amount and complication of its *matériel*, it was not only necessary to give it a suitable organisation, but to provide the means of instruction for both officers and men. The French established artillery schools and polygons, or camps for the practical instruction of troops, in 1720,[1] but the Revolution towards the end of the century destroyed all special civil and military schools. The want of instructed artillery and engineer officers led to the establishment, in 1795, of the Polytechnic in France, and previously, in 1741, to that of the R. M. Academy at Woolwich; and it would appear that artillery schools were founded in Germany about the middle of that century.[2]

[1] Artillery schools had been previously established in France in 1690, but the pressure of financial wants led Louis XIV. to decree, in 1703, that all artillery appointments should be sold; the evils of such a system became so great that in 1716 the edicts were suppressed.—*Études*, vol. iv. p. 68.

[2] *Grewenitz*, p. 64.

CHAPTER II.

ARTILLERY IN THE NINETEENTH CENTURY UP TO THE INTRODUCTION OF RIFLED GUNS.

1. Organisation of field artillery during the wars with Napoleon.—2. Reduction of the British artillery after 1815, and suppression of driver corps.—3. Question of number of horses for a battery.—4. Additions to and changes in the British artillery previous to Crimean War.—5. Improvements in *matériel.*

1. THE artillery which accompanied the armies of Wellington in the Peninsula and at Waterloo differed considerably in organisation and equipment from our present field artillery. Not only have the guns been entirely replaced by others of a more powerful description, but the numbers of men, horses, and carriages have been changed, and distributed on different principles.

During the wars with Napoleon the British horse artillery was divided into *troops*, and the field batteries into *field brigades*,[1] both troops and brigades having six pieces of ordnance.

The composition of a troop of horse artillery was about as follows, from 1805 to 1807:—

	Men					Animals	Carriages
	Officers	N.-C. officers	Gunners	Drivers	Artificers		
Horse Artillery	5	14	85	60	—	164 horses	19
Driver Corps[2]	—	1	—	20	3	36 mules	—

[1] Field brigades not termed field batteries till 1827.

[2] A *driver corps*, consisting of a few subaltern officers, with N.-C. officers, artificers, drivers, and horses, was divided into troops, and provided the means of converting a company of foot artillery into a field brigade, besides affording small detachments to troops of horse artillery; the latter had both drivers and horses,

Giving the following totals:—

Officers and men	188
Animals	200
Carriages	19

The composition of a field brigade between 1808 and 1816 was as follows:—[3]

	Men					Animals	Carriages
	Officers	N.-C. officers	Gunners	Drivers	Artificers		
Company of Artillery	5	17	123[4]	—	—	160 horses	19
Driver Corps.	1	9	—	96	10	10 mules	—

Giving the following totals:—

Officers and men	261
Animals	170
Carriages	19

The detachment of drivers with a field brigade was mustered and subsisted separately from the company, and the officer (a lieutenant), who had no authority over the gunners, ranked after all the R. A. officers.[5]

The troops of horse artillery were at this time armed with five guns and one howitzer, the latter being the 5½-in. howitzer. The guns about 1807 were 6-prs., but afterwards two of the guns in a troop were 9-prs., or heavy 6-prs., and three were light 6-prs., a very complicated arrangement, intended, doubtless, to enable the troop to employ different kinds of fire to suit various circumstances. Before Waterloo, how-

but as the numbers of these were frequently found inadequate, the deficiency was supplied by a small detachment from the driver corps.

[3] These establishments are given in detail in a very valuable paper by Captain (now Major-General) J. H. Lefroy, R.A., in *Proceedings of R. A. Institution*, vol. i. p. 167.

[4] Including three drummers.

[5] To raise the position of the officers of the driver corps, its four troops were in 1817 supplied with officers from the reduced troops of horse artillery.

ever, a change was made to the older and simpler plan of having the five guns in the same battery of a like nature.[6]

2. After peace had been re-established in 1815, the British artillery was very greatly diminished,[7] and during the succeeding two or three years the troops of horse artillery and the field brigades were reduced to skeleton batteries of two guns only.

In 1822 the driver corps was abolished, and men were to be enlisted for the Royal Artillery as both *gunners* and *drivers*. The troops of horse artillery, however, kept their drivers. The men of the driver corps, with their horses, were equally distributed among the nine battalions, and the order directed that 'one-half of the establishment of each company shall be trained to the care and management of horses, as well as to the service of artillery.'[8] Artificers were attached to the staff of each battalion, and a subaltern from each battalion was appointed weekly to superintend the drivers and horses, and for stable duties.

This system does not appear to have answered as regards efficient instruction in driving, care, and management of horses, for when three field batteries were required for service in Portugal in 1826 modifications were proposed, and in 1827 three *field batteries* with a *reserve of horses* were formed at Woolwich. Each battery had four pieces and forty-five horses.

3. A circumstance occurred in connection with the three field batteries sent to Portugal in 1826 which is worthy of

[6] The troops were armed thus:—

3. Troops { Five 9-prs.,
One $5\frac{1}{2}$-in. howitzer,

4. Troops { Five light 6-prs.,
One $5\frac{1}{2}$-in. howitzer.

Besides which there was one troop of six $5\frac{1}{2}$-in. howitzers.

There were four different armaments for field brigades:—

Five	12-prs. and one $5\frac{1}{2}$-in. howitzer (heavy),			
,,	9-prs.	do.	do.	do.,
,,	6-prs. (heavy)	do.	do.	do.,
,,	6-prs. (light)	do.	do.	(light).

[7] Artillery in 1815 numbered 23,085 of all ranks; in 1819, only 6,881.

[8] General Order, September 21, 1821, given in *Proceedings of R. A. Institution*, vol. i. p. 171.

notice, as it would seem to have decided the question as to the number of horses requisite for the draught on service of the different carriages of a battery of field artillery.

The number of horses allowed during the Peninsular War for field guns and wagons appears to have been six and four respectively; but in many cases the teams were increased by two horses from the spare horses which accompanied the batteries. A committee of artillery officers who reported to the Duke of Wellington, in 1820, on artillery equipment, recommended that the carriage of a heavy field piece should have eight horses, and that of a light piece six horses, and that all the other carriages of a battery, such as the ammunition wagon, forge wagon, &c., should have six horses each. The Duke of Wellington objected that these numbers, though sometimes necessary, were more than requisite for general service, and he considered that exceptional circumstances should be provided for by supplying a larger number of spare horses.

The batteries sent to Portugal, consisting of three 9-prs. and one 24-pr. howitzer, were accordingly provided with only six horses for a gun-carriage, and four for each of the other carriages; but the officer[9] commanding them, considering that the batteries would be inefficient if horsed on such a low scale, made up the teams to eight per gun and six per carriage, by withdrawing the horses from the ball-cartridge brigade. He did this with the sanction of the general, Sir W. Clinton, but on hearing of the deviation from his orders the Duke of Wellington at once recalled Lieut.-Col. W. Smith, whose dispositions were, however, eventually sanctioned, their necessity being confirmed by the report of his successor in command of the artillery, Sir J. May.[1]

4. Our field artillery remained for some years in a very imperfect state, the guns and horses being kept down to very small numbers; but when revolutions and wars again broke out in 1848, public attention in England, which had previously concerned itself only in cutting down our military establishments to the lowest possible scale, appeared to awake to the

[9] Lieut.-Col. Webber Smith, R.A.

[1] *Proceedings of R. A. Institution*, vol. i. p. 182.

conviction that efficiency was as desirable as economy, or rather that it might be true economy in the end; and it was fortunate for this country, which shortly afterwards drifted into the Crimean War, that the artillery was about this time largely increased, and adequate establishments were restored to the batteries for field service.[2]

In 1848 all the troops of horse artillery were increased to four pieces; but in 1852 both troops of horse artillery and field batteries were raised to six pieces, and the field artillery was augmented to twenty batteries, giving 120 pieces.[3]

The armament of field artillery, as laid down at this time, and with which it was sent out to the East in 1854, was simpler than, and differed in several respects from, that employed during the Peninsular campaigns. The heavy and light $5\frac{1}{2}$-in. howitzers[4] had been superseded by General Millar's 24 and 12-pr. howitzers; the 32-pr. howitzer had been introduced to accompany the 12-pr. gun; the heavy 6-pr., heavy 3-pr., and 1-pr. mountain gun had been practically withdrawn as field guns;[5] a second howitzer had replaced one of the guns in each battery, which were thus composed of four guns and two howitzers;[6] the rocket troop had been abolished[7] and rocket sections attached to each troop of horse artillery or field battery.[8]

[2] Notwithstanding the increase of several battalions shortly before the war, the British siege train at Sebastopol never had more than two reliefs during a bombardment, although a large naval brigade, to the detriment of the efficiency of the fleet, was also employed in trenches. As before pointed out, the field artillery was not sufficiently numerous, there not being two guns per 1,000 men; it was overmatched at Inkerman until the 18-pr. position guns and two French batteries were brought up.

[3] Three 12-pr. field batteries, 108 horses each.
Ten 9-pr. do. 94 do.
Seven 6-pr. troops of horse artillery, 136 horses each.

The 12-pr. batteries at Woolwich had, however, 6 and 9-prs., as they were more convenient to handle.

	Weight. cwt.	Length. ft. ins.
[4] Heavy $5\frac{1}{2}$-in. howitzer	$9\frac{3}{4}$	2 8
Light do.	$4\frac{3}{4}$	2 4

[5] In 1847. [6] In 1852. [7] In 1847.

[8] Rocket section given to field batteries in 1854. For these changes see *Proceedings of R. A. Institution*, vol. i. p. 191.

The constitution of the different batteries was as follows:—

Position battery[9] . . .	Three 18-pr. guns. One 8-in. howitzer.
Position or heavy field battery	Four 12-pr. guns. Two 32-pr. howitzers.
Field battery	Four 9-pr. guns. Two 24-pr. howitzers.
Horse artillery troop[1] .	Four 6-pr. guns. Two 12-pr. howitzers.
Mountain battery . .	Three 3-pr. guns. One $4\frac{2}{5}$-in. howitzer.

The experience of the Crimean War showed the defects of the *gunner and driver* system, and the necessity of providing a proportion of drivers, which should be permanently attached, as with horse artillery, to each field battery; drivers were again provided for field batteries in 1858.

5. The long wars at the commencement of this century gave ample opportunities for the employment and improvement of artillery of all kinds. The invention of the shrapnel shell, by Major Shrapnel in 1803, and the transformation of the rocket from a mere signal to a destructive projectile, by Sir W. Congreve in 1806, gave increased power to the fire of artillery.

For some time previous to the Crimean War but little interest was taken in military questions; nevertheless, several important improvements in arms had been introduced during the long European peace. The adoption of shell guns,[2] and the

[9] Two or three batteries of 18-prs. were equipped for field service as guns of position previous to the battle of Waterloo, but were not present at that engagement. 18-pr. iron guns and 8-in. iron howitzers were sent out to the East in 1854 as guns of position, and were employed in the defence of the lines of Inkerman and Balaklava. Two 18-prs were brought into action at the battle of Inkerman, and did great execution in that engagement, contributing in no small degree to the success of the day. In 1855 two heavy batteries were sent out to the seat of war, the one composed of four 18-pr. iron guns, the other of a like number of 32-pr. brass howitzers; the 32-pr. battery was engaged during the action on the Tchernaya, on August 16, 1855.

[1] Troops of horse artillery have also been armed with 9-prs. Before Waterloo the 6-prs. were exchanged for 9-prs., and one of the troops in the Crimea had 9-prs.

[2] One of the best works, in which the fire of shells against ships was treated, before their formidable effects were made apparent in warfare, was written by

consequent development of *horizontal shell fire*—the destructive effects of which were so clearly pointed out by General Paixhans, and practically demonstrated at Sinope and Sebastopol—was the most important advance in the science of attack, and eventually led to the adoption of iron armour as a protection to vessels of war.[3] The advantages of rifling, and the substitution of elongated for spherical projectiles, had, as before stated, been proposed in the middle of the last century by the celebrated Benjamin Robins; but, although rifled muskets have now been long in use, elongated projectiles were only adopted, for the first time (by the French), in 1846. Two years later the Prussians introduced the needle-gun, which has lately become so famous; and about this time the question of rifled ordnance assumed a practical shape, rifled breech-loading guns being proposed by Major Cavalli, of the Sardinian Artillery, and by Baron Wahrendorff, a Swedish nobleman, and tried in England and abroad.

Previous to the Crimean War, the 24-pr. gun of 50 cwt., the 10 and 8-in. howitzers, the 10 and 8-in. iron mortars, and the $5\frac{1}{2}$ and $4\frac{2}{5}$-in. brass mortars, were considered the best descriptions of ordnance for siege purposes; but it was intended that in any future siege which might be undertaken by us (prior to the adoption of rifled siege guns) the 32-pr. gun of 50 cwt. should be substituted for the 24-pr., and the 8-in. shell gun for the two species of howitzers, as the much greater range and precision given by the shell gun would more than compensate for the difference between the size of its projectile and that of the 10-in. howitzer. The 32-pr. and 8-in. gun were

the late Capt. T. F. Simmons, R.A. *Heavy Ordnance directed against and applied by Ships of War*, 1837. Capt. Simmons says, at page 77: 'Col. Paixhans at first, with much discretion, proposed that his guns should project *hollow shot*; he evidently feared to shock any long-established prejudices by at once proposing charged shells. His real design, however, he is at no pains to conceal; he even goes so far as to express an opinion, that the use of shells will absolutely supersede the use of shot in every case against shipping.'

[3] General Paixhans, who may be said to have introduced the horizontal shell-fire system against shipping, clearly perceived the necessity of protecting vessels of war by covering them with iron armour. This he proposed in his *Nouvelle Force Maritime*, chap. lv. p. 294, 1822; but the idea was at that time considered by the French Government to be impracticable.

employed in the Crimea, and when the war broke out, in 1854, the weapons with which both land and naval forces were supplied were much superior to those used in the wars at the beginning of this century. The British army was almost entirely armed with rifled muskets, and many of the French, Russian, and other troops had also a fair proportion of them. The artillery used on both sides, with the exception of a few Lancaster rifled guns belonging to the English, was composed of smooth-bored pieces of cast iron or bronze; but the calibres had been much increased since the Peninsular War, 8-in. and 32-prs. having taken the place of 24 and 18-prs.; and 10-in. and 68-prs., then (in 1854) thought enormous pieces, having been procured from the fleets.

The first rifled ordnance employed in warfare were the 68-pr. and 8-in. Lancaster guns used by the English at the siege of Sebastopol in 1854; these did not answer so well as was expected, and were subsequently withdrawn from the British service, in consequence of the liability of the shot to jam in the bore and cause fracture of either gun or projectile, a defect since remedied. The second employment of rifled ordnance in the field was in the Italian campaign of 1859, when the French, who had converted their smooth-bored bronze pieces into rifled guns, were said to have used them with considerable success against the Austrian troops at long ranges; the accounts of the actual performances of these guns were, however, somewhat conflicting.[4]

In the great American struggle rifled ordnance were employed in large numbers on both sides, and the effects they produced at Charleston fully confirmed the predictions of their superiority over smooth-bored pieces for siege purposes. Again, at Duppel, the fire of the Prussian rifled guns completely overpowered that of the antiquated smooth-bored pieces with which the Danish works were armed. Later instances might be cited to show the superiority of rifled over smooth-bored

[4] Major (now Lt.-Col.) F. Miller, R.A., in 'A Study of the Italian Campaign,' *Proceedings of the R. A. Institution*, vol. ii. p. 277, says of the French rifled guns, 'Their real power could hardly be observed in the first battles. At Solferino their effect was unmistakeable,' and he gives instances at p. 271.

artillery, but it will be sufficient to point out here that all the great Powers have now provided themselves with rifled cannon, which are far superior both in accuracy and power to any ordnance previously used.

In the war between Austria and Prussia in 1866 the great value of breech-loading small arms was clearly shown, and in that between France and Prussia (in 1870) a novel weapon—the *mitrailleuse*—was used by the French in considerable numbers and on some occasions with great effect.[5] The influence of the introduction of both these weapons upon the employment of field artillery will be considered in a subsequent Chapter.

[5] A weapon having twenty-five barrels arranged horizontally, called a *requa battery*, was used at the siege of Charleston in 1863, but no mention was made of its use in the field.

CHAPTER III.

ORGANISATION AND EQUIPMENT OF ARTILLERY.

1. Artillery a special arm.—2. Organisation of artillery. Field Artillery: 3. Division of field artillery.—4. Number and nature of guns for an army.—5. Constitution of a field battery.—6. Number of guns in a battery.—7. Mixed and unmixed batteries.—8. Present armaments.—9. Mobility of field artillery.—10. Conveyance of ammunition in the field.—11. Establishments of different batteries of field artillery.

1. It will have been seen from the last Chapter that the modern system of artillery organisation had been perfected and generally adopted by the commencement of the present century, and that field artillery had become a special and powerful arm, possessed of great mobility, rendering it capable, when skilfully employed, not only of merely assisting the operations of other troops, but of playing an important and necessary part in all engagements, and in some cases of deciding the fate of battles.[1]

2. Although cavalry or infantry may by dash and bravery make up in some measure for faulty organisation and inferior equipment, such is not the case with respect to artillery; everything depends upon the armament and equipment of the latter being in good order and skilfully employed. Hence, an artillery officer should consider it one of his first and most important duties to study carefully the nature and power of the

[1] Captain Boguslawski, although he gives many instances in which artillery accomplished much in the war of 1870, states that, however great the effect of artillery, there was no example of a really great result being due specially to artillery, and that Captain May's prediction 'that victory would be decided in favour of that army which knew best how to use artillery and had a preponderance of it,' had not been substantiated. (See *Tactical Deductions*, translated by Col. Graham, p. 106.) It can, however, hardly be denied that the disaster of Sedan was specially due to artillery fire; Boguslawski himself points out, at page 103, that the artillery surrounded the enemy before the infantry came up.

arm he commands, the relations of its different branches to one another, as well as the principles upon which are based a good organisation of such branches in time of war.

Modern land service artillery may be classed into—

Field artillery, to act with an army in the field.
Siege artillery, for the attack of fortresses.
Garrison artillery, for the defence of fortresses and coast batteries.

The officers and men are organised in batteries, a certain number of which are formed for administration into battalions, brigades, or regiments, the last generally on the Continent. For the service of field artillery, field batteries and batteries of horse artillery are employed; the attack and defence of fortresses, and the service of guns in coast batteries, are undertaken by garrison batteries, called by the Germans fortress or foot artillery. In the organisation of artillery, as in that of other troops, two scales of establishment are required, one for *peace* and the other for *war*. The latter is necessarily much stronger than the former, and a requisite condition of a good organisation is that the *peace* may be capable of being raised without difficulty or delay to the *war* establishment when requisite. The chief difficulty of providing an artillery organisation adapted to the requirements of our service arises from the necessary distribution of the batteries, not only in home camps and stations, but in numerous colonies and dependencies scattered over different parts of the world, some requiring a small and others a large artillery force, and a costly transport for the drafts and for the reliefs at stated intervals. In our service the Royal Artillery, constituting one regiment, was divided into a *horse brigade* and *battalions*, the former consisting of *troops* of horse artillery, and the latter of *companies* for both garrison and field service; each troop of horse artillery had its establishment of *drivers*, but for the battalions the men were enlisted as *gunners and drivers* after the abolition of the *driver corps* in 1822, and the companies were constantly transferred from field to garrison service, and *vice versâ*. The head-quarters of the horse brigade and battalions remained at Woolwich, and artillery were sent to out-stations at home or abroad, by troops or companies, the *battery unit* being thus recognised.

In 1858 the duties of gunners and drivers were separated, and an establishment of *drivers* attached to each field battery.

In 1859 the regiment was reorganised into *brigades* of horse, field, and garrison artillery, the terms *troop* and *company* abolished, and that of *battery* applied to all; the depôts remained at Woolwich, but reliefs were to take place by *brigades*, and batteries were to be changed when desirable from *field* to *garrison* duties, or the reverse.[2]

The British Royal Artillery at present consists of-

	5	Horse artillery	brigades,	or 31	batteries.
	10	Field do.	do.,	or 83	do.
	13	Garrison do.	do.,	or 91	do.
Total	28	Brigades		or 205	do.

exclusive of depôt and coast brigades.

The brigades are thus organised—

British Establishment.

2	Horse artillery	brigades	of 8	batteries each.
4	Field do.	do.	of 10	do.
9	Garrison do.	do.	of 7	do.

Depôt	2	Horse artillery	batteries.
	3	Field do.	do.
	7	Garrison do.	do.

Coast brigade[3] of 10 divisions.

Indian Establishment.

3	Horse artillery	brigades	of 5	batteries each.
5	Field do.	do.	of 7	do.
1	do. do.	do.	of 8	do.
4	Garrison do.	do.	of 7	do.

[2] In 1862 the Royal Artillery was amalgamated with the artillery of the three Indian Presidencies, and the regiment was then divided into—

5 Horse artillery brigades.
25 Field and garrison do.

[3] Formed in 1859.

It is provided with the following establishments:—

The *Deputy Adjutant-General's Department*—charged (under the Commander-in-Chief) with the discipline, promotion, and distribution of brigades.

The *Department of the Director of Artillery Stores*—to regulate armaments and the introduction of new *matériel*, and to superintend the manufactures of warlike stores.

The *Manufacturing Departments*[4]—

Ordnance, Carriages, Ammunition, } in Woolwich Arsenal.
Gunpowder factory, at Waltham Abbey.

The *Instructional Departments*—

R. M. Academy, Woolwich, for the preparation of cadets for the artillery and engineer services.

Department of Artillery Studies, Woolwich, for advanced scientific instruction, and for the instruction of officers generally in *matériel* and kindred subjects.

School of Gunnery,[5] Shoeburyness, where are combined a school for the practical artillery instruction of officers and men, and an experimental establishment.

Riding Establishment, Woolwich, for the instruction of officers, cadets, n. c. officers, and men.

Such are the chief establishments required by an artillery of the present time.

There is also an *Inspector-General of Artillery* to inspect annually both the *personnel* and *matériel* of the artillery forces in the United Kingdom; in order to ensure the efficiency and necessary provision of armaments and stores, and uniformity in drill, equipments, and dress, as well as to test, and report upon, the ability of officers, non-commissioned officers, and men to perform their respective duties.[6]

[4] There are also manufacturing departments for gunpowder and warlike stores in India. The small-arm factory at Enfield is under an artillery officer, but is not strictly an artillery establishment.

[5] Established in 1859. The School of Gunnery had previously been at the R. M. Repository, Woolwich.

[6] *Queen's Regulations*, p. 55.

Field Artillery.

3. Field artillery—that is to say, the artillery which is intended to accompany an army for operations in the field—may be divided into four separate kinds of batteries, viz:—

Horse artillery batteries.	Position artillery batteries.
Field batteries (light and heavy).	Mountain artillery batteries.

Armies in the field are generally organised into *brigades*, *divisions*, and *army corps*. Two or more regiments of infantry or cavalry usually form a brigade; two or more brigades, a division; several divisions composed of all three arms, united under one general, form together with a *reserve* or *corps artillery*—an army corps. As a battalion is a tactical unit of infantry, and a squadron of cavalry, so a *battery* is a *tactical unit*[7] of artillery.

One or more batteries are attached to each division, to assist in all its operations, such batteries being called *divisional artillery*.

Other batteries are formed into what has usually been termed the *artillery reserve*, but is now called by the Germans the *corps artillery*, to be used separately or collectively as occasion demands.

The artillery of an infantry division would consist of *field and heavy batteries*; that of a cavalry division, of *horse artillery*; the reserve or corps artillery, of *horse artillery* and *heavy field batteries*.

For the defence of posts or intrenched camps, *position artillery* must be brought up; and in mountainous countries very light pieces, which can be transported on the backs of horses or mules, are substituted for the ordinary field guns.

4. It is impossible to lay down any definite rule for the number of guns that will be required to accompany an army, for, although depending to a great extent upon the number of troops of other arms, many different considerations have to be taken into account; as, for instance, the general character of the country in which the operations are to be carried on, the

[7] The term *tactical unit* is arbitrary, and might be used to apply to larger or smaller bodies of troops.

means of transport, the nature and equipment of the troops composing the army, and also those of the enemy. When the enemy's troops are badly disciplined, or do not fight in large masses, a small force of artillery will suffice; and this also applies when an enemy is chiefly composed of light troops, for in such a case the artillery would be embarrassing to guard and conduct.

A numerous artillery saves the troops of other arms and gives them confidence, but it entails a very large amount of transport for its ammunition and stores, and may thus tend to impede the movements of an army, besides causing the destruction of the roads. In most of the Continental armies there are usually about three guns to every 1,000 combatants. At the commencement of the Seven Years' War the number of pieces was between two-and-a-half and three per 1,000 men, but at the end four, five, and even seven.[8] The Russians have always employed a large number of guns; at Eylau they had six and the French four guns per 1,000 men. Napoleon's grand army for the invasion of Russia in 1812 averaged about three guns to 1,100 men; the French in 1815 had 2·75, and the Anglo-Belgian 1·8 guns per 1,000 men; the Anglo-Portuguese army in 1813 had two guns to 1,200 men; and the army of occupation in France, three per 1,000 men. During the Crimean War the proportion of field artillery with the British force varied from rather over to not quite two guns per 1,000 combatants, but the Russians had three and sometimes more. The Prussians had, in 1870, ninety guns to an army corps of 42,500 men, thirty-six of which were reserve or corps artillery, which, deducting pioneers, administrative services, &c., gave rather under $2\frac{3}{4}$ per 1,000, but this proportion was often exceeded in the field;[9] thus the army which invested Paris had 147,000 infantry and cavalry with 622 guns, or nearly four

[8] Austria gave the impulse, and Frederic was obliged to follow the example.—Decker's *Batailles et Combats*, p. 28.

[9] *Strength and Organisation of a North German Army Corps.* Capt. H. Brackenbury has pointed out to me that the Prussians usually had only 84 guns to an army corps of 30,000 fighting men, two batteries or twelve guns being with the cavalry division which was removed from the corps; this gives about $2\frac{3}{4}$ guns per 1,000 men.—C. H. O.

guns per 1,000 men. Prince Frederick's army in the Le Mans campaign had 73,000 men and 318 guns, or about four pieces per 1,000 men.[1]

It has been pointed out that as armies have increased in numbers so the proportion of guns has been smaller on account of the difficulty of transporting and of bringing into action in time the long trains of a numerous artillery; and the conclusions have been arrived at, that large armies should not have more than three guns in a flat open country; or than two to two-and-a-half guns in a difficult one to 1,000 men; but that the proportion might, in a country favourable to the employment of artillery, be increased to even five guns, with smaller armies of 50,000 to 80,000 men.[2] In order to bring artillery more quickly into action, the Prussians and French have but a small number of carriages in a battery, some of the ammunition wagons and other carriages not actually required in action being attached to the ammunition column; also the reserve, or as the Prussians now call it the *corps artillery*, instead of being dragged in rear of the infantry divisions, is usually by the Germans pushed forwards on the march.[3]

[1] *Operations of German Armies in France, from Head-Quarters Staff Journals.* By Major W. Blumé, translated by Major E. M. Jones, pp. 23, 193. It has been constantly observed that the proportion of artillery is usually increased towards the end of a campaign. In our Flanders campaigns, in the middle of the last century, this was the case; thus (*Col. Macbean's Memoirs*)—

	Battalions	Squadrons	Guns
In 1742–3 . . .	19	19	24
„ 1748	22	14	78

From what has been stated above, it appears that the same thing occurred in the Seven Years' War and in the campaigns of Napoleon. The chief causes of this increased proportion of artillery has been—the heavy losses in men from casualties in action and from sickness, and the better appreciation of artillery as an arm. In the Prussian army which invested Paris, in 1870, the high proportion of guns was owing, as Major Blumé points out, to the heavy casualties not having been replaced; and after Eylau, where the Russian artillery inflicted such cruel losses on the French, Napoleon in three months doubled his artillery. (See Jomini's *Précis de l'Art de la Guerre*, p. 604.

[2] A German paper, 'On Proportion of Guns to Men,' translated by Captain E. Baring, R.A., *Proceedings of R. A. Institution*, vol. viii.

[3] In the war of 1870 a Prussian army corps, consisting of two infantry divisions

A British army corps consisting of three divisions of infantry and one division of cavalry, and numbering about 31,000 men of all ranks, is to have ninety guns; and by deducting men engaged in transport, police, pontoon duties, &c., there remain

and one cavalry division (42,500 men), had one regiment of field artillery of three field divisions and one horse division distributed thus:—

		Batteries	Guns
Divisional artillery	Two field divisions, each of 2–4-pr. and 2–6-pr. batteries	8	54
	One 4-pr. horse battery for cavalry div.	1	
Reserve	One field div. of two 4-pr. batteries, two 6-pr. do.	4	36
	One horse div. of two 4-pr. do.	2	
	Total		90

I have been informed by Capt. F. C. H. Clarke, R.A., of the Topographical Department, that the organisation has recently been altered as follows for the Guard corps and first eleven army corps, each of which has one brigade of artillery divided into two regiments, and distributed thus:—

		Batteries	Guns
One regt., corps artillery	Two field divisions, each of three 6-pr. batteries	6	54
	One horse div. of three 4-pr. batteries	3	
Other regiment, div artillery	Two field divisions, each of two 6-pr. and two 4-pr. batteries	8	48
	Total		102

One of the horse batteries would be attached to the cavalry division, so that while the divisional artillery remains as it was, the corps artillery is increased by twelve guns. The fourteenth corps has forty-eight corps and forty-eight divisional guns.

The French army, in 1870, had three batteries (one of mitrailleuses) per division, and six in reserve. An army corps of three divisions had then—

Nine divisional batteries	54 pieces
Six reserve do.	36 „
	90 „

But as three of the divisional batteries had mitrailleuses, there were only 72 guns.

With four divisions there were—

Twelve divisional batteries	72 pieces
Six reserve do.	36 „
Total	108

And, deducting four mitrailleuse batteries, 84 guns. See *La Campagne de* 1870, *par un Officier de l'Armée du Rhin*, and Col. Rüstow's *Krieg um die Rheingrenze*, 1870. The *German Official Account* gives eight reserve batteries to a corps of four divisions.

about 26,000 men, which gives a proportion of three-and-a-half guns to 1,000 men. The distribution of artillery is[4]—

		Bats.	Gs.
Divisional Artillery	3 Field batteries (2 heavy and 1 light) to each division of infantry	9	60
	1 Horse artillery battery to cavalry brigade	1	
Reserve Artillery	2 Heavy field batteries	2	30
	3 Horse artillery batteries	3	
	Total		90

The nature of ordnance will depend in a great measure upon the character of the country. Flat open countries are advantageous for the employment of heavy guns and horse artillery; but if the country be hilly, much cut up by enclosures, and not intersected by good roads, it will be almost impracticable to transport the former, and the effective employment of the latter must be naturally much restricted. When there is much cover, common shells are indispensable, and the proportion of pieces from which powerful shells can be projected, should be large. A great development of shell fire is now required in order to produce destructive effects among troops compelled, by the rapid and deadly fire of the small arms and artillery now used, to advance in small bodies and extended formations, availing themselves for shelter of inequalities in the ground, or of any other cover at hand.

5. In order that field artillery may perform efficiently the various duties required during a campaign, it is necessary that it should be well organised and equipped, for otherwise it would prove more embarrassing than useful to the troops of other arms. In consequence of the continual movement of a force in the field, the field artillery are obliged to carry not only a large amount of ammunition, but a great variety of stores, so that all repairs of carriages, harness, &c., may be executed without delay; the equipment is therefore very complicated, and a good organisation is essential to prevent confusion in the interior management or manœuvring of a battery.

A battery of field artillery has three chief requirements or elements—*matériel*, *personnel*, and *transport*.

[4] For the detail of the army corps, except the artillery, see Col. Sir Garnet J. Wolseley's *Soldier's Pocket Book*, p. 107.

Matériel { Pieces of ordnance.
Ammunition and Stores.
Carriages for guns, ammunition, and stores.

Personnel { Officers to command.
N. C. officers and trumpeters to execute orders.
Gunners to serve the pieces.
Drivers to groom and drive.
Artificers to repair carriages, harness, &c., and to shoe horses.

Transport—Horses, mules, or other transport animals.[5]

6. A battery should consist of as many pieces as can be readily manœuvred and worked by the requisite establishment of officers, men, and horses in the field.

The number has varied in the different European armies between four and eight pieces to a battery. In England, Prussia, and France there are six; in Russia, Austria, Sweden, Belgium, and some minor European States there are eight; while in the Swiss artillery there are but four. The number eight appears to have some advantages over six, for the extra two guns greatly increase the fire of the battery; a battery of eight pieces can also be divided into two tolerably powerful batteries of four guns each if required; and each half-battery is composed of two separate divisions instead of one and a half, as with a battery of six guns, and can therefore be more easily manœuvred. Six guns are, however, more manageable than eight, entail fewer carriages and stores, and are better adapted to the rapid movements now so requisite.

[5] In India, camels, oxen, and elephants have been used for the purposes of field artillery; the batteries raised in 1859 consisted of two 18-pr. guns, two 8-in. howitzers, two 8-in. and two 5½-in. mortars, making eight pieces, which were transported by thirteen elephants and 343 bullocks. (See Br.-General Lefroy's *Handbook for Field Service*, 1867, p. 50. Where horses cannot be obtained, it is well to have such animals to fall back on; but the horse, even though of small breed, is to be preferred, and there is no doubt but that much greater execution might have been done in any of the actions during the Indian rebellion had the guns been horsed instead of being drawn by bullocks or elephants, as was the case in some instances. See Reports from Col. D. E. Wood, R.H.A., dated 'Allahabad, Jan. 6, 1858,' and 'Head-Quarters, Camp Force, under Major-Gen. Sir James Outram, G.C.B., March 6, 1858;' also Captain Palmer's Report, dated 'Camp, Bandah, April 21, 1858.' Mules have been found to be very useful animals for artillery purposes, and especially for horsing the spare wagons, &c.

7. A battery may be composed of guns alone or of howitzers alone, or of both guns and howitzers; in the latter case it is called a *mixed* battery. All our horse artillery and field batteries of SB. pieces were mixed batteries, so were similar batteries in Austria and Prussia, and also in France until the introduction of the Napoleon 12-pr. shell gun, a short time before the Crimean War;[6] our position batteries have usually been either gun or howitzer batteries; the Belgians, Prussians, and Russians had both howitzer and gun batteries. The reasons for uniting gun and howitzers in the same battery were, that such a battery was independent as far as possible, and adapted to all kinds of ground and every circumstance of combat; there were, however, serious objections—viz., that the effective range of the howitzer and gun differing greatly, as also the objects for which their respective projectiles, common shell and solid shot, were used, the fire of the gun might under many circumstances produce great effect when that of the howitzer was nearly useless, and *vice versâ*, so that one nature of piece must be sacrificed to the other; also that the equipment of a mixed battery was very complicated. Since the general adoption of rifled field guns[7] the principle of the Napoleon

[6] The pieces employed by the French for field artillery, until the introduction of the 12-pr. shell gun (canon-obusier), were the

12-pr. gun.
8-pr. do.
Howitzer of 16 centimètres (6-in.)
„ 15 „ (24-pr.)

In order to simplify the service and equipment of field artillery, the 12-pr. shell gun was proposed as a substitute for these four pieces by the late Emperor Napoleon III., when President of the Republic, and was subsequently adopted into the French service. The chief advantages of the new system were, that there was only one gun-carriage, one description of ordnance, and four projectiles; it therefore abolished one gun-carriage, three natures of ordnance, and nine projectiles.

'There is an essential advantage in the proposed system, to which we call the attention of all scientific men, viz., the power of firing at will, either round shot or shells, from all the pieces, for it has the effect of trebling the actual power of a battery as regards hollow projectiles, or of increasing by one-third the effects as regards solid shot. At present a battery composed of four guns and two howitzers does one of two things: it either makes use alternately of the four first and the two second, or it fires these pieces together. In the first case, the effect of its fire is considerably reduced; in the second, it is acknowledged that one of the two is sacrificed to the other.'—*Emperor Napoleon's New System of Artillery*, translated by Captain (now Major-General) W. H. Cox, R.A.

[7] 1858–9.

12-pr. batteries has been followed, batteries have consisted of pieces of one calibre, and therefore of the same power, the equipment and service being also thus simplified.

8. The present armaments of the different service batteries[8] are—

Horse artillery batteries	6	9-prs.	ML. R.[9] (iron).
Field batteries . . .	6	9-prs.	ML. R.[9] (iron).
Heavy „ . . .	6	16-prs.	ML. R.[9] (iron).
Position „ . . .	4	40-prs.	ML. or BL. R. (iron).
Mountain „ . . .	4	7-prs.	ML. R. (bronze or steel).

And for India—Horse and field batteries, six bronze 9-prs. ML. R.

Most of the Continental Powers have a proportion of heavy field batteries attached to both divisional and reserve or corps artillery;[1] they are equipped and horsed like other field batteries, and therefore possess sufficient mobility to accompany an army in its operations. Experience has constantly shown the advantage of heavy armaments in the field. Before Waterloo some of the troops of British horse artillery exchanged their 6-prs. for 9-prs., and two or three batteries of 18-prs. were equipped for field service, although not present in the battle. In the Crimea some of our horse artillery had 9-prs; the Russians, both at the Alma and at Inkerman, brought 12-pr. guns and 32-pr. howitzers into action, overmatching the fire of our 9-pr. guns and 24-pr. howitzers in the latter engagement, until a couple of British 18-pr. position guns and two French 12-pr. batteries restored the balance.

In 1855 two heavy batteries were sent out to the seat of war, the one composed of four 18-pr. iron guns, the other of a like number of 32-pr. brass howitzers. The 32-pr. battery was engaged during the action of the Tchernaya, on the 16th August, 1855, and was horsed in the ordinary manner; but

[8] All particulars respecting the guns will be found in tables in the Appendix.

[9] These have superseded the BL. R. 9, 12, and 20-prs.

[1] The French have a 16-pr. converted *canon de* 8, the Prussians a 15-pr., called the 6-pr. from its having the calibre of a SB. gun of that nature. For particulars of these guns see Appendix.

with regard to the 18-pr. battery, such was not the case, for twelve horses was the number allotted to each gun, and these were harnessed four abreast, the drivers being mounted on the near and off horses; this method has since been adopted for batteries of position.

9. A horse artillery battery differs essentially from a field battery in being provided with a *lighter* armament and equipment, and in having *mounted* gun detachments, so that it is adapted to the most rapid movements; in a field battery the gunners are only allowed under certain circumstances to mount upon the wagons,[2] but, as these should be kept as much as possible out of fire, other means have been taken to give field batteries the greater mobility now required *on some occasions*, and unless such means are adopted batteries may come into action without the gunners necessary to serve the pieces, as was the case when two guns were rapidly advanced to an important position at the Alma.[3] Mobility is of the greatest value in bringing guns into action, in moving them forward to a fresh position, or in withdrawing them out of action.

Gunners have been mounted on the off-horses, as in the late Bengal Horse Artillery; the Austrians have a seat on the trail of the carriage; but the plan most approved of is to have a seat for a gunner on the axletree on each side of the gun, so that with two or three gunners on the limber, and the mounted No. 1, a sufficient number of men to serve the piece for a short time would be taken into action with the gun itself. This last method was formerly carried out in the Madras Artillery,

[2] The ammunition boxes of the gun limber and wagon are so arranged as to be able to receive the gunners, except No. 1, who is mounted on horseback; Nos. 2 and 3 are on all occasions to be mounted on the limbers, their knapsacks being strapped to it. The other numbers of the detachment are only to be mounted (their knapsacks being carried on the wagon) when the battery is under movement at regimental drill, at a review or inspection, in marching past, and during rapid movements and evolutions; where it is necessary for the gun to move without its wagon at a rapid pace and for some distance, No. 4 is to mount between 2 and 3. *Gen. Reg. Order No.* 503, *June* 1, 1864: 'In all other cases where acting with other troops, the wagons to be from 150 to 200 yds. in rear of the battery, taking advantage of any cover the nature of the ground may afford.'

[3] Major-General Sir C. Dickson, V.C., K.C.B., and Colonel E. S. Gordon, C.B., artillery officers then on the staff, dismounted and helped to serve these guns.

and the gun-carriages of the Prussian Field Artillery, and the service wrought-iron carriages, are fitted with axletree seats.

The mobility of the field artillery of the present day must not, however, be abused, by constantly changing the position of guns in action; for artillery when moving is useless, and for each fresh position the range of the object must be again ascertained, while 200 or 300 yards, one way or the other, but little affects the accuracy of fire with rifled guns.[4]

10. It is generally considered that artillery should take as much ammunition into the field as will suffice for two or three actions, but as such an amount cannot be conveyed with the battery, reserves are organised from which the wagons of the battery may be replenished. The expenditure of ammunition in different batteries of the same force in any one engagement varies so much that it is impossible to lay down any rule as to the number of rounds required per gun for an action. Thus at Alma the British Artillery fired an average of 18 rounds a gun; at Inkerman the average expenditure of the 9-pr. batteries engaged was 53 rounds per gun; two of these batteries fired 84 and 82 rounds per gun respectively, and the two 18-prs. fired 84 rounds each. In the Bohemian campaign of 1866 the artillery of three army corps (Guards, 1st and 6th) expended in several engagements, including Königgrätz, but a small average, from 8 to 23 rounds per gun; the 5th Prussian Corps, at Nachod

[4] Sir G. J. Wolseley truly says:—'The fewer the movements executed by a battery, the longer it will be in a position to inflict damage upon the enemy; for it is a recognised axiom, that guns are useless when limbered up.'—*Soldier's Pocket Book*, p. 252. And Prince Hohenlohe:—'A change of a few hundred paces for artillery would be an error on the part of the artillery, for a battery which has determined the range from one position is more effective from this position than if it advanced 200 or 300 paces nearer, where it would have to determine the range afresh. The distances which batteries should pass over in the engagement in order to approach nearer to the enemy, should not be less than 1,000 paces. It is of course understood that special circumstances may give rise to exceptions.'—*Employment of Field Artillery*, translated by Capt. F. C. H. Clarke, R.A., p. 37. And Baron von Moltke:—'On account of their extensive range, it is possible for properly placed rifled guns to be effective from one and the same position in all the different stages of the battle. It is not necessary to advance a few hundred yards in order to reach the enemy; for this object is gained by altering the elevation without essentially diminishing the efficacy of the fire.'—*Influence that Arms of Precision have on Modern Tactics*, p. 4, translated by Lieut. H. R. G. Crauford, R. A.

and Skalitz, from 40 to 70 rounds per gun. The greatest expenditure of ammunition by the Prussian artillery was at Pressburg, where one battery fired 113 rounds per gun. The Austrian artillery was more actively employed, and fired larger averages. Thus at Königgrätz the batteries of the 2nd, 3rd, and 10th corps fired, respectively, 44, 104, and 154 rounds per gun; the greatest average fired during the campaign being 218 rounds per gun, from a battery of the 3rd corps, at Königgrätz.

In the French and Prussian war of 1870 the artillery of the 12th German corps, in eleven engagements, expended an average of 14½ rounds per gun; at Sedan one of the heavy batteries fired 115 rounds, and one of the light 126 rounds per gun. It is difficult to obtain the expenditure of the French artillery, especially as the ammunition sometimes failed, but the following averages have been given:—At Borny, 15 rounds; at Rezonville, 45 rounds; and at Gravelotte, 110 rounds per gun.[5]

It has been pointed out [6] that the employment of rifled guns has not affected the consumption of ammunition, but that the greater use which will doubtlessly be made of artillery will tend to increase of expenditure; it must, however, be remembered, that rifled guns, properly placed and fired with deliberation, produce such formidable effects, that there may often be no necessity for a very large expenditure to accomplish the desired objects.

The number of rounds per gun taken into action by the gun-carriage and ammunition wagon in our service are—

		9-pr. Batt. Rounds	16.-pr. Batt. Rounds
Gun-carriage	Limber [7]	36	24
	Axletree boxes (case) .	4	4
Wagon . .	Limber	36	24
	Body	72	48
	Total	148	100

[5] The above averages are taken from Lt.-Col. Reilly's *Supply of Ammunition to an Army in the Field*, p. 10.

[6] By Lt.-Col. Reilly, R.A., C.B.

[7] Each box on the 9-pr. limber holds 18 rounds, and on the 16-pr. limber, see Part I. p. 83.

And the proportions of different kinds of projectiles are—

	9-pr. Batt. Rounds	16-pr. Batt. Rounds
Case shot	4	4
Common shell	48	34
Shrapnel shell	96	62
Total	148	100

The total number of rounds per gun taken into the field are to be[8]—

		9-pr. Batt. Rounds	16-pr. Batt. Rounds
With battery	Limber and gun	40	28
	Wagon	108	72
1st Reserve	Divisional reserve	108	72
2nd Reserve	Corps column	44	108
	Total	300	280

Establishments of Field Artillery.

11. The war establishments of batteries, which with SB. guns included only eighteen or nineteen carriages, had been gradually much increased of late years by the addition of both gun and small-arm ammunition wagons, of rocket and other carriages, till in 1870-71, for the batteries of BL. R. guns, they stood thus:—

	Officers and Men.	Horses.	Carriages.
9-pr. horse artillery battery	228	249	25
12-pr. field battery	277	252	31

The peace establishment being:—

9-pr. horse artillery battery	191	147	15
12-pr. field battery	191	94	15

The system now being carried out is to decrease the number of carriages in the war establishments of the different batteries

[8] In the above method of supply (adopted by the French in 1867), the divisional reserve forms between the battery and the corps reserve a connecting link, which is indifferently supplied by the detachment of one-third of the corps column in the Prussian artillery.—Lt.-Col. Reilly's *Supply of Ammunition*, p. 15.

(horse, field, and heavy) to only fifteen carriages, including six gun carriages, six ammunition wagons, and three general service wagons, one fitted with a forge; and to transfer the second line of gun ammunition and the small-arm ammunition wagons to a *divisional reserve column.* The first gun ammunition reserve both for the divisional batteries and for those not attached to divisions (the battery with the cavalry and the reserve batteries) is to be carried by the *divisional reserve column,* and the second gun ammunition reserve by the *corps reserve column.* The reserve gun ammunition, with the exception of that conveyed in the ammunition wagons of the divisional column (4—16-pr. and 3—9-pr.) and in the limbers of the spare gun carriages, will be carried in the general service wagons, 13 of which are attached to a divisional column, and 29 to each of the three divisions of the corps column. The spare gun carriages and rocket wagons are to be attached to the *divisional reserve* and *corps column.* The small-arm ammunition is to be conveyed in twenty-nine two-horse carts with the divisional column.

By thus reducing the war establishments, the batteries will be less complicated in equipment, more handy to manœuvre, and will occupy less ground. The home or peace establishments[9] for 1872-3 are as follows, and it will be seen that they would require to be but slightly increased to raise them to the war strength.[1]

[9] Horse Guards, April 1872.

[1] The Prussian war establishments are as follows:—

	Officers	Men	Horses	Carriages
4-pr. field battery . . .	5	147	126	16
Horse battery . . .	5	152	209	16
6-pr. field battery . . .	5	153	128	16
Artillery ammunition column	3	170	164	24

The gun-carriages have six horses each.

The 4-pr. battery is provided with 600 shells and 312 shrapnel; the 6-pr. with 438 shells, 72 incendiary shells, 228 shrapnel, and 52 case. The incendiary shells contain a bursting charge and from four to six cylindrical copper capsules filled with inflammable matter. An artillery ammunition column carries 2,400 projectiles, the five columns therefore 12,000, or 133 per gun.—*Strength and Organisation of a North German Army Corps.* The above proportions do not, however, represent

		9-pr. Horse Artillery Battery	9-pr. Field Bat.	16-pr. Heavy Bat.
Officers and Men	Officers	5	5	5
	N.-C. officers	18	18	18
	Gunners	70	66	66
	Drivers	56	61	62
	Trumpeters	2	2	2
	Artificers	7	7	7
	Total	158	159	160
Horses	Riding	58	18	18
	Draught	54	66	74
	Total	112	84	92
Carriages	Gun	6	6	6
	Ammunition wagons	3	6	6
	Store cart	1	1	1
	Total	10	13	13

The war establishment of a divisional reserve column will probably be 212 officers and men, 255 horses, and 55 carriages; of each of the three divisions of a corps reserve column—178 officers and men, 183 horses, and 35 carriages.

A 40-pr. position battery, which has only four pieces, has 13 carriages, including a platform wagon; it takes into the field 160 rounds, or 40 per gun. The draught is arranged for four horses abreast,[2] but it is intended that 40-pr. and 20-pr. batteries may, 'according to circumstances, be drawn either by field artillery horses with service equipment or by country horses with cart harness, procured where the forces are operating. The latter mode of draught will, as a rule, be adopted for 40-pr. batteries serving *at home*, these batteries having been specially fitted for the attachment of farmers' harness.'[3] Guns of position require, when horsed, a much larger and stronger stamp of animal than that necessary for ordinary field pieces; size and power, rather than activity, should therefore

those carried during the late war, in which shrapnel were not fired from Prussian field guns. In Capt. C. H. F. Ellis's translation of *The War of* 1870–71, by a Prussian artillery officer, the proportions supplied are thus stated: 4-pr. battery, 864 common shell and 54 case shot = 918 rounds; 6-pr. battery, 738 common shell and 42 case = 780 rounds. Capt. E. O'Hollist, R. A., has pointed out to me that the Saxon and Bavarian batteries fired shrapnel on some occasions; thus, at Sedan, the former expended 1080, and the latter 191 shrapnel shell (see *Militair-Wochenblatt*).—C.H.O.

[2] Part I. p. 89.

[3] *Revised Army Regulations*, vol. iii. p. 113, 1870.

be looked to in their purchase, as these guns are not intended to execute rapid manœuvres. The strongest men should also be posted to them as gunners, on account of the weight of the trail, and the having to shift the piece from the travelling to the firing trunnion holes and *vice versâ.*

In mountainous countries, or in those inaccessible to ordinary artillery carriages, it is necessary to employ very light guns and equipment, which are usually transported on the backs of mules; each gun and each carriage requires one mule, the stores and ammunition being packed on others.

The establishment for a ML. R. 7-pr. mountain battery has not yet been decided on, but the following details respecting the battery sent to Abyssinia, in 1868, will give an idea of the stores and transport required:[4]—

	Mules.
Six 7-prs. (ML. R. steel)	6
Six carriages (iron, brackets)	6
360 rounds of ammunition	18
120 rockets and two tubes	6
One forge	1
Miscellaneous stores	1
Total	38

The number of pieces is now to be reduced to four per battery.[5] The gun carriages can be adapted to single draught, one carriage forming a limber to another, and the leading carriage having shafts attached to the train. As there is no howitzer, double shells are supplied,[6] and can be fired, if necessary, at 34° elevation by removing the elevating screw and lowering the breech of the gun into a hollow between the brackets, the carriage resting on its wheels.

[4] The details of this equipment were given by Capt. C. O. Brown, R.A., in the *Proceedings of R. A. Institution*, vol. v. p. 452.

[5] The French formerly employed howitzers alone for mountain service, six pieces to a battery; but a mountain battery is now composed of six rifled *canons de* 4, which fire projectiles of about $5\frac{3}{4}$ lbs. weight; 150 rounds per gun, and 44,928 small-arm cartridges, are conveyed with the battery. It seems preferable, however, that mountain batteries should have, as with us, a reduced number of pieces, from the circumstance that they can be but seldom employed together, and from the obstacles with regard to export and transport before mentioned.

[6] Part I. p. 144.

CHAPTER IV.

EMPLOYMENT OF FIELD ARTILLERY.

Transport, Marching, and Encamping: 1. Transport of artillery by rail.—2. Marching.—3. Encamping. Formations and Fire of Field Artillery: 4. Peculiar function of artillery.—5. Objects of field artillery.—6. Formations of field artillery.—7. Choice of position.—8. Effective ranges.—9. Nature of ground.—10. Choice of object.—11. Use of projectiles.—12. Rapidity of fire and finding ranges.—13. Value of mitrailleuses.

Transport, Marching, and Encamping.

1. The equipment and organisation of field artillery having been explained, it remains to consider the application of this branch of the service in time of war; but before examining the tactics or employment of artillery on the field, it is necessary to make a few remarks on the transport of artillery by rail, and to give some of the more important general rules to be observed when batteries are marching or encamping in an enemy's country.

Railways have of late years been much used for the conveyance of troops to the seat of war, and in movements of concentration or retreat. If an army be advancing into an enemy's country, it would generally find the railways more or less useless, from the breaking down of bridges, blocking of tunnels, and tearing up of rails; so that time and means would be required to put them again into working order. The great value of a regular system of railway transport for large bodies of troops carefully organised during peace time has lately been shown by the rapid concentration of the very numerous Prussian armies, and by their being kept well supplied with the necessary ammunition and stores while constantly fighting and advancing.[1]

[1] Mr. R. Mallet, in a very interesting and instructive pamphlet, *Our Railway System, viewed in reference to Invasion*, says that it is a mistake to suppose that

The number of carriages to one engine will vary according to its power, the gradients and curves of the line, and the state of the weather; 24 to 34 carriages have been given as the load for one engine, which, to lessen the risk of breaking down, should not travel at a speed of more than 25 miles an hour. An artillery carriage, with limber, requires one truck; a second or third class carriage holds 32 men; a horse-box will convey three, and a cattle truck six to eight horses.[2] Various estimates have been given of the number of trains per battery; but this will obviously depend upon the number of carriages on the establishment of the battery, and the number of carriages and trucks in the train. In France and Germany one *axle* or pair of wheels is taken as the *unit* for the load; thus in the latter, a military train consists of twice the number of axles in an ordinary train, and is drawn by two powerful goods engines; such a train of eighty axles will convey a battery of artillery, or an ammunition column, weighing about 200 tons.[3]

In France, a demi-battery weighing about 100 tons is considered the load for a train, which has only about half the number of axles of the German train. Colonel Hamley states that a battery of horse or field artillery, or an ammunition column, takes two trains of thirty-one to thirty-three carriages, and Sir G. J. Wolseley that a horse artillery or field battery requires two trains of 30 carriages each. The latter estimate is, however, for only 10 or 11 carriages with smaller numbers of men and horses than would be necessary for the reduced war establishments of 15 carriages.[4]

Precise regulations are laid down abroad for loading stores, embarking and disembarking troops, and for their safe conduct *en route*; rules are made for the number of carriages

the French was inferior to the Prussian railway system in 1870-71. The concentration of the French on the frontier at the outbreak of the war was made with facility, regularity, and speed. The disasters were in no way attributable to railways (page 12).

[2] Col. Hamley's *Operations of War*, p. 23.

[3] Mallet's *Our Railway System*, p. 14.

[4] See *The Soldier's Pocket Book*, 2nd edit., p. 316. Sir G. J. Wolseley, in the article on 'Movement of Troops by Railway,' treats the subject in detail, and gives some useful information respecting the capabilities of the railways in Great Britain, Ireland, America, Germany, and India for the transport of troops.

and guns per truck (according to the size of the latter), for the best method of placing them so as to avoid friction and shocks on starting, for the conveyance of ammunition and its examination from time to time, and for sweeping up or wetting loose powder. Artillery are expected to arrive two hours before the time of departure; the loading may be done with the help of ramps and manual force, but cranes and ample platform space are required to ensure regularity and despatch.[5] If suitable platforms be erected, and the men be practised at loading, a battery could be placed and secured on a train in about half an hour.[6]

Gunpowder or explosives should never be conveyed in the same trains with troops. 'Nearly 150 Austrian soldiers were killed or wounded in an accident on the Verona Railway in 1859, during which some ammunition wagons in the train exploded.'[7]

2. When artillery is marching with other troops, as with a brigade, division, or army corps, no special escort is required. Of the batteries of a division one would usually accompany the advanced guard in rear of the leading battalion, the other batteries being in front of the main body of infantry, with a battalion or regiment preceding them. The *corps artillery* of an army corps on the march should be massed together, and not kept in rear, as was the custom with the *reserve artillery*, but pushed as far forward as circumstances will allow; if possible behind the first brigade or regiment of the main body, but never behind the reserve infantry. The object of pushing the corps artillery forward is, that with the artillery of the advanced guard it may by opening fire conceal the advance of the main body and allow of the changes of formation and dispositions requisite for an advance without exposure to heavy fire,[8] the divisional artillery being occupied in supporting the

[5] Mallet's *Our Railway System*, pp. 20, 21. An interesting paper on the Prussian system of railway transport, by Capt. J. T. Barrington, R.A., is given in *Proceedings of R. A. Institution*, vol. vi.

[6] General Lefroy's *Handbook for Field Service*, p. 266. Colonel Hamley's *Operations of War*, p. 23.

[7] General Lefroy's *Handbook for Field Service*, p. 267.

[8] 'The infantry of the present day is far too costly and valuable an arm to be

infantry in attaining local objects. Pushing forwards the corps artillery in front of the main body would sometimes, however, be a hazardous proceeding, for as Colonel Hamley points out—'But there are topographical circumstances in which this would be dangerous. In North Italy, with its numerous canals and vineyards limiting the front of the advance, in the woods of America or Eastern Europe, and in very broken or hilly ground, to push it forward on the march would be to expose it to destruction.'[9]

Great care and attention, even to the minutest details, are required when marching or encamping in an enemy's country, as faults or negligence may entail grave disasters. The officer commanding a battery should, before starting, examine closely into the exact state of his charge, and ascertain that nothing be wanting, that the horses and carriages are in a fit condition for the march, and that the ammunition and stores are properly packed and serviceable.

As a battery consists of a long train of carriages, most of which are incapable of defence against attack, it must when detached have an *escort*, chiefly composed of infantry;[1] if there be a deficiency of this arm the gunners must to some extent supply its place. A battery when marching should always have an *advanced guard*; in a narrow road, the latter should be considerably in front, to stop all carriages which might cause obstruction; in a hilly road it should reconnoitre the top of every hill, and see that all is clear before the guns come up.

In marching in a hilly country where the road passes through ravines and defiles, great care should be taken to prevent surprises, and to avoid ambuscades. A ravine or defile should be passed as quickly as possible, whether the column be in retreat or otherwise, as it is a hazardous opera-

allowed to await the effect of artillery, like so much food for powder, within range of the hostile artillery. It is better to utilise the time while it is coming up.'—*Employment of Field Artillery*, by Kraft, Prince of Hohenlohe. Translated by Capt. F. C. H. Clarke, R.A., p. 30.

[9] *Operations of War*, third edition, p. 431.

[1] Two companies at least are laid down in the *Field Exercise and Evolutions of Infantry*.

tion in an enemy's country, and as artillery can seldom be made available in any way while passing through. In retrograde movements the ammunition wagons should be sent to the front, though two or three may be kept nearer than the others to supply ammunition, and on emerging from a defile it should be ascertained that no carriage or wagon has been left behind.

When on the march, constant attention should be directed to the *preservation of the correct distance* between the carriages, so as to avoid increasing unnecessarily the length of column,[2] and a halt of ten minutes or a quarter of an hour should be frequently made, not only to rest the horses, but also to allow any carriages which may have dropped a little to the rear to close up. In long ascents, a halt should be made from time to time and the wheels scotched, in order to rest the horses, and there should be a greater interval between the carriages; in descending a hill, the drag-chain or shoe must be used, and it should be put on the wheel and taken off without loss of time, as the stoppage of each carriage retards the whole battery. In passing through villages or other inhabited places, precautions must be taken against fire. When halted for some time, the horses of the carriages and wagons should not be unharnessed, and the same precautions should be taken as upon the march.

In case of an attack when *en route*, the carriages should close up and the battery continue its march, while the escort falls in and shows front to the enemy. Should, however, the battery be closely pressed, and there be hopes of support, a couple of guns may be brought into action if the road be wide enough, the escort being posted on the flanks to keep up a fire upon the attacking party. In night marches, where there is a chance of an attack, strict silence should be observed: the men should not be allowed to call to one another, nor to make any noise in cracking their whips, nor should any lanterns or matches be lighted, for on a dark night the smallest spark may be seen at a considerable distance.

[2] Col. Hon. G. Cathcart, in his *Observations on the War in Russia and Germany in* 1812–13, describes the special precautions taken by the Russians, who were then the best marchers, to prevent columns on the march losing their distance.

When an accident happens to a carriage either on the march or in manœuvring, those in its rear should pass it on the most convenient flank and fill up its interval; it can resume its place as soon as the damage has been repaired; a gun must not wait for its disabled wagon, but only leave a sufficient number of men to repair it.

When it is necessary for artillery to cross a river, a reconnaissance must first be made to ascertain the exact position of the fords, which are usually situated at the rapid parts of the stream. Artillery can cross a river of the depth of about two feet and a half; much, however, depends on the strength of the current. When the water is deep and the current strong, great attention must be paid in fording, and the leader of the column should keep his eye steadily fixed on some point or object on the opposite bank, which may serve to mark the direction of the ford; as otherwise he is likely to be deceived by the appearance of the water, which seeming to carry him down, might induce him to keep too high up the river, and so miss the ford. No carriage should be allowed to swerve in the least from the line marked out by the leader, nor should any of the horses be allowed to halt, trot, or drink while crossing.

In passing over a pontoon or other temporary bridge, field and position artillery (up to 40-pr.) should with trained horses cross fully horsed, and at increased intervals; with unsteady horses carriages must be passed over by hand. Taking out the lead horses, and crossing with the wheel horses only, is strictly forbidden. Halting on the bridge is to be avoided, but if necessary on a pontoon bridge, the gun wheels must rest as nearly as possible between two boats; should the bridge sway very much, the carriages must be halted, and not moved forward till the swaying has ceased.[3]

3. The position of a camp depends in a great measure upon the plans of the general in command, and these will be modified by the nature of the ground, and by the disposition of the enemy's troops, if such are at hand.

Five different ways of encamping a battery of artillery are

[3] Memo. in Instruction in *Military Engineering, Chatham.*

laid down, and any one of these can be followed or modified according to the nature of the ground or other local circumstances. The second method, in which the battery is formed to either flank in column of subdivisions, is probably the best for a temporary encampment, as it possesses the advantages of celerity, economy of labour, and convenience, it occupies a comparatively small space (81½ yds. deep and 110 yds. broad), and the guns can be quickly brought into action at full interval.[4]

In choosing the site for a camp, it should be ascertained that a tolerable supply of water may be procured, as upon this depends not only the comfort, but also to a great extent the efficiency, of the battery or brigade of artillery; for unless horses be regularly supplied with a sufficient quantity of water, they will get out of condition and be incapable of hard work. Should the ground to be occupied be near a village, the camp should be pitched if possible to windward of it, and at the distance of at least one hundred yards, in order to avoid danger from fire. While in camp, advantage should be taken of the spare time to re-examine the state of the horses, carriages, stores, &c., and to repair any damage which may have occurred upon the line of march. In encamping and picketing, strict attention should be paid to the system laid down, as not only is nothing gained, but, on the contrary, much time is lost, by performing any such duty in a hurried or slovenly manner. In encamping on the march in an enemy's country, the men should not be permitted to stray away from the camp and its vicinity, and precautions should be taken against surprise while the horses are being watered.

Formations and Fire of Field Artillery.

4. The advantages field artillery possesses over other arms consist in the *longer ranges* and *greater power* of its projectiles; its chief function should therefore be *distant combat*, in which it can produce most destructive effects without the

[4] See *Manual of Field Artillery Exercises*, 1861, p. 176. In *Regulations and Instructions for Encampments*, 1871, the depth is reduced (see Pl. XIV.) to 62½ yards by leaving out the guard tent, and thus getting rid of 19 yards.

probability of being disabled by losses in men and horses. Although in some cases very formidable at short ranges, it is little suited to close combat, and less so at the present time than formerly, on account of the exceedingly rapid and accurate fire of BL. R. small arms, and of machine guns, such as the Gatlin battery or the mitrailleuse.

5. The objects of artillery in the field are—

(1) To *prepare* the way for the action of other arms by creating disorder and confusion in the enemy's ranks, dismounting his guns, destroying obstacles, or rendering cover untenable.

(2) To *support* troops of other arms in their movements, by preceding an attack, forming a rallying point in case of repulse, checking advancing columns of the enemy, harassing a threatening foe, defending the key of an important position, or covering a retreat.

(3) To *decide* an action by the concentration of a number of batteries on an important point.[5]

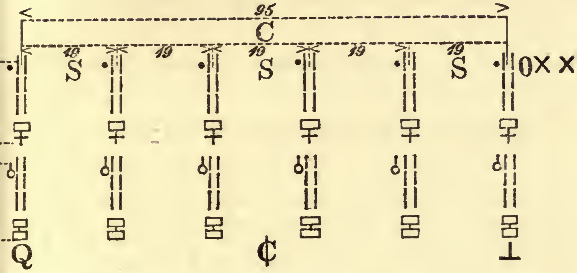
Field artillery, to be effective, should be able if required to combine accuracy and rapidity of fire[6] with considerable celerity of movement; the former of these will depend on the instruction and general efficiency of the officers and men composing the battery, as well as on the nature of the guns employed, and the latter will be secured by having the carriages of suitable construction, well horsed, and driven.

6. The different formations of a battery or brigade of batteries are given in Figs. 138 to 143, which show the extent of ground occupied in each case.

[5] 'The artillery, by means of the force of its projectiles, prepares for the decision of battles, and even, under certain circumstances, *decides* them.'—*Army of North German Confederation*, by a Prussian General. Translated by Col. E. Newdegate, p. 72. Capt. H. Brackenbury, in looking over the proof, objected to the term *decide*, and his objection would probably be endorsed by the greater number of military writers; but in cases like Friedland, Warsaw, or Sedan, artillery did more than prepare the way for or support the movements of infantry: it rendered the positions occupied by the enemy untenable; and, notwithstanding the subsequent occupation of the ground by the infantry, the issue appears in each case to have been decided by artillery fire.

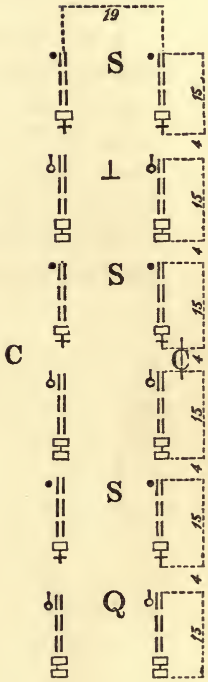
[6] A very rapid fire may be absolutely required on some occasions, but the fire should generally be deliberate.

Fig. 138.



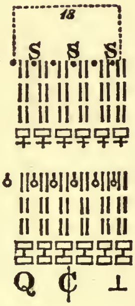
Battery in line, full intervals.

Fig. 139.



Battery in Column of Divisions.

Fig. 140.

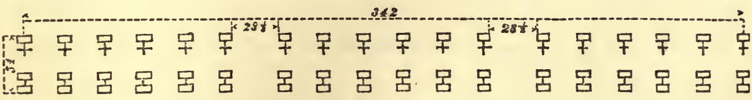


C. MAJOR.
₵. CAPTAIN.
S. SUBALTERN OFFICER.
⊥. BATTERY SERGT-MAJOR.
Q. QUARTER-MASTER-SERGT.

•. No. 1.
DIVISIONAL MARKER.
×. TRUMPETER.
0. STAFF OFFICER.

Battery at close intervals.

Fig. 141.



Brigade of three Batteries in line, full intervals.

A battery is told off into—sub-divisions, divisions, and half batteries.

A sub-division consists of one gun and its ammunition wagon.

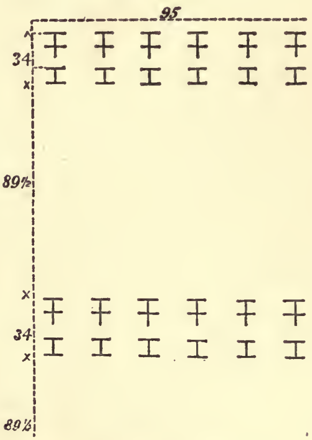
A division consists of two sub-divisions (or two guns and wagons).

A half battery consists of three sub-divisions (or three guns and wagons).

A brigade is composed of three or more batteries.[7]

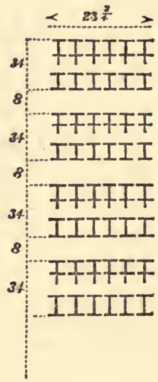
In addition to their fire-arms, infantry when in action sometimes make use of the bayonet, and cavalry frequently use swords or lances; artillery, however, employs *fire alone*, and, in order to obtain the greatest possible effect, the whole of the guns are in general formed in line; column formations, except

Fig. 142.



Open Column of Batteries, full intervals.

Fig. 143.



Close Column of Batteries, quarter intervals.

for movement, would, with artillery, lessen necessarily the effect produced. Guns and batteries are sometimes formed *en échelon*, but they are usually deployed when they come within effective range of the enemy.

7. The choice of the most favourable positions for guns

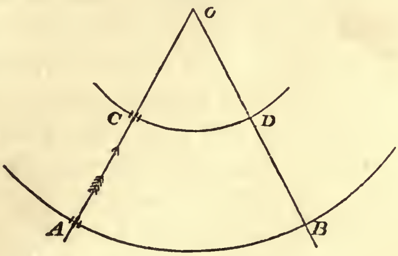
[7] In the German artillery, a *field division* consists of three or four batteries (see *note*, p. 375).

being of the greatest importance with regard to their effective fire, it is necessary that commanding officers of artillery should precede their batteries in order to examine the ground which is to be taken up by them. In action, the ammunition wagons should keep in the rear, sheltered as much as possible from the enemy's fire, and within such distance as will ensure a supply of ammunition to the guns when required.

In choosing a position upon the field for artillery, the following principles should be borne in mind—viz., that the guns should command not only the approaches to the weakest points of the position, but also, if practicable, the whole of the ground within their range; that they should not inconvenience the manœuvres of the troops they support; and that they should be as far removed as circumstances will permit out of the range of any place which might afford a shelter for the enemy's infantry, and from whence the latter could harass the gunners. If this, however, be impracticable, one or more guns must be told off to keep down, with the assistance of the escort, the enemy's fire. When guns are employed to prepare for an attack, to defend a position, to protect troops in passing a river, &c., it is advisable that the batteries should be posted at some distance from each other, but that they should be able to *concentrate* and *cross their fire* on the ground in front.

The fire of guns should always be *concentrated* or *converging*, when practicable, such fire taking an enemy's line obliquely, covering a large extent of ground by cross fire, leaving intervals for the movements of other troops, and entailing less liability to losses from the dispersion of the enemy's fire. The introduction of rifled guns has much increased the scope of concentrated fire, for the ranges being much longer than those of SB. pieces, more ground can be covered, and the choice of ground will be less restricted. Thus (Fig. 144), if A O be the effective

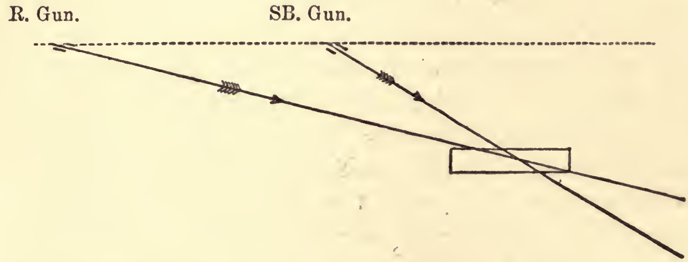
Fig. 144.



range of a R. gun, and C O the effective range of a SB. gun, the latter piece could not be placed outside the arc C D, but the R. gun could be posted anywhere beyond and as far as the arc A B.[8]

The greater ranges of R. guns will also give them an advantage in oblique fire, since they can be directed from points further to the right or left of the flanks of the object, and thus fire at a less angle to it than could be done with SB. guns, the fire of which would be merely wasted at such distances (Fig. 145).

Fig. 145.



No position should be occupied by artillery from which it could not retire with facility, and guns should never take up a position directly in front or in rear of infantry, as by so doing a double object would be presented to the fire of the enemy. Guns should not be posted too soon, but be brought forward at the moment they are required to come into action; previous to this they should be *masked*, either by taking advantage of the irregularities of the ground, if such exist, or of any cover that may be near at hand, or, when such shelter does not present itself, by placing troops, particularly cavalry, in such a position as will screen the guns from the observation of the enemy. Horse artillery can always do this by means of their mounted gun detachments.

Should there be in front, or on the flanks, a sunken road, a wood or village, artillery should be placed so as to be able to direct a fire upon them, that they may not facilitate the

[8] General Ambert, in his *Études tactiques*, p. 401, gives a diagram to show that 'the powers of concentration of guns are as the squares of the ranges.'

approach of the enemy's columns. Guns of position should be stationed so as to command the greatest extent of range in order to profit fully by their superior power. These guns should be protected as much as possible by ditches, abattis, &c., and, if there be time, two or three feet of earth may be thrown up in front of them; cover from infantry fire may be easily obtained by sinking the piece in a pit about a foot and a half deep, and throwing the earth up to form a low parapet in front, side ditches being dug for the men.[9]

8. With regard to the distances at which field artillery should be placed from the objects fired at, no fixed rules can be given; they must necessarily depend upon the effective ranges of the guns, the nature and formation of the ground, and the positions of other troops; it is probable that under ordinary circumstances field batteries will be employed at ranges of from 1,000 to 2,500 yards; position guns, being more powerful, several hundred yards further, if the ground offers favourable situations; and horse artillery at 800 to 2,000 yards. Guns will still have to engage in some cases at very short ranges, as when attacked by infantry or cavalry, or if an opportunity should occur of bringing pieces to bear suddenly upon the flanks of an enemy's troops; but, when practicable, the longest *effective* ranges should be chosen, so as not to expose the men and horses to the deadly fire of the breech-loading small arms and machine guns, which should render ranges under 1,000 yards very dangerous to artillery. Batteries should not, however, waste their ammunition by firing at objects beyond *effective* range, a fault not unfrequently committed at the commencement of an engagement.[1]

[9] *Taubert*, p. 26. This has been practised of late in France and this country.

[1] The above remarks, written in 1870, coincide so nearly with the rules laid down by German officers who have written with later experience of war than ourselves, that no alteration is required. Thus, Prince Hohenlohe says:—'For a decisive struggle of artillery against artillery, the range must be under 2,000 paces; above 2,500 it can only be for purposes of delay; against other troops, 800 to 3,000 paces; artillery must never, if possible, approach within 800 paces of unbroken infantry; but against a shaken enemy, and when on defensive with other arms, artillery must not shirk the closest quarters.'—*Employment of Field Artillery*, p. 10. And at page 3: 'Artillery can no longer approach to case-shot range, unless indeed, it wishes to expose itself to a speedy and total annihilation.'

9. It is also essential to consider the formation of the ground and nature of the soil, not only of the part of the field the battery or brigade is to occupy, but also of that surrounding it. For precision in firing, the ground on which the guns are posted should be tolerably level, and should not have too great a command over the space which the enemy must cross over to the attack, as a *plunging* fire is little destructive. This was shown at the Alma, where the Russian heavy batteries, placed in chosen positions above the valley, and served by gunners well acquainted with the ranges, caused comparatively little destruction among the advancing British troops. A gently falling slope of not more than 1 in 15 is to be preferred;[2] the fire of artillery produces the most effective results on a slope of about 1 in 100. Batteries should not be placed on stony ground, as the enemy's projectiles make the stones fly in all directions, often causing considerable damage; marshy ground in front of a battery is good, should the latter not be likely to advance, as the shell, with either percussion or long time fuses, will either penetrate without bursting or do but little harm on explosion; undulating ground prevents the enemy from observing the effects of his projectiles, and thereby rectifying his fire.

A short distance behind the crest of a low hill, with the muzzles of the guns alone exposed, is sometimes a very favourable position for artillery, giving it both command and protection; but if, as at Inkerman, the reverse slope be inclined at such an angle that the trajectories of the enemy's projectiles passing over the crest are nearly parallel to the ground behind, the men and horses (if kept in rear of the pieces) will suffer severely.[3] The position of the two 18-prs. just behind the crest, and covered by a low unfinished breastwork of gabions sunk in the ground, which stopped many shot and shell, afforded

[2] Col. E. B. Hamley does not think a gentle slope gives any advantage, now 'that the effect of artillery depends on the right bursting of shells.'—*Operations of War*, third edition, p. 368. It must, however, be remembered, that the cone of spread of the bullets or fragments of shells (shrapnel or common) will cover more or less ground, according as the trajectory of the shell conforms more or less to its surface, to say nothing of the ground covered before the shell bursts, or before and after the graze, if blind.

[3] The British artillery lost 80 horses in the action.

considerable protection; for although the losses in men were very heavy (seventeen in the two detachments), neither carriages nor guns were disabled.[4]

Another instance of the advantage of slight natural cover is given in General Mercer's 'Journal of the Waterloo Campaign.' Mercer's troop of horse artillery had at Waterloo to sustain successive charges of cavalry, their retreat being succeeded by showers of shot and shell, which must have annihilated the troop if the little bank in front had not covered it and thrown most of the projectiles over the guns.[5]

10. The choice of the object for the fire of artillery must depend upon circumstances, and may require to be varied from time to time. Jomini's maxim that 'artillery of every kind employed in battles ought never to forget that its principal mission is to batter the troops of the enemy and not reply to his batteries'[6] is a good one. Taubert says—

'On the offensive, the fire is chiefly directed against the enemy's artillery, in order to divert their fire from the other troops, and to facilitate the advance of the latter; on the defensive, on the other hand, it is especially directed against the enemy's infantry or cavalry, to prevent their advance.

'In the last case, should the artillery be plied by that of the enemy, it should not on that account be induced to divert itself from its object. In an engagement between artillery on either side, it is the most advantageous plan for several pieces to concentrate their fire upon one of the enemy's until it is dismounted, and not to change to another until that object has been effected.'[7] It must, however, be added, that as the deadly effect of small-arm fire has so greatly increased since the introduction of BL. R. rifles, an offensive movement must always be preceded by a heavy artillery fire upon the enemy's infantry as well as his artillery.

Ammunition should never be wasted on unimportant positions

[4] Letter from Sir Collingwood Dickson, K.C.B., V.C.

[5] Vol. i. p. 317.

[6] *Précis de l'Art de la Guerre*, p. 601. This work, translated by Major Winship and Lieut. McLean, U.S.A., is called *Summary of the Art of War.*

[7] Col. Maxwell's translation of Taubert's work, *On the Use of Field Artillery on Service*, p. 73.

or skirmishers, for the mere sake of creating a few casualties, or when the enemy is at such a distance as to render the fire very uncertain; for by such a course the ammunition of a battery might be exhausted during the commencement of an action, without producing any adequate results. In general, the fire of artillery should be concentrated when practicable. Jomini laid down the rules, that advancing lines of infantry should be battered by cross or flank fire; advancing columns by direct or flank fire; and he points out that if troops can be taken in reverse by artillery fire, the moral effect produced will be incalculable.[8] The great difficulty of checking an infantry attack by artillery fire is now caused, as Col. Hamley says, by the advance being made in multitudes of small columns taking advantage of shelter.[9]

When a particular point of the enemy's line is to be attacked, it is necessary to open fire upon such obstacles as intrenchments, houses, barricades, hedges, &c., which might oppose the advance of the assaulting columns, as well as upon the enemy's artillery, if it be in such a position as to be able to harass the former; and in order to keep up a fire for the greatest length of time, and to avoid incommoding the attacking troops, the batteries should be placed so far that their fire will not be in the direction of the roads which will be traversed by them.

11. Solid shot have now been discarded as projectiles for field guns, which are supplied with common shell, shrapnel, and case shot. In our service the segment shell had since the adoption of the Armstrong R. guns taken the place of shrapnel; but the ML. R. guns, with which the field artillery is now armed, have shrapnel but no segment shell; the Prussian field guns have a proportion of incendiary shells,[1] which act like carcasses, and are more effective in producing conflagration than common shells; the SB. howitzers were formerly provided with carcasses. The Germans fired but few shrapnel from their field guns, but the French fired a large proportion of these shells

[8] *Précis*, p. 601.

[9] *Operations of War*, third edition, p. 430.

[1] See page 384.

during the war of 1870–71; the French shrapnel fuzes can, however, be adapted to only three ranges. Little experience of the formidable effects to be expected from shrapnel fire was therefore gained.

In general, common shell are fired against troops sheltered in woods or behind cover; or to destroy buildings, palisades, walls, or other obstructions; case shot and shrapnel or segment, against troops unprotected by cover, the former being used at short ranges up to about 300 yds., and the latter at the same ranges as those at which shell are fired.

Case shot may be employed with advantage against troops at the distance before stated, and especially if there be no great exposure of the gunners to the fire of musketry from the flanks; if troops, especially cavalry, are advancing upon a battery within a very short distance, double charges of case fired from the guns will do very great execution;[2] case is not nearly so effective on soft or marshy as on hard and stony ground.[3]

Common shells are particularly useful in the field when the enemy's troops are sheltered from the direct fire of the guns by being stationed in hollows, under cover of a wood, or posted behind artificial cover or rising ground. They are of great service also in the attack of villages, buildings, intrenched posts, &c., as well as against cavalry, as in this latter case the bursting of the shells frightens the horses and causes confusion. It would frequently be necessary to employ *curved fire* for these purposes, so that the shells, being fired with reduced charges and at high angles, might reach objects completely sheltered from fire with full charges and low angles.[4]

[2] BL. R. guns, having chambers like the Armstrong, could not fire two case shot at the same time.

[3] Capt. A. v. Boguslawski considers 'the age of effective case shot is passed,' for infantry, armed and handled as they are now, make it impossible for artillery to come into action and maintain itself at short ranges. (*Tactical Deductions*, translated by. Col. L. Graham, p. 105.)

[4] Capt. H. W. L. Hime, R.A., in his essay on *The Minor Tactics of Field Artillery*, says, this 'is one of those rules which it is so easy to preach and so hard to practise.' My own experience on the practice-ground and in warfare, however, assures me that such fire is formidable both morally and in destructive effect; and that it is so considered by the Germans is evident from their practice of carrying

Shrapnel with time fuzes are of little use against troops posted behind cover, as the bullets proceed forward over the cover, but have not sufficient velocity to penetrate through on striking it; but segment shell with percussion fuzes have proved very effective against men under shelter of walls or slight parapets, the shells bursting as they passed through, and scattering segments and fragments inside.[5] In New Zealand a practicable breach was made in the stockade of a *pah* in rather more than an hour's time, and at a range of 900 yds., by the fire of segment shells from six BL. R. 12-prs.[6] The Committee on Shrapnel *v.* Segment recommended that 'in the future equipment of field artillery, the proportion of shells should be 40 per cent. of shrapnel to 60 per cent. of segment;' but the ML. R. guns have no segment shells.

In firing shells it is better to aim a little short of the object than over it, as it is then easier to rectify the *laying* of the piece from observation of the graze or explosion.

Rockets are fired against large bodies of troops, especially cavalry; into villages, to set them on fire; into ammunition columns or batteries of artillery, to cause explosion, and to frighten horses.

12. When rapidity is combined with accuracy of fire the effect is greatly increased, but the latter should not be sacrificed to the former, except at case shot ranges; a too rapid fire is dangerous to the gunners and wastes the ammunition. As a general rule, the fire may be more rapid as the range decreases, the probability of hitting being less as the range increases; in ordinary practice R. guns can be fired as quickly as SB. guns, and ML. R. as rapidly as BL. R. pieces. With well-drilled gunners about two rounds of shell can be fired from a rifled piece in a minute,[7] the gun being properly laid

a proportion of reduced charges with their field guns. One of our own artillery officers was so convinced of its utility, that he had, during the Indian mutiny, a number of reduced charges made up for his battery.—C. H. O.

[5] See Reports on Armstrong 12-prs. in China, by Captain (now Colonel) Milward, R.A., and Capt. (now Lieut.-Col.) Hay, R.A. Also evidence of Capt. R. Harrison, R.E., *Report of Armstrong and Whitworth Committee*, p. 69.

[6] A similar pah had resisted the fire of an 8-in. gun, two 24-pr. howitzers, and a 9-pr. during two hours, and at a range of 200 yds.

[7] Segment with percussion fuzes rather more quickly—about seven rounds in

at each round; three or four rounds of case can be fired in the same time.

The chief difficulty in obtaining the formidable results to be expected from the superior accuracy of fire of R. guns arises from the incorrect estimates made by the gunners of the distances from the gun to the object. However well men are trained to estimate ranges merely by eye, it is often impossible when standing behind a battery to know by ordinary observation how far a shell may have burst under or over the object; the deflections may be guessed with tolerable accuracy. Many attempts have been made of late to contrive a simple and portable instrument for determining the ranges of objects with precision, and one of the best of these is Captain Nolan's *range-finder*.[8]

13. With respect to the value of the *mitrailleuse*,[9] which the French used in large numbers (latterly organised in batteries) during the late war, very different opinions have been expressed.[1] It is doubtless a formidable weapon for the defence

three minutes; but shrapnel with time fuzes only about five rounds in the same time.

[8] A description of this instrument, and of the different methods of employing it, will be found in the *Proceedings of R. A. Institution*, vol. viii. The advantages of using such an instrument will be seen by the figures below, the results of practice at Aldershot in 1869:—

Range	Error by range-finder	Error when judged by N.-C. officers
yds.	yds.	yds.
1,180	15	120 to 320
1,320	8	320 „ 470
2,350	13	150 „ 1,150
3,660	5	1,570 „ 2,340

Times taken to find the ranges by this instrument were from $1\frac{1}{4}$ to $3\frac{1}{4}$ minutes.

[9] Described in Appendix III.

[1] Boguslawski says:—'This mongrel weapon possesses neither the advantage of infantry in being able to get under cover and to move rapidly, nor the power or range of artillery;' and he states that it could on no occasion answer artillery fire with effect, nor can it defend itself against skirmishers.—*Tactical Deductions*, p. 104. Col. H. A. Smyth, R.A., who was with the 7th Prussian Corps shortly after Gravelotte, remarks 'of mitrailleurs the Germans have a high opinion, especially against cavalry attacks; horses, they say, being more alarmed by its horrid noise than by any other.' 'Observations among German Armies,' *Proceedings of R. A. Institution*, vol. vii. p. 201. Rüstow considers the concentsation of

of flanks, bridges, streets, breaches, or open ground at short ranges; but as it is unable to fire shells, to damage *matériel*, or to reach troops behind cover, its scope is limited; and at long ranges it is very difficult to see the effect produced, and therefore to alter the *laying* of the weapon if requisite.[2] The Committee which reported on them in this country, in 1870, stated that the small Gatling would be a valuable weapon for the defence of villages, field entrenchments, caponnières, têtes-de-pont, a breach, and for employment in advanced trenches or field works.

Very different accounts have also been given of the performances of mitrailleuses during the late war. For instance, at Gravelotte, it has been stated that, on the heights of La Villette, a battery of mitrailleuses placed behind small epaulments received no injury from the concentrated fire of 120 guns, and repulsed repeated infantry attacks;[3] while, on the other hand, three out of four mitrailleuses were quickly destroyed and the fourth obliged to withdraw, by the fire of three German artillery batteries, which came into action under their fire and that of the French artillery.[4]

Lt.-Col. H. C. Fletcher, S. F. Guards, in a Lecture delivered at the R. U. S. Institution, 22nd June, 1872, quoted the evidence of several British officers who accompanied different armies in France, in 1870–71. From these it would appear that the fire of mitrailleuses, on some occasions, produced very destructive effects upon infantry and cavalry, and compelled batteries to retire; and, at one of the battles before Orleans, Lt.-Col. Reilly 'distinctly saw batteries of mitrailleuses in the open, employed for a considerable time within 1200 yards of the Prussian horse artillery, and the horse artillery did not touch them the whole of that time.' The discussion after

their fire too great; and that, although suitable to defile fighting, they are more adapted to fortress than field purposes. *War for the Rhine Frontier*, translated by Lieut. J. L. Needham. Appendix A.

[2] This difficulty has been noticed at Shoeburyness, and Boguslawski points it out among other objections to its use.

[3] Essay by Lieut. J. T. Hildyard, 71st Highland Light Infantry, for the Wellington Prize. No authority is, however, quoted.

[4] 'Observations amongst German Armies,' by Col. H. A. Smyth, R. A. *Proceedings R. A. Institution*, vol. vii.

the Lecture showed the general opinion to be in favour of mitrailleuses for defence, but opposed to them for offensive purposes; and Brig.-Gen. Adye, after giving an extract from Col. Hamley's 'Operations of War,' to prove that a surplus artillery is a great disadvantage to an army, pointed out that—if mitrailleuses were added to the usual proportion of gun-batteries, an army would be embarrassed by a large amount of additional impedimenta; but if they were substituted for a certain number of gun-batteries, a loss of artillery power would result, from the acknowledged inferiority of mitrailleuses to guns for general purposes. Capt. H. Brackenbury's suggestion, that a lighter carriage, and one occupying less space than an ordinary gun-carriage, is required, would doubtless be endorsed by those who have considered the circumstances under which a machine gun would often be found most valuable.

CHAPTER V.

EMPLOYMENT OF FIELD ARTILLERY.

Tactics of Field Artillery: 1. Command of field artillery.—2. Divisional artillery.—3. Horse artillery.—4. Reserve or corps artillery.—5. Artillery masses.—6. Retiring and abandoning guns.—7. Defence and attack of positions.—8. Passage of a river.—9. Embarkation and disembarkation of field artillery.

Tactics of Field Artillery.

1. The formations, objects, choice of ground, ranges, and the uses of the different projectiles, having been pointed out, it is now necessary to consider briefly the movements or tactics of the arm, the long range and great mobility of which should, it is now generally acknowledged, give it more independence in action and more influence upon the result of an engagement than formerly.

It must be remembered that the field artillery with an army is divided into *divisional* and *reserve* or *corps* artillery, which have different functions; and that, while the former would usually be left to co-operate with the division of infantry or cavalry to which it was attached, the latter should be at the entire disposal of the officer commanding the artillery to employ in any manner required by the Corps Commander. In our service two batteries are usually placed under the orders of a Lt.-Colonel, who is the divisional artillery commanding officer; the third battery would be with the advance guard, if a division were advancing singly. The corps artillery would require two Lt.-Colonels, one for the horse artillery, and the other for the heavy batteries, and an officer of superior rank[1]

[1] Jomini observes: 'One of the most suitable means for obtaining the best possible employment of the artillery, would be always to give the superior command of this arm to a General of artillery, who is at the same time a good tactician and strategician.'—*Summary of the Art of War*, p. 320, or the *Précis de l'Art de la Guerre*, p. 604.

would doubtless be placed on the staff of the General commanding the corps, to assist him in distributing and superintending the corps artillery, so that it might be employed to the best advantage in carrying out the necessary movements and combinations. The following orders, issued by H.R.H. the Duke of Cambridge at Aldershot, just before the autumn manœuvres of 1871, emancipated the field artillery of the British Army from the supposed necessity of exactly conforming to the movements of the troops with which they were acting, but they are judiciously worded so that unity of action and the necessary control of the commanding officer may be duly preserved.

1. 'General officers commanding divisions or detached brigades should indicate to the officers commanding Artillery under their orders the general object of the movements about to be executed, and these officers will give directions to the captains of batteries as to the best mode of cooperating with and supporting them.' 2. 'Officers commanding batteries should be permitted (under the direction of their own commanding officers) to use their own judgment in selecting the best positions to enable them to operate with advantage either in covering an attack or retreat; conforming, of course, as much as the nature of the ground will permit, to the movements of the corps to which they are attached.' 3. 'Any special directions received by the officer commanding Artillery from the general or other officer in command of troops, relative to any change in the disposition of the batteries during the movements, will, of course, be promptly carried out.' 4. 'No battery ought to be exposed to the risk of Infantry fire, unless under unavoidable circumstances, which occasionally occur in action.'

A German artillery officer of high reputation remarks: 'The general *rôle* of artillery, as laid down by military writers for more than a century, has undergone no change from the introduction of rifled arms.' 'But if artillery is to fulfil its duties, and always to carry them into effect at the right moment, it is urgently necessary that it be at hand when required, and that it be worked in intimate relation with the other arms. For this purpose, it is also urgently necessary that the *object* should *be pointed out to it* by the commander of the troops.'[2] Great stress is laid by recent German military writers on the necessity of establishing by regular *organisation and command a close connection between the artillery and the other arms.*

Prince Hohenlohe points out that with a view to the communication of orders, to the concentration of a powerful fire upon a decisive point, as well as for reasons affecting the practice made from the guns, which will be presently noticed, batteries should be attached (in combined command by divisions of two or three batteries) to divisions, and not to brigades by single batteries. The artillery divisional commander riding with the general of the division hears and sees everything affecting the division. 'He can then send to his batteries, for which he selects positions, orders, either dictated by the division commander, or independently, being acquainted with his views.'[3] He need only keep with his batteries if the whole or greater part are in action. Batteries must, however, be employed singly under many circumstances, such as when a battery is attached to an advanced guard or outpost, if a brigade be detached with a battery for independent duty, or when a battery is with a cavalry brigade acting independently.[4]

The employment of two guns or single guns is strongly deprecated by Prince Hohenlohe, except for local objects, such as the destruction of a barricade, a reconnoissance with a small detachment, &c.

2. The *divisional artillery* must support the division, whether it be acting on the offensive or defensive, and the dis-

[2] *Employment of Field Artillery*, by Prince Hohenlohe, translated by Capt. F. C. H. Clarke, p. 11.

[3] *Ibid.* p. 13.

[4] From the stress laid by German writers on the necessity of keeping and working the divisional batteries together under combined command, some military critics have lately suggested that the battery is too small a unit for artillery. The gradual adoption and perfecting of the battery as an administrative and tactical unit has been shown, its suitability to most of the circumstances arising in warfare has been proved in recent campaigns; and, it may be added, that the Prussians have within the last few years reduced the unit itself from eight to six guns, as we and the French had done long ago, with a view doubtless to decrease of establishment and increased mobility.

position and fire of the batteries must be adapted to carry out the common object in view. The distribution of the batteries should be arranged by the officer commanding the artillery of the division, who would receive instructions from the general, the movements and working of each battery being left to its own commander (major or captain). The divisional artillery should *not be scattered* more than necessary, as the fire will be more formidable when several batteries *are massed*, but to avoid casualties the gun should be at *full intervals* when practicable. The batteries were usually placed on the *flanks* of the infantry, so as not to impede their movements or mask their fire, and also in order that the infantry might not suffer from the projectiles fired at the batteries; but now that large masses of guns are so frequently pushed forwards, positions, offering the best advantages as regards fire, are taken up by batteries, and the infantry in less rigid formations than formerly, are able to work past them. As the flanks of a line are in general its weakest points, guns posted there will require a strong support of cavalry or infantry. If the infantry and artillery of a division are accustomed to work together, a *special escort* is seldom required; for, as Prince Hohenlohe remarks, 'the other troops and the artillery, which look upon themselves as part and *parcel* of one another, will not leave each other in the lurch.'

Should batteries, however, *be detached to exposed situations*,[5] *they must* have a strong escort, which, if the ground be sheltered by cover, should be composed of infantry, but in open ground of cavalry; an infantry escort should be posted under shelter on the outer flank, but a cavalry escort generally in rear on the same flank. Should a battery in action be suddenly taken in flank at effective ranges by either artillery or infantry, it would most probably suffer heavy losses before it could change its front or retire. Captain Mercer's troop of horse artillery suf-

[5] Artillery, as the Prussian general points out, 'is unable to defend itself if unexpectedly attacked by cavalry; and the smallest body of infantry which succeeds in approaching it concealed from view, and fires upon the serving troops and horses, can compel a whole battery to drive off.'—*Army of North German Confederation*, p. 72.

fered fearfully at Waterloo from a battery which unexpectedly opened on its left flank at 400 or 500 yds. range. Horses and limbers, before covered by a slope, were struck by the shot that now plunged among them, and the battery was soon reduced to a wreck, capable of only keeping up a slack fire from two or three guns.[6]

3. The movements of horse artillery in action are more rapid and over greater distances than those of field batteries, and the fire is not usually so prolonged as that of the latter. Horse artillery is attached to cavalry brigades or divisions, and forms part of the reserve or corps artillery. Its chief duties when attached to a cavalry division are—

To commence the action by engaging the enemy's guns.
To prepare the way for attacks on cavalry and infantry.
To cover the cavalry when retiring.

To prepare the way for a charge, the horse artillery should advance on the flank to effective shell range and open a vigorous fire; but when the cavalry has passed the line of guns it should limber up and retire to a position adapted to cover the retreat of the cavalry. Should the charge be successful, it must again advance with the supports. Horse artillery should never be posted in front of cavalry, which would have both in advance and retreat to pass through the guns, for in the latter case the gunners and horses might be ridden down.[7]

Cavalry can effect little against infantry unless they have been rendered unsteady, and their formation broken by the fire of artillery.

4. The *reserve* or *corps artillery* attached to an army or corps should consist of both light and heavy batteries, the former (horse artillery) to be employed when great rapidity of movement is of consequence, and the latter when an overwhelming fire has to be brought upon any point. The reserve or corps artillery fulfils two purposes—one to support the

[6] *Journal of Waterloo Campaign*, by Gen. C. Mercer, vol. i. p. 326.

[7] Col. Maxwell, R.A., in a note on p. 55 of his translation of Taubert's work, gives an instance of the teams and gunners of a troop of horse artillery being ridden down in India by H.M. 14th Dragoons, when returning in confusion from an unsuccessful charge.

divisional guns, and the other to give the means of combining a large number of pieces as an *artillery mass* for a decisive effort either offensive or defensive. Thus the divisional batteries may be supported or relieved, or fresh ground may be occupied, or an advanced guard may be strengthened; but in the war of 1870 the Prussian corps artillery was frequently, as before pointed out, massed and pushed forwards at the commencement of an action, so as to enable the infantry columns to take up their positions under cover of a powerful artillery fire. It must not, however, be forgotten that circumstances may arise, as for instance at Lützen,[8] when a strong reserve of artillery is urgently required to ensure success, or even to prevent disaster, at a critical moment perhaps late in the day; in pushing forwards the corps artillery such a contingency must not be lost sight of. In the war of 1870 the Prussian artillery was better armed, more numerous, and manœuvred with greater skill than the French artillery, and the former was therefore enabled to take liberties, which might have proved disastrous against an enemy as well supported by artillery fire as the Prussians were.

5. *Artillery masses* must not be confused with what Taubert terms an *agglomeration of pieces* destitute of mobility, such as was employed before the formation of light or field artillery, and which may still be used in the defence of positions. Artillery masses of the present day should combine great mobility with powerful fire, which can be concentrated on some definite point of an enemy's line to be broken through,[9] strong

[8] This battle, which is described in the first edition of this work, p. 370, affords an instance of what may be accomplished by field artillery inferior in number to that of the enemy, but employed with more skill; the fewer guns, by being economised during the action, but massed at the right moment, overpowering the superior force which had been wasted by dispersion of the pieces and indiscriminate firing. The Prussian general remarks (*Army of North German Confederation*, p. 79), 'If the attack makes no progress, the reserve (first of all its artillery) is brought into action. Supported by the divisional batteries, it succeeds in silencing the enemy's artillery by a superior fire, or at any rate in weakening it, and covers his line with shells; in short, the enemy is shaken, and the way is opened for the reserve infantry and cavalry to strike the last and decisive blow.'

[9] 'To term the artillery a defensive arm, as is sometimes the case, can only be based on the untenable ground, that it cannot immediately break through the

forces of infantry and cavalry being ready to complete what has been effected by an overwhelming fire.

To accomplish the desired object with SB. artillery, it was also considered necessary to advance the guns gradually, as the fire became more unbearable, up to close quarters, and by pouring in a storm of case shot to utterly shake and demoralise the part of the line attacked. This was the method urged by eminent artillery tacticians, such as Taubert and Okouneff, and carried out in practice by General Senarmont at Friedland, and Field-Marshal Paszkiewitch at Warsaw; but against troops armed with modern weapons an attempt to bring a large force of field artillery into action at close quarters would probably result in an annihilation of the batteries; it would, moreover, be an obvious neglect of the peculiar advantages of the arm, which is now capable of producing very destructive effects at considerable ranges. Few troops could long stand the concentrated fire of six or eight batteries of rifled guns at 1,200 yards range, or even farther.

Masses of artillery have usually been employed after troops have been engaged for some time, and the weak parts of the enemy's lines have been ascertained. Thus Napoleon frequently commenced an action with numerous light troops along the whole front and a desultory cannonade from various points, his object being to conceal his intentions, cause the enemy to compromise his whole force, and thus obtain a knowledge of his position. At the decisive moment an overwhelming force, preceded by swarms of light troops, and supported by a *concentrated artillery fire*, was brought to bear upon some weak point, large masses of cavalry being kept ready to complete any advantage. Masses have, however, been employed at the opening of an engagement, as at Gross-Beeren, Warsaw, and Inkerman; at the two former with great success.

It may be as well to refer briefly to the bold, but hazardous, tactics recommended by General Okouneff, who prophesied that artillery would become the scourge of mankind, and that, its full capacity never having been shown, it would be used as

enemy's ranks like the infantry and cavalry.'—*Army of North German Confederation*, by a Prussian general, p. 71.

the *principal arm*, cavalry and infantry being mere subordinates. Okouneff's plan was to form a breach in the centre of an enemy's line by the fire of a concentrated reserve (mass) of 80 to 100 guns of large calibre (12-prs.); when the enemy's pieces are silenced and the breach complete, a large force of heavy cavalry, followed by a numerous body of fresh infantry, supported by guns, must charge into the gap made. He says: 'To attain this result every nerve must be strained, and every consideration must give way; if necessary, let the last gun and the last gunner be sacrificed.'[1] The guns, he considers, should be drawn up in a concave line, so as to obtain a cross fire on the object, enfilading fire being neither applicable nor desirable;[2] and he points out that, to obtain the desired result, the front must be clear of obstacles, such as villages or enclosures, which would protect the enemy's troops. Okouneff lays great stress upon obtaining 'at starting the upper hand' of the enemy's fire, and not allowing your own fire to slacken, but by increasing it prevent fresh batteries being brought up to the assistance of troops engaged; he cites Borodino as an instance, where the Russian artillery was paralysed by the French guns.[3]

Although Okouneff thus claims a greater power for artillery as an arm than would be generally conceded, and the favourable circumstances he required for the success of his method would be difficult to find in actual warfare with even a moderately capable enemy, his pamphlet was of value in calling attention to the chief principles which should be followed in employing a large force of artillery in action, viz.:—

To concentrate a mass of artillery.

To place the guns so as to obtain a cross fire on the object.

To obtain with artillery fire 'the upper hand at starting,' and to maintain if possible the superiority.

Whether the attempt be made to break through the centre (as Okouneff suggested) or any other part of the line, these

[1] *Use of Artillery in the Field*, by Major-General Okouneff, translated by Capt. Weaver and Lieut. Jones, p. 38. 1856. Jomini considered justly that 'the author has rather overstepped the mark.'—*Précis de l'Art de la Guerre*, p. 606.

[2] *Ib.* p. 30.

[3] *Ib.* p. 35.

principles should be observed; and it was by carrying them out during the war of 1870 that the Prussian artillery regained the reputation lost by inactivity during the war of 1866.

The requisite conditions for the successful employment of an artillery mass are—

(1) That the conformation of the ground be suitable, affording favourable positions not necessarily close together, but within easy reach of each other.

(2) That the batteries be possessed of great mobility, so that there may be no delay in getting into position and opening fire.

(3) That the number of batteries be not greater than can act together under due control.

During the war of 1870 the Germans massed their guns whenever practicable; and usually at the opening of an engagement, so as to shake the enemy and cover the deployment of the infantry, the divisional and great part of the corps artillery being so employed. At Wörth sixty guns were massed at Gunstett to cover an overwhelming attack on MacMahon;[4] the Guard, 12th, and 10th corps deployed nearly 230 guns against St. Privat (Gravelotte); at Sedan ninety guns of the 11th corps were massed, also those of the Guards.[5]

The great extent of ground required for a large *mass* of guns at full intervals, now usually necessary, as before pointed out, to avoid casualties, would sometimes be an obstacle to its offensive employment. Twelve batteries, or 72 guns, would require 1,453½ yards, or more than three-quarters of a mile, frontage;[6] the increased accuracy of fire and range of rifled artillery would, however, in many cases, allow of the separation of such a mass into two of six batteries, or three of four batteries each, without loss of effect; and some separation would generally be required in order to take advantage of the features of the ground. Colonel Hamley thus points out the advantages of massing guns: 'Although it is true that batteries posted

[4] See article on French and German armies in *Quarterly Review*, July and October, 1870, p. 432. Also *La Campagne de* 1870, par un Officier de l'Armée du Rhin. Rüstow says that the 5th corps deployed 14 batteries, or 84 guns, at Wörth.

[5] The writer was informed at the time by Major Roerdanz, an eminent Prussian artillery officer, 'that massing was the rule strictly observed.'

[6] See Fig. 141.

widely apart can concentrate their fire, yet the importance of the point to be aimed at is not always apparent from every part where separate batteries may be posted, and separation is in itself a great hindrance to singleness of purpose and promptitude of action. It is found best, therefore, to concentrate the batteries in masses—not necessarily in lines, but near enough to each other to be subject to simple direct control, and to give each other the benefit of any experience gained, as to range or effect, in the course of practice.'[7]

6. When it is advantageous to retire without ceasing fire, the order may be given to do so from either flank of the battery or brigade, by half-batteries or batteries, the remaining guns continuing their fire until the others have taken up their fresh position and are ready to open, when the former in their turn perform the same movement, and so on as required. Should it be desirable to retire slowly, keeping up a fire upon the enemy, the *prolonge* may be made use of, the limbers being reversed, and ready to move to the rear; cavalry will hesitate to attack the rear of a column retiring in this manner along a road, or through a defile.

The retreat of an army after an unsuccessful action is generally protected by cavalry and artillery, horse artillery if available; thus, at Königgrätz, the Austrians in retiring were covered by the reserve artillery and cavalry. 'The former especially sacrificed itself heroically on that day, to prevent the entire destruction of the conquered army.'[8]

Guns should not be abandoned without absolute necessity, as

[7] *Operations of War*, third edition, p. 432. See also Prince Hohenlohe's *Employment of Field Artillery*, p. 14. Sir Garnet Wolseley, in his *Wellington Prize Essay*, strongly deprecates the concentration of batteries, but apparently with the idea that they might be thus brought into action in ground without cover, and be consequently exposed to destruction from the accurate fire of modern guns and rifles. Under certain circumstances, even in general actions, batteries must doubtless be employed singly, but those who have described the war of 1870 are unanimous in their condemnation of the practice of bringing batteries one at a time, instead of several together, into action. Major Fox Strangways, R.A., in a Lecture delivered at Aldershot, says: 'There may be occasions when guns will be massed together in considerable numbers, but the introduction of rifled guns must tend to make them very rare.' This opinion is contrary to that of the victors in the late war, and to those of others who have lately written on tactics.

[8] *Army of North German Confederation*, p. 73.

a discharge of canister shot in the face of a charge of cavalry or advance of infantry might at the last moment not only check the attacking troops, but also considerably change the aspect of affairs, as regards the fortune of the day; as for instance, when the Brunswick squares were kept steady and the French cavalry repulsed by the case shot fire of Capt. Mercer's troop of horse artillery at Waterloo.[9] A charge of cavalry may pass through a battery in action, and do but little damage, as the gunners can shelter themselves in a great measure by getting underneath the guns and carriages; the drivers can do the same, by dismounting and getting between their horses. At the battle of Balaklava, the English light cavalry rode through one of the Russian batteries, and, though cutting down many of the gunners, were eventually obliged to retire, without taking or spiking any of the guns. In this case, however, the Russian artillery was strongly supported by flanking batteries, as well as by both infantry and cavalry. The British gunners, at Waterloo, when attacked by masses of cavalry, served their guns till the last moment, and then retired within the nearest infantry squares for protection, but on the retreat of the French cavalry they issued from their shelter and again served their pieces.

Should it prove absolutely necessary to abandon guns upon the field, care must be taken to render them unserviceable. This may be done in various ways—viz. by spiking them, by knocking off a trunnion, with BL. guns by taking away the vent-piece or wedge, by breaking the wheels of the carriages, and even by setting fire to the latter. If it appears at all likely that the guns will shortly be recaptured, or that the gunners will only have to retire from them for a short period, they may be rendered unserviceable for the time by using spring spikes, and by carrying away the side-arms and elevating screws. All repairs which may be required upon the field of battle should be executed with the utmost promptitude and despatch, and after an action the whole material of a battery should undergo a searching examination, with regard to the damage which it may have received.

7. Intrenched positions, villages, &c., are constantly occupied

[9] *Journal of the Waterloo Campaign*, vol. i. p. 314.

by a comparatively weak force in order that it may be able effectually to withstand the attacks of a powerful enemy, which it could not do in the open field. When an army is disputing the advance of an enemy, it usually occupies and intrenches certain positions which are most favourable according to the formation of the ground for defence, and which will therefore give it a great superiority over the invader; even should the defenders be driven from their position, the enemy will suffer much loss in taking it, and his progress will be retarded. In the defence of positions artillery plays a most important part, great care and skill being required in the disposition of the guns in order that their fire may produce the greatest possible effect.

In the *defence of a position*, a great part of the artillery, especially the heavy batteries, is usually disposed of in arming the works, so that a powerful fire may be directed at long ranges upon the enemy's artillery and infantry. Some batteries must, however, be held in reserve to strengthen the line at any required point, or to act decisively in driving back any of the enemy's troops, should they force their way into the works; the artillery placed in position should be posted so as to obtain a *cross fire* on all the approaches to it, and the heaviest guns be placed in those works which are capable of offering the most prolonged resistance to the enemy's attack, and in such a manner as to be able to keep up a fire on the assaulting columns without incommoding their own troops.

The batteries composed of the lightest pieces should be stationed at the most advanced posts, so that they may retire from them with facility, if obliged to do so. A large quantity of artillery should be placed to defend those points of the position to which the approach is easiest, but those which appear almost inaccessible should not therefore be left undefended. Common and shrapnel shells may be employed for the purpose of shelling the ravines, cross roads, woods, villages, &c., which may be within range, and so prevent their forming a safe shelter for the enemy's riflemen. The ground surrounding the works should be cleared of objects which might afford cover to the enemy's infantry, or prevent the effective use of shrapnel shell, and the *distances* of each battery from different *marked* *objects* on the ground in front should be ascertained, in order to ensure accuracy of fire.

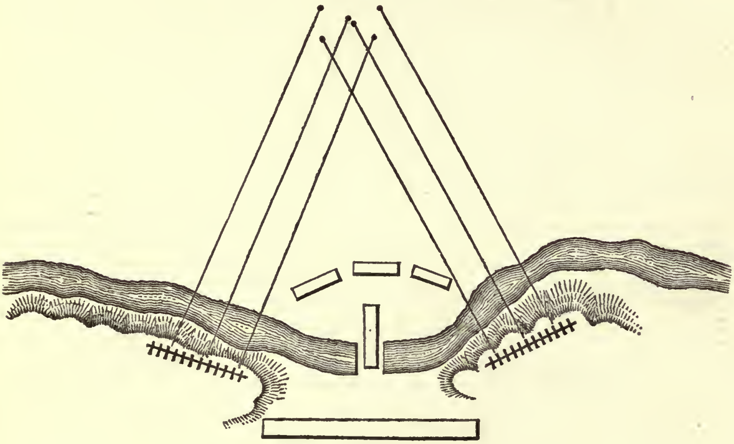
Should the enemy be repulsed, the guns must fire on him so long as he remains within their range, unless by thus doing they would interfere with the movements of troops sent in pursuit. If, however, it is necessary to retire from the position, either temporarily or otherwise, the guns should be withdrawn, according as they may seem in danger of being taken, to such positions as shall have been *selected beforehand*, in order that they may by their fire arrest or retard the enemy's march.

Before *attacking an intrenched position*, the commanding officer of artillery should accompany the officer charged with the execution of such operation, in order to make a reconnaissance of the roads which lead to the position, the nature of the works to be attacked, as well as that of the surrounding country, with the view of placing his guns in the most favourable and commanding situations.

In the attack of works in the field, the guns should be placed in the *prolongation of the faces* in order to *enfilade* them, and to destroy their accessory defences, such as traverses, &c. Heavy batteries, from the nature and size of their projectiles, should be used for this service. The guns of the largest calibre which accompany the attacking force should be placed at such ranges as fully command the position, in order to fire, not only upon the intrenchments, but also on the *troops in rear*, if the works be supported. The artillery *prepare the way* for the infantry attack by a heavy and well-directed fire, which may be continued while the attacking forces advance to the assault, as rifled guns can frequently fire over the heads of troops without danger to them; the batteries then take up such fresh positions as to be able either to support the infantry in case of a *repulse* or of a *counter attack*, or if successful, to *follow* these troops when the works are carried.

Good instances of the attack of intrenched positions were given at the battle of Borodino in 1812, when the Russians so obstinately defended themselves against the French; at the taking of Warsaw by the Russians in 1831, which latter is cited by Okouneff as an example of what immense results can be accomplished by the concentrated and well-sustained fire of an enormous battery of 100 guns or more; 120 is the number he gives at Warsaw, but the Polish account states that there were 200 guns. It is worthy of remark that at the taking of Warsaw the light pieces advanced with the assaulting columns, in order by the fire of canister to keep the defenders from the parapets; this was also done in the most gallant way by two field batteries[1] at the taking of the Malakoff at Sebastopol, but

Fig. 146.



the enemy's heavier guns not being silenced, the batteries were obliged to retire with heavy losses.

Instances of the employment of intrenched positions were given by the Duke of Wellington at the celebrated lines of Torres Vedras, and by the French at Metz in 1870.

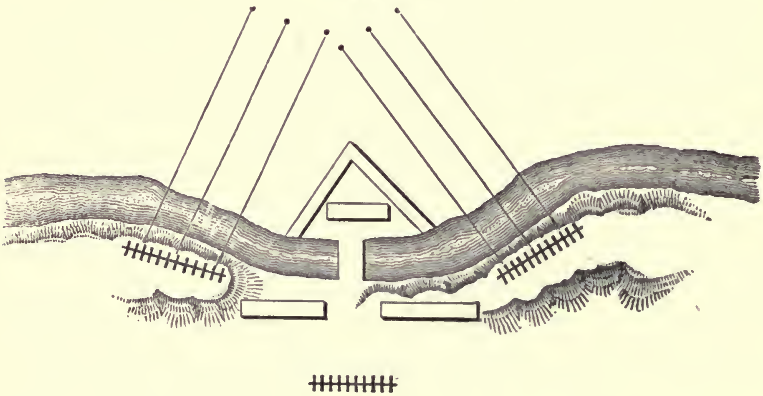
The rules which should be observed in the employment of artillery for attacking or defending an intrenched position would also apply to the attack or defence of a village. It may, however, be added that in the attack of a village, car-

[1] 'Two field batteries placed near the Lancaster battery received the order to advance towards the curtain in order to sustain these attacks; but they could not maintain themselves before the terrible fire of the Russians, and after having fired some rounds, losing almost all their gunners and horses, they were obliged to retire.'—*Siége de Sébastopol*, par le Général Niel, p. 435.

casses or incendiary shells might be employed with advantage; and in the defence mitrailleuses would doubtless do great execution in the streets and open spaces.

8. When a *corps d'armée* or division is about to cross a river in the face of an enemy, the guns should be disposed so as to command the space which the enemy would occupy to oppose the passage and formation of troops upon the opposite bank; the employment of artillery is indispensable to enable them to effect this object. The batteries should be disposed as in Fig. 146, so that *their fire may cross* on the opposite bank, and thus protect the deployment of the troops after passing

Fig. 147.



over; in order that the guns may do this most effectually, the ground upon which they are placed should command that on the opposite side of the river; the covering batteries do not cross until after the rest of the troops.

In the defence of the passage of a river, the heaviest guns should be posted so as to command the bridges, fords, and the approaches thereto, and to take in flank any troops which may have already crossed the river. The other guns should be placed so that they may be able to concentrate their fire upon the main body of an approaching enemy. In the defence of a *tête-de-pont*, two batteries should be posted as in Fig. 147, so as to play upon the advancing troops, and a third battery should be placed on favourable ground in rear of the bridge, in order to prevent its use or repair by the enemy after the work has been taken.

9. In embarking artillery in the presence of an enemy, or when the latter is close at hand, the officer commanding should endeavour to embark as much of his charge as possible at the earliest period, and with the utmost despatch. He must, however, remember that the possibility or probability of having to leave some guns should not interfere with the more important consideration of keeping on shore a sufficient force of artillery to repel any attack which may be made.

The horses and carriages should be first embarked, with the exception of such a proportion of guns and limbers as is calculated for the defence of the position, which the other troops may be occupying; if this be near the water, the limbers may also be sent off, and the guns dragged to the boats by men. A sufficient supply of ammunition should be at hand in a boat or two, close to the shore. If the position be a mile or two from the place of embarkation, it will be necessary to retain a certain proportion of horses. In all cases the guns are embarked the last; and should the enemy be actually present, the embarkation of the last of the troops generally takes place at night.

In disembarking, the artillery should endeavour to gain the shore and land with the troops whose object is to cover the landing of the main body; a sufficient supply of artillery ammunition and stores should be in boats near the shore. If on a coast, the landing would generally be covered by the fire of the large vessels and gun-boats.

In disembarking guns from boats, they should be run on shore muzzle foremost, so as to be ready for action immediately; this operation should not at the most take longer than five minutes, provided the water be tolerably smooth.

No absolute rules can be laid down for the employment of artillery in the field under all the different circumstances that may arise, and rules and principles can only be properly applied by those who have both skill and judgment as well as professional knowledge; but the previous remarks, which are based upon the experience of numerous wars, will it is hoped be of use to artillery officers.

CHAPTER VI.

EMPLOYMENT OF FIELD ARTILLERY.

1. DECISIVE effects have usually been accomplished by artillery in the field either by overwhelming a particular point in the enemy's lines with direct or slightly oblique fire from a large artillery mass, or by pushing guns forwards to take troops in flank; for the latter purpose fewer guns are required than for breaking through a line, two or three batteries, or even one, brought rapidly and unexpectedly to bear upon the flanks of troops, having not unfrequently stopped or broken them.

A few instances taken from engagements fought in this century, in which field artillery has played a conspicuous part, will be given to illustrate the remarks made in preceding chapters, and the examples will be divided into several groups to show how successive changes in arms have necessitated modifications in artillery, as well as in infantry or cavalry, tactics. Thus—

Up to the Crimean War	SB. guns, and SB. small arms were used.
In the Crimean War of 1854	SB. guns, and R. and SB. small arms.
In the Italian War of 1859	R. and SB. guns, and R. small arms.
In the French War of 1870	R. guns, and BL. R. small arms.

Examples previous to Crimean Campaign.

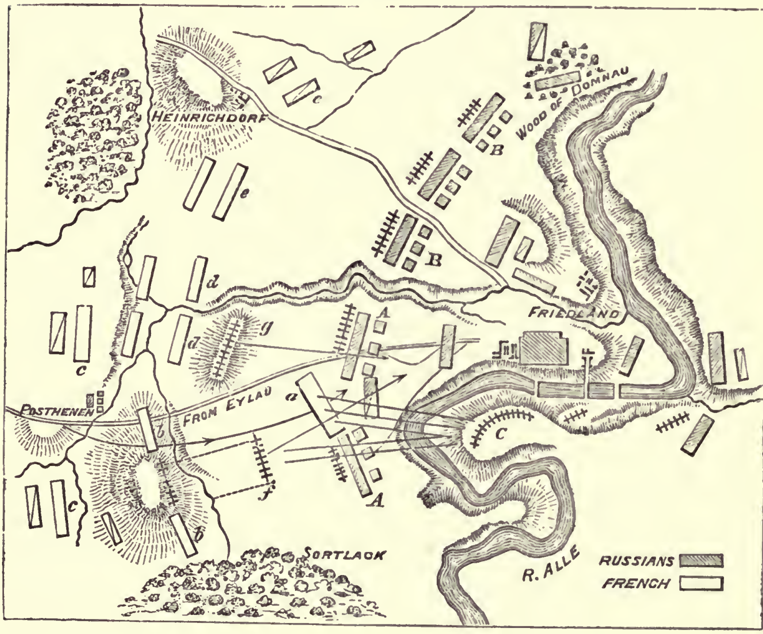
2. A new era in the employment of field guns may be said to have been inaugurated by Napoleon, and his able artillery commanders, Senarmont and Drouot, who, recognising the advantages to be obtained by the right use of what, by better organisation and increased mobility, had become a powerful arm, no longer condemned their field artillery to wait until the other arms had performed their part, but used it vigorously and skilfully to fulfil its proper function of preparing the way for the action of the infantry and cavalry.

3. *Friedland.*[1]—This battle was fought on June 14, 1807, between the French and Russian armies, and terminated in favour of the former—a result often attributed to the admirable handling of their artillery and the concentration of its fire. The French advanced guard, under Marshal Lannes, having on June 13 arrived at Posthenen, about three miles from Friedland, Benningsen, who commanded the Russians, determined to attack it before the arrival of other corps, and to pass his army over the river Alle in order to march to Königsberg by the main road through Heinrichdorf. Mortier arriving, however, shortly after the Russian general's attack (on the 14th), the latter meeting with so much resistance, deployed his force into two lines in an extended position (see Fig. 148), having the town of Friedland and the river Alle in its rear. The two French corps, occupying an extended position between Heinrichdorf and Sortlack, and a mass of cavalry, sustained the conflict alone until five o'clock in the afternoon, when the rest of the French army arrived upon the field, united itself with the above corps, and formed a fresh order of battle under Napoleon himself, Ney's corps being on the right, Lannes in the centre, Mortier and the cavalry on the left. The corps of General Victor and the troops of the imperial guard formed the reserve. Ney's column advancing from the woods behind Posthenen, drove in the Russian left, and prepared to storm

[1] See Grewenitz, Taubert, *Mémoire sur le Lieut.-Gén. Senarmont;* and Alison's *History of Europe.*

the town, obtain possession of the bridges, and thus complete the ruin of the enemy. Ney's right column was assailed in flank by some Russian batteries on the opposite bank of the Alle, and his left column being charged by the Russian imperial guard, he was driven back, the artillery causing frightful ravages in his ranks. The Russian guard was repulsed by the advance

Fig. 148.



Battle of Friedland.

of one of Victor's divisions, assisted by the fire of the batteries of that corps, and the Russian left driven off the ground by the brilliant artillery manœuvre of General Senarmont, who commanded the French artillery. Collecting, with Victor's consent, the divisional artillery of the first corps, consisting of thirty-six pieces, he divided it into two batteries of fifteen guns each, and a reserve of six guns. The right battery (*f*) was placed in front of the wood of Sortlack, the left (*g*) in advance of Posthenen, the intention being to destroy the enemy's guns and masses by the cross fire of the two batteries. The reserve was posted behind Posthenen. The guns opened at 200 toises,[2] and after a few rounds advanced to 100 toises, and then with the prolong to sixty toises, at which range only case shot were fired. Disregarding after a short time the fire of the Russian guns, Senarmont's batteries poured the most terrible storm of case shot into the Russian masses, whose ammunition was nearly exhausted, and which were thus driven into the defile before Friedland. Senarmont passed from one to other battery to direct the movements, their commanders being wounded; but the ground being in the form of a triangle, the batteries found themselves at last reunited.

Each piece fired seventy-two round shot or shell, and twelve case shot, each battery consisting of ten 6-prs., two 4-prs., and three howitzers. The French artillery losses were three officers and fifty-two men killed and wounded, and fifty-three horses killed.

The Russian cavalry attempted to check the advance of the battery, but Senarmont promptly changed front and repulsed it with ease. Napoleon himself was astonished at the effect produced by this battery, acting thus independently. The town was stormed, and the bridges set on fire, the retreat of the Russian right being thus cut off; it succeeded, however, in crossing by a ford higher up; the defeat of the Russians was complete, and their loss severe.

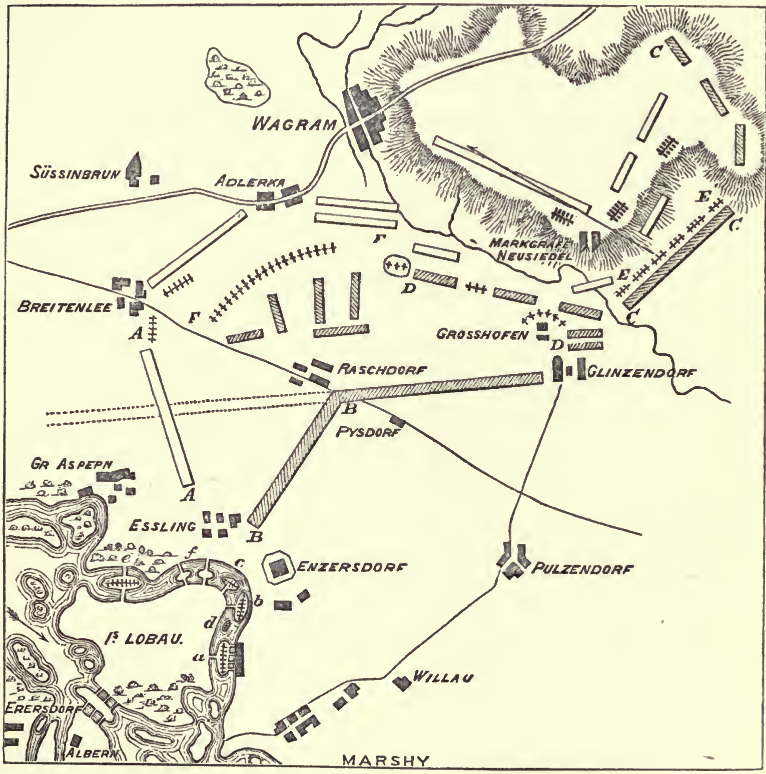
The position of the Russian batteries on the right bank was good, and the guns would probably have succeeded in protecting the Russian left flank, had it not been for Senarmont's unexpected and overwhelming manœuvre.

The division of the guns into two batteries was skilful and well adapted to obtain by cross fire the crushing effect required; the ground was, however, favourable to the manœuvre, the Russians being driven into a confined space, from which retreat was difficult; but there does not appear to have been any reason for advancing the guns to such short ranges as sixty toises (130 yds.), for the fire would probably have been as effective from 100 yds. in rear.

[2] A toise = 2 mètres, and a mètre = 39·37 in.

4. *Wagram.*[3]—In this battle the use and application of artillery is shown very conspicuously, both as regards its employment upon the field of battle and also with respect to its utility in covering the passage of a river. In order to enable them to cross to the left bank of the river, the French had

Fig. 149.



Battle of Wagram.

placed powerful batteries upon different islands (see Fig. 149, *b*, *c*, *e*), situated between that of Lobau (across which it had been determined to force the passage) and the opposite bank, consisting in the aggregate of twenty-eight mortars and sixty-two guns, making in all ninety pieces of ordnance. This

[3] See Grewenitz, Taubert, Okouneff, and Alison's *History of Europe.*

judicious disposition of their artillery enabled the French to open a heavy fire on the evening of the 4th June, 1809, on the Austrian lines between Aspern and Enzersdorf, under cover of which six bridges were thrown at another point of the river (*a*, *d*, *b*); across these the army passed over, and was formed on the right bank on the morning of the 5th.

The Austrians retired, their left wing taking position on the plateau of Wagram, and their right wing to the plateau north-west of Süssinbrun. Napoleon assaulted the plateau of Wagram on the evening of the 5th, but without success; for, not having taken any bridges to throw over the Russback, he was unable to bring up cavalry and artillery to the support of his infantry.

On the morning of the 6th the Austrian right wing advanced between Breitenlee and Gros-Aspern, driving back the French left (*B B*) behind Essling and Enzersdorf; while on the other hand the right wing of the latter army (*C C* and *D D*) was attempting to turn the left and force the front of the plateau of Wagram. The reserve of the French, composed of infantry, cavalry, and artillery placed near Raschdorf, awaited the issue of the attack upon the plateau of Wagram. Up to this point the victory remained undecided, the right wing of the Austrians was already priding itself, as at Marengo, on having gained the day, when the corps of Davoust and Oudinot succeeded in turning and forcing the left wing. Their artillery (*E E*), covered by a cloud of riflemen, commenced a fire so rapid and well directed that almost all the Austrian guns on that flank were dismounted, and the position on the plateau was enfiladed. At the same time the famous artillery attack against Adlerka was ordered by Napoleon, who sent General Lauriston with 100 guns from the reserve to take up a position in front of the Austrian centre. This formidable battery (*F F*) advanced until within a short distance of the enemy, and then poured death and devastation among his ranks; while protected by this artillery the attacking columns marched upon the Austrian lines, as soon as Napoleon saw that Davoust's attack upon Neusiedel was successful. The result of the day did not remain much longer doubtful, although the Prince of

Liechtenstein attempted for some minutes to defer the decisive blow near Adlerka. The Austrians retreated in good order.

Okouneff, in criticising this artillery manœuvre, observes that it failed to effect what it was doubtless intended to accomplish—viz., to break the Austrian centre; and the reasons he gives for its want of complete success are, (1) that it opened at too great a range and remained stationary instead of advancing; (2) that the fire was not kept up for a sufficient length of time, as the Austrian artillery was not by any means silenced or their infantry broken; and (3) that the attacking columns were formed in an unsuitable manner.[4]

Taubert gives the above manœuvre as a magnificent example of the employment of artillery in masses, but as a less successful one than that of Friedland. He says: 'To the fire of this enormous battery, which continued for half an hour, succeeded the attack of imposing masses of cavalry and infantry; but they threw themselves upon troops completely unbroken, and were repulsed. Before the formation of fresh reserves was completed to renew the attack, the Austrian commander-in-chief was induced, in consequence of the occurrences on his left wing, to commence the retreat; so that it may be said with perfect truth that the great attack against the Austrian centre did not decide the day, but that the turning attack under Davoust did.'[5] The chief causes of failure assigned by Taubert were, (1) the too great number of guns in one mass, rendering individual command of it impossible; (2) the want of mobility of the foot artillery, which only advanced at a walk, while the horse artillery moved at a trot, the consequence being that fifteen guns were dismounted in getting into position, besides the losses in men and horses being great; (3) the guns should first have taken position at round shot range, the enemy's fire not being subdued.

Notwithstanding the above criticisms, this artillery manœuvre appears to have fully accomplished its object; for it held in

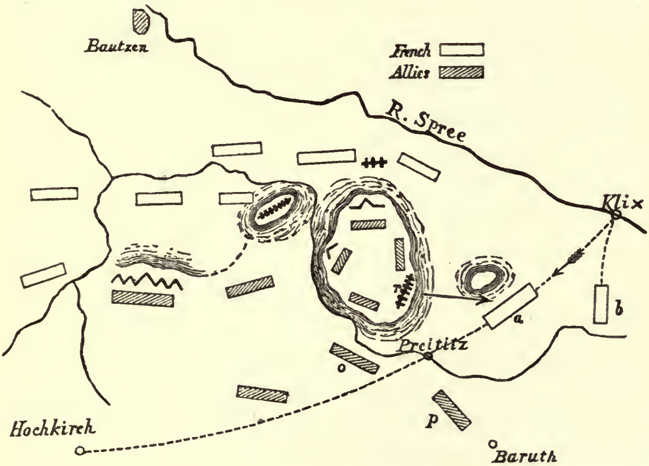
[4] *Use of Artillery in the Field.*

[5] Taubert's *Use of Field Artillery*, p. 189. Jomini, however, says that the turning wing of Davoust would not have succeeded had it not been seconded by the vigorous attack on the centre.—*Summary of Art of War*, p. 224.

check the Austrian centre and inflicted severe losses upon it, and thus led to the success of the subsequent attack of Macdonald's columns. The range cannot have been too great, as Okouneff says, for case shot were fired.

5. *Bautzen.*—The allied Prussians and Russians occupied a strong position, strengthened with fieldworks hastily thrown up; and to force this position Napoleon determined to make vigorous false attacks with the bulk of his army on the left and centre; while Ney, who was marching further to the north, was ordered to advance upon the right rear, and if possible to

Fig. 150.



a. Ney. *b.* Lauriston. *o.* Kleist. *p.* Barclay de Tolly. *r.* Prussian guns.

surround at least the right wing of the allied army. The action commenced on May 20, 1813, but as Ney was unable to arrive on that day, the combat ceased towards evening. On the 21st it was resumed; the attention of the allies being distracted by an attack on their left, and a vigorous cannonade from the French artillery, which had been advanced to the heights opposite Kreckwitz, in the centre, Ney was ordered to advance on the steeple of Hochkirch, in rear of the allied position (Fig. 150), and Lauriston, round by Baruth, in the same direction. Ney took Preititz; but Blucher, being determined to retake it, despatched Kleist with fresh troops to the assistance of Barclay de Tolly, while twenty Prussian guns (*r*, Fig. 150) played with such effect upon the flank of Ney's columns, causing the most dreadful destruction, that they were compelled to change their direction and abandon the village of Preititz. This check suffered by Ney, who was unable to attack again till one o'clock, saved the allied army from total defeat, and allowed them sufficient time to withdraw in perfect order.

Jomini gives this as an instance of the effect produced upon troops by a flank fire from artillery. He says: 'The fine movement of Ney upon Preititz (battle of Bautzen) was neutralised by a few pieces of Kleist, which took his columns in flank, arrested them, and decided the marshal to change his good direction.'[6]

6. *Gross-Beeren.*—On August 23, 1813, a French force, under the command of Oudinot, attacked the allied army[7] under Bernadotte, the latter being posted in and around the village of Gross-Beeren to oppose the French advance upon Berlin.

The French having taken the village, General Bulow was ordered to attack it with 35,000 men and a powerful artillery. The ground in front of Gross-Beeren being favourable to the deployment of artillery, and the rain which had fallen all day having rendered small arms nearly useless, Bulow advanced in two lines, preceded by forty pieces, deployed under the command of General Holzendorff, and followed by a reserve with cavalry on the wings of the latter. The artillery consisted of

A 12-pr. Russian		battery of	12	pieces.
A 12-pr. Prussian		do.	8	do.
Half a 6-pr.	do.	do.	4	do.
Two 6-pr.	do.	do.	16	do.

The guns opened fire at 1,800 paces[8] (*A A*, Fig. 151), but as the 6-prs. were of little use at this range, the whole were advanced by alternate batteries to 1,200 paces (*B B*, Fig. 151). The French artillery, which was numerous, causing great dam-

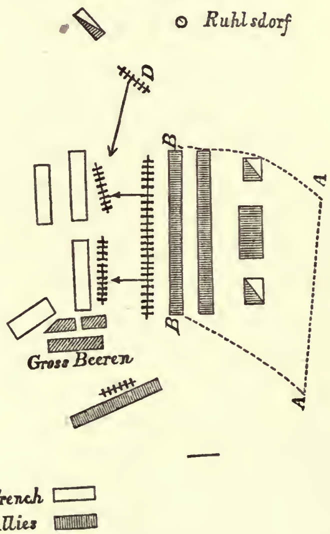
[6] *Précis de l'Art de la Guerre*, p. 601. Jomini was in this battle chief of the staff to Ney.

[7] Prussians, Russians, and Swedes.

[8] Pace = 30 in. nearly.

age to the allied guns, the latter were reinforced to sixty-four pieces and advanced up to 700 or 800 paces, while a Swedish battery on the right (*D*, Fig. 151) took the enemy's guns in flank.

Fig. 151.



The French guns being almost silenced by this combined fire, General Bulow attacked with the bayonet, the 6-pr. guns accompanying his movement and assailing the French with case; in order to bring his guns into action with sufficient rapidity for this latter movement, Holzendorff mounted his gunners on the carriages. The village was quickly carried, and the defeat of the French completed by the vigorous charges of the allied horse.

This attack on Gross-Beeren was a good example of the use of an artillery mass with the aid of the skilfully disposed flanking battery; the success of the advance of the light guns, to aid with case fire the bayonet attack of the infantry, was entirely owing to Colonel Holzendorff promptly mounting his gunners on the carriages, contrary to custom. The employment of artillery in this battle was very similar to that of the Russian artillery at Warsaw; the Polish guns were in redoubts, but the principle of attack was the same—viz. first a concentrated fire of a powerful battery, maintained and gradually advanced until the enemy's fire was silenced; second, a bayonet attack supported by case fire of light guns advancing with infantry. The Prussians, having felt the want of heavier guns, had recently added 12-prs. to the reserve artillery, and they no doubt proved most useful in this action. De Grewenitz also informs us that shortly before the battle the N.-C. officers of the Prussian artillery had been mounted, and that dispositions had been made for mounting the gunners on the limbers. He, however, laments that, notwithstanding the great advantages derived from these arrangements during the campaign, the N.-C. officers were again dismounted after the peace.

This battle gives us the first instance of the employment by the allies of a large mass of artillery, a manœuvre taught them by Napoleon.

7. The British army was so poorly provided with field artillery in the Peninsular War, that few instances can be found of the fire of guns producing any special influence upon the result of an engagement. Among these, the following are worthy of notice in several respects. At *Vimiero*, in 1808, Laborde's attack was repulsed, chiefly by the fire of a battery which opened on his left flank from the 8th Brigade; but, among other reasons for not pressing the French in their retreat, Sir H. Burrard gave these: the state of the artillery carriages, which were so shaken as to be scarcely fit for service, the scarcity of horses and mules, and the making off of the hired Portuguese carmen with their carriages.[9] The importance of strength and durability in artillery *matériel*, and of providing the requisite number of horses and trained drivers for the transport of stores, was on this occasion clearly shown.

8. An instance, on a small scale, of the successful concentration of artillery, was given at the battle of *Talavera*, in 1809. Three heavy French columns advanced to attack the British right, which rested on an unfinished redoubt, armed with a battery of 3-prs.; three batteries placed at intervals to the left of the redoubt were massed in a line oblique to the advancing columns; and a heavy fire being thus brought to bear on their flank, in addition to the direct fire of the 3-prs. in the redoubt, the French infantry were driven back.[1]

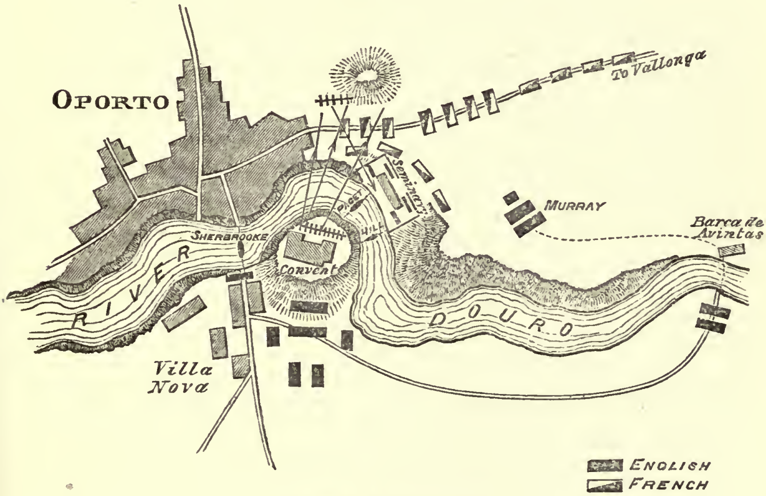
9. In Wellington's daring *passage of the Douro*, on May 12, 1809, in the face of Soult, who held Oporto with his army, the fire of several British batteries, which were massed and skilfully posted, enabled the infantry to maintain themselves after crossing until the success of the operation was assured (Fig. 152).

[9] Napier's *Peninsular War*, vol. i. p. 212.

[1] *Field Battery Exercise and Movements*, 1831, p. 136.

Wellington (then Sir A. Wellesley) fixed upon an unfinished building, a seminary, surrounded by a high stone wall coming down to the water on both sides, capable of holding two battalions, and with only one entrance, a gate opening on the Vallonga road. This structure, in which the French had neglected to post any men, commanded everything near, except a mound within cannon shot, but too pointed to hold a gun; and being situated round a bend of the river and higher up than the town, the line of passage to it was hidden from the troops in the town. A small skiff obtained from a barber enabled a

Fig. 152.



Passage of the Douro.

party to cross and secure three barges, and these boats had crossed with troops several times before the French were alarmed. Clouds of skirmishers then made a fierce attack upon the seminary, and the French artillery commenced to play upon the building; but a battery of eighteen or twenty British guns, established in front of the convent on Mount Sarea, commanded the whole enclosure round the seminary and swept the left wall, so as to confine the French attack to the side of the iron gate. General Murray, who had been sent with a small force round by Barca de Avintas, having arrived, and

General Sherbrooke having crossed in boats pushed over by the citizens, the French beat a hasty retreat, General Hill's troops in the seminary sending a damaging fire into the masses as they passed, and the artillery from the heights of Sarea searching the enemy's columns as they hurried along in retreat. Five French guns, checked by musketry fire on coming out of the town, pulled up, and having most of their drivers shot down, were abandoned.[2]

10. At the battle of *Waterloo*, the British artillery, which was greatly inferior, both in numbers and in weight of metal, to the French, did excellent service; and the commanding officers appear to have been allowed more independence than was usual at that time. The Duke of Wellington permitted Sir A. W. Fraser, who commanded the British horse artillery, to dispose of his batteries as he chose, and, as already mentioned (p. 379), to change their armament from 6 to 9-prs. before the battle. Sir A. W. Fraser says: 'The English horse artillery did great execution, and I must be allowed to express my satisfaction that, contrary to the opinion of most, I ventured to change (and under discouraging circumstances of partial want of means) the ordnance of the horse artillery (from 6 to 9-prs.). Had the troops continued with light guns, I do not hesitate to say the day had been lost. The earlier hours of the battle were chiefly affairs of artillery; but, kept down by the admirable and steadily continued fire of our guns, the enemy's infantry could not come on *en masse*; and his cavalry, though bold, impetuous, and daring, was forced to try the flanks rather than the front of our position. The steadiness of our infantry, too, became confirmed by the comparative repose afforded by our fire.' Fraser mentions the good service done by Bull's howitzer battery in clearing a wood of the French. He also says: 'Our guns were taken and retaken repeatedly. They were in masses, especially the horse artillery, which I placed and manœuvred as I chose. We retired from them (the guns) only to shelter ourselves under our squares of infantry, and instantly resumed our posts

[2] See Napier's *Peninsular War*, vol. ii. p. 287.

the moment the cavalry was repulsed.'[3] The French pieces consisted of 8 and 12-pr. guns, and 6-in. and 24-pr. howitzers; the British pieces were (see note, p. 361) 9-prs., 12-prs., and heavy and light 6-prs. guns, and 5½-in. howitzers.

11. During the long peace which succeeded the battle of Waterloo, but little attention was paid to the development of artillery tactics; but the following example will show that the Russians continued to appreciate the great importance of employing a large force of the arm in a bold and independent manner.

Warsaw.—The taking of Warsaw was the final act of the war between the Poles and Russians in 1830–31. The Russian general, Field-Marshal Paskievitch, having united his corps, determined to take Warsaw by a *coup de main.* His force consisted of 60,000 men[4] and 386 guns. On September 6, 1831, the Russians succeeded in taking some strong detached outworks, Nos. 54, 56 (Wola), 57 (beyond Wola), and 59 (Fig. 153),[5] by battering them for two hours with an overwhelming artillery, 120 guns, and then assaulting, the columns being preceded by horse artillery batteries, which swept the parapets with case.

On the 7th, after a truce lasting till one o'clock, the attack recommenced: 200 guns, according to the Polish account, were deployed ($M N$ Fig. 153), and opened fire, to prepare for the assault of Czyste and the Wola barrier. Only a portion of the Polish artillery on the ramparts could reply, the greater number not bearing on the field of combat; but the field artillery, 30 guns, were deployed, and the pieces in work 23 took the Russian lines obliquely, and made great havoc among them.

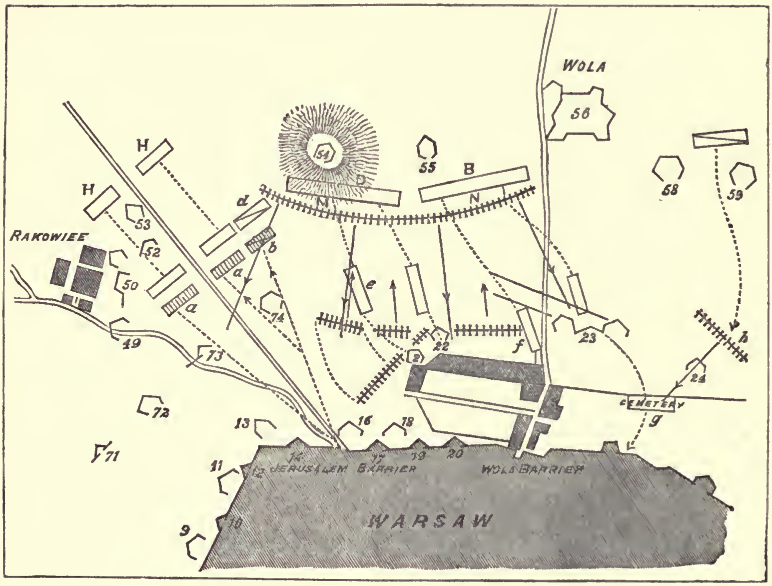
[3] Sir A. W. Frazer's *Letters during the Peninsular and Waterloo Campaign,* and Gen. C. Mercer's *Journal of Waterloo Campaign.* The slur cast on the performances of the British artillery in this action, which appeared in a *letter* of the Duke of Wellington recently published, caused much surprise, as being altogether at variance with the Duke's official dispatch, giving credit to the British artillery for the assistance it had rendered in repulsing the French, and with the accounts generally received as correct. A reasonable explanation of the passage has been given by Capt. F. Duncan, R.A., and will appear in vol. ii. of his *History of the Royal Artillery.*

[4] A Polish artillery officer, M. Brzozowski, in his account of the war (*La Guerre de Pologne en* 1831), says 100,000 men. Jomini considered the attack on Warsaw 'one of the most splendid operations of this kind.'—*Summary of Art of War,* p. 230.

[5] Nos. 55 and 58 were undefended.

An attack was then made by Murawiew (*H H*) opposite the Jerusalem barrier, but the Poles (*a*) charged, threw the leading columns back on the others, and the Polish cavalry (*b*) would have cut them to pieces but for the arrival of the Russian cavalry (*d*), which succeeded in driving the Poles into their intrenchments. By five o'clock the Polish batteries were silenced, and the columns of Pahlen (*B*) and Kmety (*D*)

Fig. 153.



Capture of Warsaw.

advanced, when, the latter taking work 21 (*e*), the centre of the line was pierced, and the other points were carried with comparative facility, being taken in flank.

The Russian losses were very great, the artillery alone losing 40 officers and 400 gunners killed and wounded, and 800 horses killed. What, it may be asked, would the losses have been had the Poles been armed with breech-loading rifled muskets, and had they possessed a few batteries of mitrailleuses, which might have been kept securely behind the parapets till the moment of assault?

12. The following example will serve to show that the value of artillery was appreciated in India by Lord Hardinge, who was afterwards mainly instrumental in raising the British artillery from its lamentably reduced condition to a respectable strength shortly before the Crimean War. At the battle of *Sobraon*, February 10, 1846, Sir H. Hardinge was informed by his artillery and engineer field officers that the fire of our heavy guns and mortars would be thoroughly effective in the lines of the enemy, but that our open batteries would be out of range of the 6-prs. of the latter, and the Sikh intrenched camp was therefore bombarded by 36 heavy pieces for two hours before the infantry advanced to the assault. With regard to the effect produced by their fire, Sir H. Hardinge thus expressed himself: 'In confidence I will say that if the thirty-six heavy guns had not been brought to bear we should have been repulsed. The Sikh General and Col. Monten (a French officer) afterwards stated that "when the bombardment was going on, the Sikhs in the camp were so discouraged—our artillery having dismounted some of their guns and killed their men, whilst it was evident their shot could not and did not reach us—that they sent to their batteries on the other side and took away all their artillerymen to reinforce the camp batteries, took up two of the boats of the bridge, and told their men there was no retreat.' [6]

Example from the Crimean War.

13. In the battle of the *Alma*, fought by the allied English, French, and Turks against the Russians, on September 20, 1854, some Russian columns were much shaken by the fire of a British battery brought to bear upon their flank. 'In advance of, and separated for the moment from, his army, and on the flank of that part of the position which his own troops were about to storm, Lord Raglan, who could now plainly distinguish the position of the Russian columns and batteries, at once perceived the important advantage he should gain, could an artillery fire be opened from the spot where he stood.

[6] See a letter to Sir Howard Douglas, given in his *Life* by Fullum, p. 382.

He despatched accordingly an urgent message for some guns. A battery (Turner's) of the 2nd division was close to the ford, but had not crossed it. Two of its guns were speedily brought up to the desired point, and the remainder of the battery soon followed. Its fire, directed against the Russian columns and batteries on the opposite slopes, and who were now very heavily engaged with the general advance of the Light and 2nd divisions, had a powerful effect, not only materially, but also morally, as showing the enemy that whilst the front was being stormed their flank was already turned. The battery moved subsequently up the heights, and harassed the Russian columns in their retreat.'[7]

14. In the battle of *Inkerman*, fought November 5, 1854, the Russians surprised the British army early in the morning, under cover of a fog—planting twenty-two heavy pieces, 32-pr. howitzers and 12-pr. guns, in such a position that they completely enfiladed by their fire the camp of the 2nd division on the right flank of the army—before the troops could assemble for action. (See Fig. 154.) They eventually brought into line 94 guns, 54 of which were heavy pieces of the calibres named; and, as Todleben's account and maps show, they had 40 guns in reserve behind Cossack Hill.[8] The British field guns, greatly

[7] Lieut.-Col. (now Brig.-Gen.) J. Adye's *Review of the Crimean War*, p. 52. The French historian states that the French artillery came to the rescue, and by pouring in *mitraille* enabled the English to capture the position. Lieut.-Col. Adye, who was on the artillery staff with Lord Raglan, says on this point: 'No French battery was brought to bear upon the ground attacked by the English. The only artillery in action on that flank at that time was the English battery as already described; and as the heights gained by the French were divided from the chief position attacked by the English by an amphitheatre a mile wide, the possibility of using *mitraille* with effect, at such a range, is put out of the question.' P. 62.

[8] *Défense de Sébastopol*, tome i. deuxième partie, p. 474. The map giving the second stage of battle shows 86 in line and 48 in reserve, but Todleben says those in line were increased to 94.

Force engaged at Inkerman.

Lt.-Gen. Soïmonoff	had	18,920	men, and	38 guns.
Lt.-Gen. Pavloff	„	15,806	„	96 „
		34,726	„	134 „

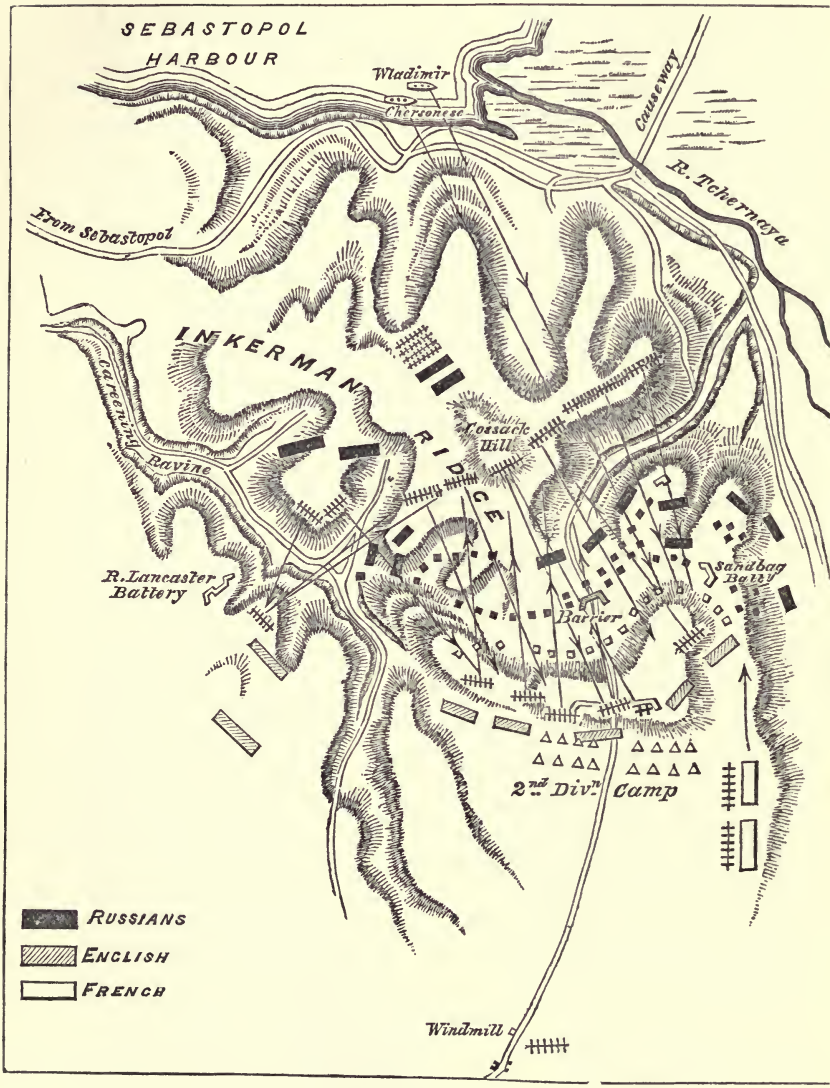
General Prince Gortschakoff in the valley, watching Balaklava, had 20,000 men and 88 guns, besides other troops and guns to watch the Baktchiserai road, inferior in number, and of small calibre (9-pr.) compared to the heavy Russian batteries, only arrived gradually, and had to come into action under a storm of shot, shell, and bullets concentrated on a very narrow space. Two batteries of the 2nd and a battery of the light division, came first into action, taking up a position just behind the ridge covering the 2nd division camp, and a battery of 1st division was sent to the west of Careening Ravine (near the Lancaster battery), so as to take the Russians in flank; a battery of the 1st division afterwards came up on the right, and one of the 4th division on the left of the line of the guns first formed,[9] thus making six 9-pr. guns and 24-pr. howitzer batteries, or 36 pieces, engaged. These light guns being unequally matched against the heavy Russian pieces, Lord Raglan ordered up two 18-prs., which were brought into action by Lieut.-Col. Dickson, R.A., and worked with gun detachments of the siege train. Two French batteries (12-pr. shell guns) also came up on the right of our position, and a third battery just at the end of the fighting, so that the total number of pieces brought into action by the allies was 54. The British guns were well posted, most of them just behind the crest of the ridge, so that little but their muzzles could be seen, and some of them were sheltered behind a low half-finished breastwork, which accounted for their escaping with only slight injuries to a few carriages. The losses in men were severe, and the horses with the limber and wagons in rear suffered heavily, the slope of the ground behind the ridge being nearly parallel with the path of any projectile passing over the crest. The front engaged was so narrow, and so constantly exposed to close infantry attacks, as well as pressure on the flanks, that it was necessary to keep the horses and ammunition at hand. Six British guns (three of the 2nd and three of the 4th division) were taken by the Russian infantry, and three of them spiked, but they were all retaken.[1] The

and make a sortie on the French at the extreme left.—*Défense de Sébastopol,* t. i. p. ii. pp. 446–8.

[9] Between a Light and 2nd Div. battery. A horse artillery battery was at the mill, in reserve.

[1] Todleben says that the guns in No. 2 work (the redoubt) before the 2nd Div. camp were spiked and the carriages broken, and asserts that nine guns were

Fig. 154.



Battle of Inkerman.

ranges of the Russian guns from our positions varied from about 1,000 to 1,450 yards.

This battle has usually been described by popular writers as mere infantry *mêlée*, and the important part played by the artillery (on both sides) has not been appreciated in this country. It may be then as well to give the remarks of one or two competent authorities upon the employment and conduct of the artillery.

Todleben says: 'It must be remarked that the English artillery in general sustained its infantry perfectly. It followed them everywhere, and opened fire at sufficiently close distances against the assailing columns of the Russians. On one side Codrington's brigade, established on the Careening Ravine, left bank, battered our reserves, and took in flank those troops of ours which attacked the left wing of the English army. On the other hand, our artillery rested always on the same spot, in its primitive position, on the slope of Cassock Hill, and did not sustain the attack of our battalions. These batteries had, however, at the commencement of the action, supported the infantry, and prepared our first success; but that did not last long. In proportion as the infantry advanced, the action of the artillery became almost null, as the batteries persisted in keeping their original position.'[2]

Lieut.-Col. Adye remarks as follows: 'The two 18-pr. guns had no less than seventeen casualties among the men who served them; and they, as well as the batteries of the 2nd division, fired away upwards of eighty rounds of ammunition per gun during the day, a very large proportion for one action.' 'It was a battle also which brought conspicuously forward the sterling courage and unmatched steadiness of the English artillery. The Russian columns repeatedly were close to the

captured near the Sandbag Battery, three taken down the ravine at once, and the others spiked. The allies, however, lost no guns, nor was the redoubt armed or even made at that time; two 18-prs. from Balaklava had been fired from the Sandbag Battery a few days before, against a battery at Inkerman ruins, which annoyed the 2nd Div. camp; these two 18-prs. were sent back to Balaklava, and were not the 18-prs. brought up from the siege train. (Sir Collingwood Dickson, K.C.B., V.C., informed me of this fact.—C.H.O.)

[2] *Defence of Sebastopol*, Russell's translation, p. 193.

muzzles of their guns, and were driven back by volleys of case. In some instances the batteries were actually run into, and the gunners bayoneted at their posts. Both Lord Raglan's and Menschikoff's despatches bear tribute to the effect they produced by their fire. The casualties in the English batteries amounted to ninety-six men. Their carriages were repeatedly struck, and they had eighty horses killed.'[3]

In this engagement the repulse of the Russians was doubtless due in a great measure to some of the infantry columns taking a wrong direction, but their large artillery mass failed to accomplish fully its object from not being skilfully handled. The Russians succeeded in bringing a large force of artillery unobserved into position by dawn, and in placing them so as to prepare the way for the infantry attack, and to crush any attempt of the British to form up under such a concentrated fire directed upon such a narrow space.[4] Had their light guns been pushed forward early in the engagement, the British position would probably have been carried, when the Allies, with no ground suitable for a second stand on the plateau, and with a large force on their flank in the valley, would have been in the most critical situation. The British artillery displayed great gallantry and good discipline in coming into action and serving their guns under such a terrible fire from both artillery and small-arms, and the pieces were well placed; but a striking instance was afforded of the necessity of providing a reserve (or corps) artillery in addition to the divisional guns. Two or three heavy batteries, sent to support the one on the west of Careening Ravine, might have directed such a powerful fire upon the right flank of the Russians, that they would most probably have been compelled to withdraw with great losses.

[3] *Review of Crimean War*, pp. 132, 140.

[4] 'Rarely has such an artillery fire been so concentrated, and for so long, on an equally confined space. The whole front of the battle-field, from the ravine on the left to the two-gun battery on the right, was about three-quarters of a mile.'—Col. Hamley's *Campaign of Sebastopol*, p. 107. And at p. 105:—'The Russians succeeded in posting their artillery, in sweeping the field selected with a tremendous fire, and in bringing an enormously superior force to a vigorous and close attack. According to all calculation, they were justified in considering the day their own. But the extraordinary valour of the defenders set calculation at defiance.'

The advantage of heavy over light guns was shown by the fire of the Russian heavy batteries overpowering that of our field-pieces, and the effect produced by the 18-prs. Todleben remarked that they 'acted with much success till the end of the battle;' and Prince Menschikoff, in his dispatch, partly attributed his defeat to the English having placed their siege artillery in position.[5]

The Russians deserve great credit for their orderly retreat, and for carrying off the field their numerous artillery without loss of guns,[6] although the French batteries in following approached to within 350 yards of the retreating columns. The heavy batteries were removed under cover of the light guns, which remained in position for some time longer. The losses in the Russian artillery must have been heavy, for three batteries were replaced during the action by others from the reserve;[7] and Todleben accounts for the guns retiring so slowly that they were not within the lines of defence till 8 P.M.,[8] by stating that they lost the greater part of their horses.[9] Had the pursuit been pressed, the Russian artillery must have been destroyed. Lord Raglan urged the French General to follow up the enemy with his fresh infantry and artillery, but he hesitated to do so until too late, and the French battery did not get further than the ridge to the east of Cossack Hill. It appears that the fire of the steamers 'Chersonese' and 'Wladimir,' anchored at the head of the harbour, stopped it. The Russian accounts mention 'the frightful ravages produced in their (Allied) ranks by the enormous shells' thrown from these steamers; but Lieut.-Col. Adye, in pointing out that something must be risked when a great result is at stake, says: 'The guns of the steamers were firing at too great an elevation, and those of the works were too distant, to be very effective.'[1]

In the Crimean War the Russian artillery suffered severely from the fire of our rifled small arms (Enfield), both at Alma

[5] *Review of Crimean War*, p. 132.

[6] They left only one gun-carriage, without a gun on it, and some wagons with ammunition, on the ground.

[7] *Défense de Sébastopol*, p. 474.

[8] The fighting ceased about 2 P.M.

[9] *Défense de Sébastopol*, p. 480.

[1] *Review of Crimean War*, p. 139.

and Inkerman. In his description of the latter engagement, Todleben says: 'But these injuries very imperfectly compensated the enormous losses which the enemy's riflemen inflicted on the Russian artillery. A perfect cloud of riflemen, hid in thick brushwood, opened a very violent and very accurate fire against our artillery at the distance of 800 paces. Some of our guns from time to time rained case upon them, but the discharge only checked the fire of the enemy's riflemen for a moment.' And, 'It was more the fire of rifled small arms than that of the artillery of the enemy which reached our artillerymen, of whom the greater part were killed and wounded.'[2]

Examples from the Italian War of 1859.

15. In the war of 1859 the French displayed more skill and enterprise in handling artillery than the Austrians, and on one or two occasions brought together large masses of guns, the fire of which produced considerable effect. The French also deserved the credit of being the first to employ rifled *field* guns[3] in warfare.

At *Magenta*, 'Clam Gallas and Liechtenstein still struggled doubtfully in front of the village, when Auger, commanding the artillery of the 2nd (French) Corps, brought up battery after battery by the Buffalora road to the railway, until he had forty pieces ranged along it. Their fire hastened the final retreat of the Austrians.'[4]

At *Solferino*, 'when MacMahon began to advance on San Cassiano, Vinoy's division, pivoting on Casa Nova, followed his movements. The reserve artillery, and Partouneaux's and Des Vaux's cavalry, strengthened the interval between them. The enemy soon tried to penetrate it; but the artillery, which had forty-two guns in action at this point, checked his advance by

[2] Russell's Review of Todleben's *Defence of Sebastopol.* This useful little book is sometimes quoted, Todleben's very large work being inaccessible to the general reader. The word *case* has been substituted for *grape*, the latter not being fired from bronze pieces, of which the Russian artillery was composed.

[3] Rifled ordnance had, as before stated, been used by the English at the siege of Sebastopol in 1854.

[4] 'Study of Italian Campaign,' by Major (now Lt.-Col.) F. Miller, R.A. *Proceedings of R. A. Institution*, vol. ii. p. 242.

a heavy fire, and the cavalry made some charges with good effect.'[5] And again: 'From the foot of the hills to Casa Nova, along MacMahon's and part of Niel's line, the action was confined for some hours to artillery fire, with episodes of cavalry charges. MacMahon reports twenty-four, Niel forty-two, guns engaged; horse artillery also took a part, and there must have been at least seventy-eight guns drawn up for action together; no wonder that the 1st Austrian Corps fell back to San Cassiano without making any serious attack, and before it was entirely brought up.'[6]

With regard to the effect produced by the fire of the French rifled pieces, Major Miller stated: 'Their real power could hardly be observed in the first battles. At Solferino their effect was unmistakable; but the fuzes, which are an equally new invention, often failed.'[7] And again: 'There can be no doubt that in this action the rifled cannon gave a considerable advantage. At Solferino they played on the village with effect (nicht ohne Erfolg) from a distance 2,500 yards, and the guns which stopped the Austrian column from turning the Sardinian right must also have fired at a considerable range.'[8]

A writer in the 'Edinburgh Review,' an eye-witness, stated: 'Mensdorf's cavalry, and a battery of horse artillery, were ordered to advance and cover its retreat; they had hardly got within 1,700 yards, when, of six guns, five were dismounted. Another battery was sent up; in one minute from starting, three were dismounted.' There were three French batteries of rifled pieces on this occasion.

Examples from the French War of 1870.

16. The American war between the Northern and Southern States afforded some valuable lessons in the use of artillery, but chiefly in the attack or defence of very strongly intrenched positions or of harbours or rivers. Some of these are noticed in other parts of this work. As regards the field artillery, SB. and R. guns were to be found on both sides, but many of the

[5] *Study of Italian Campaign*, p. 267. [6] *Ibid.* p. 271.
[7] *Ibid.* p. 277. [8] *Ibid.* p. 271.

latter were rifled on different experimental systems; and as the country is covered with thick woods, and most of the batteries had to be formed and trained during the war, the tactics of the field artillery were limited.

17. In the war between Prussia and Austria in 1866, the field artillery, with some exceptions,[9] was not handled very skilfully. The Prussians, trusting to the BL. small arms, displayed little skill or enterprise in the use of their artillery, which was generally kept back on the line of march, and engaged at very long ranges (often 4,000 to 5,000 paces) when in action.[1] In the war of 1870 the assistance of the artillery could not be dispensed with by the Prussians, whose BL. rifles were inferior to those of the French; and the German artillery had been wisely prepared, and had itself resolved, if possible, to perform an active part in the war, and to recover the reputation lost in 1866. Space will only allow of a few remarks being made upon the employment of artillery in the earlier actions; but a description of the manner in which the German artillery was brought forward and engaged at Sedan will give an idea of the tactics which frequently led to important results. The essential points in the German artillery tactics may be briefly stated as being—

(1) Pushing the artillery forward on the line of march.

(2) Engaging both corps and divisional artillery at the commencement of the action.

(3) Massing the batteries when practicable.

(4) Firing deliberately at moderate ranges, so as to ensure the requisite effect without waste of ammunition; and not fearing to risk the guns at close ranges if necessary.

On the other hand, the French appear to have committed the faults of keeping batteries too long in reserve,[2] of fre-

[9] As when the Austrian artillery covered the retreat of the beaten army at Königgrätz.

[1] See Captain May's *Tactical Retrospect*, translated by Colonel H. A. Ouvry, p. 45.

[2] Rüstow states that the reserve artillery of a French corps, consisting mostly of 12-prs., were usually treated as position guns and dragged in rear of the column, so that it was rarely possible to bring it into action at the commencement of a battle. He also says that the French had a special reserve of sixteen batteries,

quently engaging them singly instead of in masses, and of firing too rapidly and at too long ranges for effective practice.[3]

18. The German practice during the war of 1870, of pushing forward large masses of artillery to prepare the way for the deployment and attack of the infantry—as at Wörth, Gravelotte, and Sedan—has been pointed out. At Wörth, the whole of the artillery of the 5th corps, fourteen batteries (or 84 guns) were deployed in line, and were joined by part of the artillery of the 11th corps. The effect produced by the fire of such a large number of pieces upon the French positions must have been very destructive.[4]

At Gravelotte large masses of guns were, as before said, deployed by the different German corps,[5] but some of these coming into action under a heavy fire from the French guns and mitrailleuses, suffered considerable losses; for instance, the artillery of the 9th corps, which was exposed to an oblique fire from the French batteries, had fifteen guns disabled. The German batteries gradually obtained a superiority of fire over those of the French, and some of them (those of the Guard and a few batteries of the 7th corps) were advanced to shorter

96 guns; but that they never came into action together, and portions only were engaged by chance. (See Appendix A of Rüstow's work.)

[3] General Frossard has paid the following tribute to the German artillery at the battle of Gravelotte:—'Notre artillerie, dans tous les corps, fit son devoir, comme toujours, avec dévouement et audace; mais son infériorité matérielle nous paraît avoir été plus manifestée encore le 18 août que dans les autres journées. Les Prussiens l'emportaient sur nous, non-seulement par le nombre des pièces (3 au moins contre 2), mais aussi et surtout par la puissance du projectile, par la portée, et pourquoi ne le dirions-nous pas, par la précision du tir. Nous ne pouvons pas ne point remarquer leur soin à choisir les positions qui convenaient pour leur artillerie, à la défiler des vues, à constituer rapidement pour leurs batteries des moyens artificiels de protection, enfin à provoquer par un tir d'essai, d'apparence timide, les batteries de l'adversaire, pour en faire accuser la présence et l'importance, et pourvoir leur opposer un nombre très-supérieur de pièces, toutes choses, d'ailleurs, que notre artillerie sait faire aussi, mais qu'elle ne pratique peut-être pas assez.'—*Opérations du deuxième corps de l'armée du Rhin*, p. 116.

[4] See Rüstow, Boguslawski, and *La Campagne de* 1870, par un officier de l'Armée du Rhin.

[5] Prince Hohenlohe, commanding the artillery of the Guard, first brought nine batteries into action, the corps batteries and those of one division; these were afterwards increased by two horse batteries, and later on by three more divisional batteries, making altogether fourteen batteries, or 84 guns, which were at 4 P.M. advanced to a closer position. (Rüstow and Nieman.)

ranges than those at which they had opened, but they were long unable to shake the French infantry in their strong intrenched positions; the latter, with ammunition both for small arms and guns gradually failing, were at last compelled to give way under the murderous fire from the German artillery.[6] A German writer says that the artillery of the 7th, 8th, and notably of the 9th corps, chose positions with uncommon boldness, so near the enemy that the infantry were obliged to come into action to cover the guns.[7] The gallant way in which the German artillery was brought into action, and the deliberate manner of serving their guns, has been thus described: 'At noon the German right (being the 7th corps), which had been feeling its way and the enemy since the 17th, having first occupied the village of Gravelotte with some hussars, and massed supports in the neighbourhood, threw up on to the adjoining plateau, 2,000 yds. from the French left, and 100 ft. lower than it, battery by battery, as fast as they could get up from the head of the ravine at a gallop, the whole of their eighty-four guns, into action against the French artillery, which in somewhat similar numbers was in position opposite. The German batteries were not exactly in line, but rather, alternately, 100 yds. in advance or rear of one another; the pieces were somewhat crowded together, in order to avoid extending in front of Gravelotte and drawing the enemy's fire that way, as it was intended to use the village as a field hospital.' 'As the batteries galloped up, vast numbers of French shells burst short in the air, or on the ground in rear, but struck nobody; a continuous rain of mitrailleuse bullets also fell into one particular hollow behind them where nothing was; but the German commander of the first three batteries in action directed their whole fire to be given together on the first French mitrailleuse on the right; thereupon a confused storm of explosions was seen to spring all over where that mitrailleuse

[6] 'Mais vers 6 heures les munitions manquaient autant à l'infanterie qu'à l'artillerie.'—Capt. H. Brackenbury's *Les Maréchaux de France*, quoted by Lieut. F. Maurice in his *Wellington Prize Essay*, p. 77.

[7] Graham's translation of Boguslawski's *Tactical Deductions*, p. 64.

had stood, succeeded only by a vacant space with some wreck on the ground; the same treatment was adopted with the second and third mitrailleuses, on which the fourth vanished of its own accord, and the process of successive concentrations of fire was carried on upon the guns, with such effect that by two P.M. the French artillery of the left wing was completely silenced.'[8] And again: 'At four o'clock General Von Zastrow ordered some batteries across to try the effect of case shot at 600 yds.; the first that got up, a field battery, had so many men and horses struck down that it could only get two guns into action, to be withdrawn again as soon as practicable. The next battery, of horse artillery, getting some little advantage from inequalities of ground, opened fire at between 700 and 800 yds. from the French intrenchments, and kept it up till 6 P.M., with great gallantry and loss to itself, but with doubtful effect on the enemy.' The French officer of the Rhine army states that, when his troops gave way on the right, Marshal Bazaine brought up four or five batteries of the artillery of the Guard, by the Châlet ravine and the Lorry wood, to take the offensive, but it was too late.

The advantage of pushing forward a small force of artillery was shown at Spicheren, where two Prussian batteries succeeded in ascending, over most difficult ground, the wooded heights on the left; and, although they suffered heavy losses, their accurate fire prevented the French right from taking the offensive.[9] Some more batteries were afterwards brought up on to the plateau, but the French retreat was protected by General Frossard massing his artillery on the hills between Herbach and Behren.

The dependence of the effect of artillery fire upon the features

[8] Some Observations amongst German Armies during 1870,' by Col. H. A. Smyth, R.A. *Proceedings of R. A. Institution*, vol. vii. p. 195. This mitrailleuse battery Frossard says was placed too far in advance, and, although he admits that it lost a great many men and horses, he does not confirm the above account of the rapid destruction of the mitrailleuses. He says, 'Un bataillon du 23e et 12e bataillon de Chasseurs, qui l'appuyaient, aident le commandant de cette batterie à se dégager et à ramener ses pièces.'—*Opérations*, p. 108.

[9] Col. H. A. Smyth's *Observations amongst German Armies*. Nieman's *French Campaign*, and Capt. Ellis's translation of *The War of* 1870–71.

of the ground was conspicuous at Spicheren, where the fire of the Germans produced but little destruction among the French troops posted on very much higher ground; most of the shells, having percussion fuzes, either burst harmlessly in the face of the steep hill, or, passing over the crest, exploded far in rear. The French left, stationed on lower ground, was well sheltered from artillery fire; on the other hand, the fire of the French guns from the heights was too plunging to be very damaging, though their shrapnel had doubtless great effect upon the Prussian columns advancing in the plain.[1]

The following Table gives the artillery losses in some of the battles fought in 1870; the establishments of the Prussian batteries have been given at p. 384.

Battle	No. of guns engaged	Total losses		Greatest losses in single batteries
		Officers and Men	Horses	
Wörth	231	149	300	12 men and 70 horses
Borny, 14 Aug. .	137	149	159	
Vionville, 16 Aug.	222	726	993	5 officers, 45 men, and 44 horses
Gravelotte, 18 Aug.	616	919	1477	3 „ 35 „ 73 „ 3 „ 45 „ 49 „ 2 „ 36 „ 102 „
Sedan	599	460	800	2 „ 22 „ 32 „

These figures, taken from the 'Militair-Wochenblatt,' were pointed out to the writer by Capt. E. O. Hollist, R.A., who is now translating a work which will be most interesting on the subject of artillery, viz., 'Die deutsche Artillerie in den Schlachten bei Metz.'

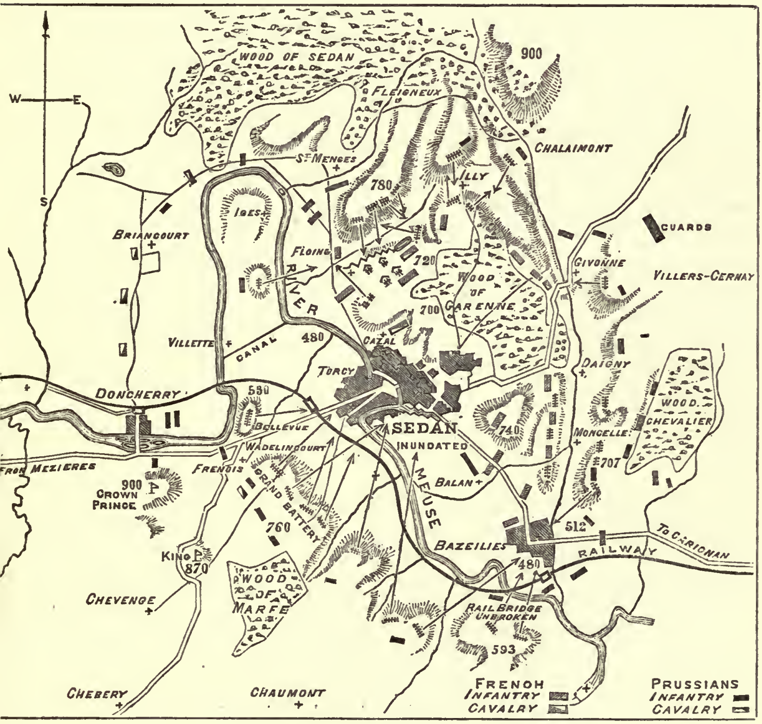
19. *Sedan.*—In order to consider the employment of field guns in what has been called by a German military writer 'the greatest artillery battle of the war,' it will be unnecessary to follow the movements of the other troops in detail; it will be sufficient to indicate their respective positions around Sedan on Sept. 1, 1870.

The French had posted their corps round the north, east, and south sides of Sedan, thus (Fig. 155):—7th corps in a strong entrenched position between Floing and Illy; 1st corps

[1] This instance was given to the writer by Capt. H. Brackenbury, R.A.

extending from between Givonne and Illy to Moncelle; the 12th corps from Bazeilles to Moncelles occupying Balan; and the remains of the 5th corps in Sedan, and the old work north-east of the town. Sedan was but a small fortress, with works and armament adapted only to resist the fire of SB.

Fig. 155.



Battle of Sedan.

guns, and commanded by hills within the range of rifled guns on the west of the Meuse. No ground was occupied on that side of the river, so that bridges could be thrown across at Donchery, and the railway bridge opposite Bazeilles was not destroyed. The Germans were thus enabled to place large masses of artillery without molestation on the heights near Frenois, and to pass two corps round by Donchery to attack from the north, and unite with the other army advancing from the east.

Of the two German armies, that of the Crown Prince of Prussia attacked Bazeilles with the 1st Bavarian corps, the 2nd Bavarian corps remaining on the west of the Meuse; the Würtemberg division was posted at Donchery to watch the Mézières road; the 11th corps was sent round by Donchery to attack from St. Menges the village of Floing and the entrenched position above; and the 5th corps, following the 11th, were to extend beyond and attack at Illy. The army of the Crown Prince of Saxony, advancing from the east, attacked with the 12th corps from Moncelle to Daigny, the Guard at Givonne; and the 4th corps, which came late into action, was to support the 1st Bavarians with one division, and keep the other as a reserve behind the 12th corps and Guard. The French had rather over 100,000 men and 400 guns (including 70 mitrailleuses); the Germans about 200,000, and between 600 and 700 guns.[2]

The action commenced about 6.30 A.M., when Bazeilles was vigorously shelled by the batteries of 1st Bavarian corps on the opposite side of the Meuse, and the artillery of the 4th

[2] Some writers, as Rüstow, give the French 120,000 men, and the Germans from 170,000 to 180,000 men; Nieman gives the latter 250,000 men and 800 guns. The German official report of the battle says that 400 to 500 guns were concentrated on the enemy, but this must be under the mark; for from the official *History of the War*, First Part, translated by Capt. F. C. H. Clarke, R.A., the numbers would be (including the horse artillery batteries of the cavalry, which appear to have been engaged)—

	Guns
Guards Corps	90
12th Corps	90
4th Corps (only corps artillery)	36
11th Corps	84
5th Corps	84
1st Bavarian Corps	96
2nd do.	96
Total	576

Exclusive of 54 guns of the Würtemberg Field Division at Donchery.

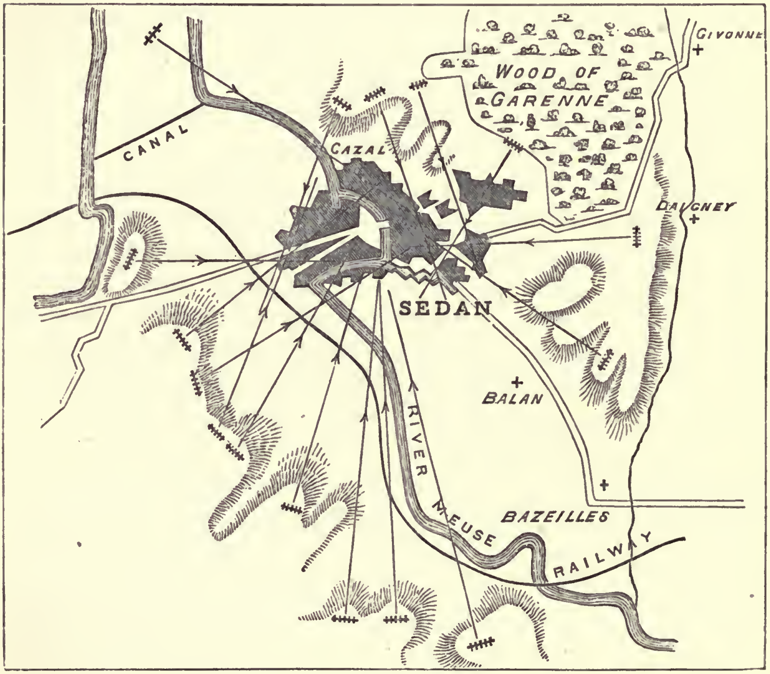
The four French corps, with 90 guns to each, would have had 360 guns; the Officer of the Rhine Army says only 288, but most writers put the number at 400 (including the 70 mitrailleuses), which were taken by the Germans.

corps was pushed forward to support the attack by a fire from the east side of the village; the Bavarian infantry crossed by the railway bridge and pontoon bridges thrown over the river. The guns of the 2nd Bavarian corps were massed on the heights above Frenois to prevent any outbreak from Sedan on the Mézières road, and to take the entrenched positions held by the 7th French corps above Floing in flank and rear. The Prussian 11th corps, advancing from St. Menges, had by 8.45 driven the French into their entrenchments, the artillery being massed so as to prepare by a heavy fire for the infantry attack. The artillery of the Prussian 5th corps was also massed to the south of Fleigneux to shake the French positions at Illy, and it continually outflanked the right of the 7th French corps, causing it to bring up battery after battery into line. Boguslawski says that the artillery of the 11th and 5th corps, notwithstanding difficulties of ground, pushed on in front of the advanced guards at Floing and Illy, and surrounded the enemy before the infantry came up, and that the French masses advancing against the guns were brought to a standstill over and over again at 2,000 yards. The 12th Prussian corps attacked along the line from Moncelle to Daigny and Givonne.

Bazeilles was subjected to a fearful shell fire, but it was gallantly defended with the aid of guns and mitrailleuses, which latter were said to have caused the Bavarians heavy losses. It was only taken after some hours' hard fighting, and when scarcely a house was left standing. The 7th French corps, a French writer states, easily held its ground against the front attack; for, protected by the ground and entrenchments, it received little injury from the artillery fire; and he states that two batteries of mitrailleuses inflicted heavy losses on the Prussians. The first batteries of the Prussian Guard came into action about 9 o'clock near Villars-Cernay, and General Wimpffen then attempted an offensive movement near Givonne, but on too small a scale; he was repulsed, and Daigny fell into the hands of the Saxons about noon. At this time the French lines were still intact, but soon after the 1st French corps retired precipitately from Illy into the wood of Garenne, and thus uncovered the flank of the 7th corps. The Prussian Guard and

5th corps united between 2 and 3 at Illy, thus completing the circle and deciding the battle. The 7th French corps, deprived of its supports, the mitrailleuses failing in ammunition, and the reserve batteries brought up to replace them being subjected to such a heavy cross-fire that they could not get into position, could only retire as slowly as possible. Some brilliant

Fig. 156.



Battle of Sedan.

cavalry charges were made by the French on the plateau above Cazal; but although they entailed serious losses, they did little to impede the advance of the Prussians, who, getting a couple of guns up a steep ascent and opening suddenly, drove the French within their lines. The heights above Bazeilles being captured about 4 o'clock, the place was swept on all sides by artillery fire (Fig. 156), and many conflagrations produced by the shells from the grand battery near Frenois. The King of

Prussia, seeing the desperate condition of the French, ordered the firing to cease, and offered terms of unconditional surrender, which were eventually agreed to. They required the surrender of the French Emperor with his army of over 80,000 men and all its *matériel*, including 400 fieldpieces (70 mitrailleuses), 150 fortress guns, and a large quantity of stores and ammunition.

The German report of the battle, and the military writers who have described it, attribute the great losses of the French especially to the artillery fire; and the correspondent of the 'Daily News,' riding over the field the day after the action, says:—'The ghastly wounds inflicted on most of the French dead whom I saw upon the hill, showed that they had fallen under an artillery fire; and the ground was in many places so ploughed up that a blanket could scarcely have been laid on it without covering some spot where a shell had exploded.'

In this battle the artillery was pushed forwards in large numbers at once, and came into action at from 2,000 to 3,000 yards range before the arrival of the infantry, so as to prepare, by an overpowering concentrated fire, for the attack of the latter. The corps and divisional artillery were mostly united, so that the French were exposed on all sides to the fire of enormous batteries, posted generally on ground commanding and in some cases flanking or taking in reverse their positions. As pointed out elsewhere, and illustrated in this action, massing guns does not consist in deploying them in a well-dressed line, as at a review, but in keeping large numbers together under unity of command and with a common object, and posting them according to the facilities offered by the features of the ground. The ranges at which artillery fire was employed appear to have varied between 700 or 800 yds. and 3,000 yds.; Rüstow says that the horse artillery batteries opened against the French position at Floing from a distance of 4,000 paces.[3]

[3] The works chiefly consulted for the above account of the employment of artillery at Sedan, are:—Rüstow's *Krieg um die Rheingrenze* 1870, and Lieut. J. L. Needham's translation; General de Wimpffen's *Sedan*, which contains the German report of the battle; *La Campagne de* 1870, par un officier de l'Armée du Rhin; and Nieman's *French Campaign* (translated from the German by Col. E. Newdigate). The plans have been reduced, with the omission of some names and a few additions, to show the positions and lines of fire of the batteries clearly, from the excellent map in Capt. Fitz-George's *Battle of Sedan.*

CHAPTER VII.

SIEGE ARTILLERY.

Organisation and Equipment of Siege Artillery.

1. The object and equipment of siege artillery are very different from those of artillery for service in the field, the quantity and variety of the *matériel* required being very much greater, as well as the time necessary for its collection. The organisation of artillery for siege purposes is, however, in some degree simpler than that of field artillery, as there is generally a surer basis on which to ground such organisation.

The purposes for which artillery is employed in sieges may be enumerated as follows:—

(1) To keep down the fire of the besieged, and protect the besieger's works, thus enabling him to make his approaches to the fortress with greater facility.

(2) To defend the batteries and parallels against sorties, &c.

(3) To drive from their lodgments any troops which may hinder the progress of the parallels or batteries, by harassing the working parties and guards of the trenches.

(4) To ruin the defences of the besieged, and to prevent his repairing the damages which they may have received.

(5) To destroy the enemy's stores and magazines.

(6) To form such breaches in the revetments as may be necessary to admit the assaulting columns; and

(7) To cover and support the movements of the attacking columns on the day of assault.

From the above remarks it will be seen what an important part artillery has to perform in all the principal operations of a siege; unless its *matériel* be sufficient in quantity and in good order, and the siege train be well organised, it might be necessary to suspend the fire at a critical time, and to frustrate the objects of the attack.

2. The principles which regulate the organisation of a siege equipment are based not only on the plan and probable number of guns in the place to be attacked, but also on the state of the fortress, and of its armament at the period of the siege, as well as on the strength of the garrison which defend it. The foregoing having been ascertained, approximately at least, the chief points to be decided are the nature and quantity of ordnance required for the siege, and the proportion of ammunition which the length of its duration is likely to demand.

The pieces of ordnance employed for besieging a fortress are organised in what is termed a *Siege Train*, the requirements of which, as with field artillery, embrace three elements—*matériel*, *personnel*, and *means of transport*. Unfortunately, in our service, little attention has been usually paid to the two latter beyond assigning a certain number of batteries of garrison artillery to man the siege guns. An efficient staff and the requisite means of transport, with suitable organisation, will, it has generally been assumed, be always forthcoming, without any special provision or preparation.[1]

The necessity of a regular organisation and transport for the troops engaged in siege operations was made manifest in the Crimea, where such heavy losses were suffered from men having to serve in trenches or batteries as guards or gunners, and then to transport their food and ammunition over miles of snow or mud.[2]

[1] The detail of a brigade of artillery for the service of a siege train of thirty-five SB. pieces was laid down a few years ago, but neither draught animals nor drivers were provided for in it. (See *Supply of Stores to an Army*, p. 64.)

[2] Prince Hohenlohe says on this point: 'In all former regulations, text-books, and historical accounts of sieges, sufficient value is not attached to organisation; yet the proper conduct of the siege is as much dependent upon it as the correct

3. The quantity of ordnance necessary for a siege must be in a measure determined by various circumstances, such as the extent of the works, armament of the fortress to be attacked, &c.; though experience has shown that on many occasions the number of guns employed depended rather upon expediency, and the resources of the besieging army at the time, than upon any fixed rule. Different numbers and natures of ordnance have been chosen at various times as the basis for a siege train, but after the Crimean War those laid down for the British and French services were as follows respectively:—

British Siege Train.[3]		French Siege Train.[4]	
24-pr. guns . .	45	24-pr. guns . .	40
8-in. shell guns	30	16-pr. do . . .	40
10-in. mortars .	15	22 c. m. howitzers	40
$5\frac{1}{2}$-in. mortars .	15	27 c. m. mortars .	20
Total ordnance	105	22 c. m. do. .	20
		15 c. m. do. .	15
		Total ordnance	175

In the British siege train, the 8-in. shell gun had thus taken the place of the 8 and 10-in. howitzers, and it was intended to substitute the 32-pr., which was used at Sebastopol in 1855, for the 24-pr., for the reason given at p. 41. The guns were intended to dismount ordnance, injure parapets, and breach revetments; the heavy mortars to search the interior of works and destroy magazines and buildings; and the small mortars to annoy working parties.

The introduction of rifled ordnance rendered such siege trains obsolete. Thus, in 1870, a siege train was to consist of:—[5]

25	BL. R. Guns	7-in. (72 cwt.)	on naval slides.
20	BL. R. Guns	64-pr.	. . on travelling carriages.
30	BL. R. Guns	40-pr.	. . on travelling carriages.
15	SB. Mortars	10-in. (iron)	on travelling carriages.
15	SB. Mortars	$5\frac{1}{2}$-in. (bronze)	on wood beds.
105 total.			

employment of field troops upon a proper order of march and a well-regulated distribution of troops.' (*On Sieges*, p. 6.)

[3] Major (now Lt.-Col.) F. Miller's *Artillery Equipment*.

[4] *Aide-Mémoire d'Artillerie*, 1856. A centimètre = ·3937 inches.

[5] *Revised Army Regulations*, 1870.

The substitution of ML. for BL. rifled pieces has, however, now been decided on, and the proportions of the different natures of ordnance are to be,—

55	64-pr. guns	ML. R.
20	40-pr. guns	
30	8-in. howitzers	
Total, 105	pieces.	

The number of pieces in a siege train is arbitrary, and merely gives the proportions of the different natures of ordnance. The number would require to be multiplied for the siege of a large fortress, and divided for that of a small one, unless a low number such as 30 or 40 be chosen.

Although field pieces do not form part of the equipment of a siege train in our service, they may be found very useful in the defence of the advanced trenches, and in places where it would be difficult to move guns of larger calibre. Several were made use of in this way at the siege of Sebastopol.[6]

[6] A considerable amount of experience was acquired by the Germans in siege operations during the war of 1870–71, and it may therefore be useful to give the suggestions of a distinguished German artillery officer on the natures and proportions of ordnance required for a siege train; and it may be here pointed out that in this war curved fire for breaching and rifled mortars for bombarding were used for the first time in sieges, and by the Germans.

Major-General Prince Hohenlohe, in a pamphlet, *On Sieges* (translated by Capt. F. C. H. Clarke, R.A.), gives the following proportions:—

	per cent.
21 c. m. (8-in.) mortars	10
9 c. m. (6-pr.) guns	10
12 c. m. (12-pr.) guns	30
15 c. m. (24-pr.) guns, half short, half long . .	50

besides some of the captured French mitrailleuses.

The 9 c. m. gun to be used for *emplacements* against sorties, and for effecting lodgments on captured works; the 12 c. m. gun for close quarters and when large enough, as the ammunition requires less transport than that of higher calibres; the long 15 c. m. gun for earlier engagements on a large scale, and where greatest destructive effect is necessary; the short 15 c. m. gun for high angle fire and for breaching by curved fire; and the 21 c. m. mortar for vertical fire.

The Prussian General, in *The Army of the North German Confederation* (Col. Newdigate's translation), states that 'the North German Confederation possesses a Prussian siege train for siege operations, composed of the ordnance and *matériel* necessary for attacking the strongest fortress. It is divided into three sections, which are quartered, in peace time, in Magdeburg, Wesel, and Coblentz.' (P. 30.)

Wall pieces were used by the Germans in the attack of fortresses in 1870–71, but the same value does not appear to have been placed upon their performances at different sieges. Thus, at Strasburg the artillery were said to have been greatly assisted in carrying forwards their batteries from one position to another by the fire of wall pieces and light field guns; but at Belfort it was not considered that wall pieces could compete successfully with chassepôts in the attack.[7]

4. The nature and number of ordnance for a battering train having been determined, it is desirable to fix in some measure the amount of ammunition that may be required, though this quantity, depending as it does upon the duration of the siege and on the vigour of the defence, must of course be very variable. Fifteen hundred rounds per gun, exclusive of case, shrapnel, and carcasses, is the utmost limit which has been assigned to cast-iron ordnance; but this large proportion would not be required in the ordinary attack of fortresses of the second or third class, and might therefore be reduced to what was considered sufficient in the latter cases. In many of the Peninsular sieges, even in the case of the most vigorous resistance, a much less proportion was made use of, not exceeding in some instances 500 rounds per piece of ordnance; but this was mainly attributable to the want of transport and limited time, the latter often requiring that the assault should take place as early as possible. Rifled ordnance require a less number of projectiles than with SB. guns, and shells are now substituted for shot, as elongated, unlike spherical, shells are effective against solid masonry. Prince Hohenlohe states that the number of rounds fired at different sieges in the war of 1870–71 varied between 300 and 500 per gun;[8] the latter is the number laid down for our siege guns.

The proportions of the different projectiles for the ML. R. pieces have not yet been settled, but judging from those laid down for the BL. R. guns in 1870 (see first edition of this

[7] 'Position of some of the Siege and other Batteries used in the War of 1870–71.' By Lieut. Fraser, R.E. *Corps Papers of Royal Engineers*, vol. xx.

[8] *On Sieges*, p. 14.

work, p. 380), they would probably be for the 64 and 40-pr. guns,—

Case shot	10	per cent.,
Common shell	60	do.,
Shrapnel shell	30	do.;

besides carcasses and light balls, which might be fired from a few SB. mortars, and a proportion of rockets.

As to the proportion of powder required for a siege train, it is determined not only by the number of rounds per gun, but also by the charges employed, and varies according as these are intended for direct, ricochet, or curved fire; there should be a number of extra barrels of powder provided above that which may have been calculated as adequate to the quantity of projectiles required, in order to allow of increase in the charges for the different natures of ordnance.[9] Ten per cent. spare fuzes, and 20 per cent. spare tubes, are allowed.

5. The proportions of the different carriages would probably be as follows:[1]—

Gun Carriages.

Travelling	64-pr. gun	1 per piece, and 1 spare to 7 carriages.
	40-pr. do.	
	8-in. howitzer	

[9] RLG. powder is used for cannon cartridges, shell LG. for bursters of common and segment shells, and pistol powder for bursters of shrapnel.

[1] Carriages supplied with first siege train of 40 pieces, Siege of Sebastopol:—

Travelling carriages for 8-in. gun	10
do 24-pr. do	15
Flanders wagons	6
Store do	6
Sling do	2
Forge do	3
Platform do	5
Hand carts	15
Trench do	15
Large drag	1
Small do	2
Total	80

Transport Carriages.

	Trench carts . . .	no fixed proportion,
Wagons	Gen. service . . .	1 to two pieces of ordnance,
	Forge	1 to 10 pieces of ordnance;
	Store	

besides a few platform wagons.

The platforms provided would probably be—

Clerk's	1 per 64-pr. and 40-pr.,
Ground	1 per 8-in. howitzer;

and a few spare of each kind.

6. Besides the guns, carriages, and ammunition, a siege train is supplied with a very large quantity of stores, such as gyns, handspikes, skidding, tackles, rope, &c.

7. The number of men required for a siege equipment is based upon what is sufficient to allow of three full reliefs, exclusive of magazine and store duties, and a reserve to replace casualties. Allowing ten men for the detachment of a gun, five for that of a 10-in. mortar, and three for that of a $5\frac{1}{2}$-in. mortar, the proportions for three reliefs for the SB. pieces formerly used would be—

30 men per gun,
15 do. large mortar,
9 do. small do.

But the ML. R. pieces now proposed (64 and 40-pr. guns and 8-in. howitzers) would each require a detachment of ten men, or for three reliefs thirty, so that the 105 pieces would take 3,150 men to work them.[2]

[2] The siege of Sebastopol was commenced with the two first battering trains (each consisting of fifteen 24-prs., ten 8-in. guns, five 10-in. mortars, and ten $5\frac{1}{2}$-in. mortars) sent out, and to those were attached eight companies of artillery, four to each train. As the number of ordnance mounted in the batteries increased, more companies were sent from England to join the siege train, until at the end of the siege the number of companies was about thirty, there being at that time 158 pieces of ordnance in the batteries manned by the Royal Artillery. Notwithstanding this large proportion of artillerymen, and that only seven men were then allowed per gun, there were never sufficient to give more than two reliefs during a bombardment, owing to sickness and casualties.

A garrison battery of the strength of those now in the Mediterranean would give (omitting the battery staff sergeant, and trumpeters) 142 gunners and 13 N.-C. officers = 155 men; and three brigades of seven batteries each would furnish 1,085 × 3 = 3,255 men, which would be sufficient for the service of 105 ML. R. pieces and 105 men for extra duties.

8. At the commencement of the investment of a fortress by a besieging army it is necessary to establish artillery depôts and parks for the reception of the *matériel* required for the siege train, the former of these being generally on or near the coast or frontier, and the latter as close to the ground on which the batteries are to be placed as is compatible with safety from the enemy's fire, and also as circumstances will permit. The besieger's works are frequently divided into two or more attacks (as the British right and left attacks at Sebastopol), each of which requires an artillery park to supply the ordnance and stores to its own batteries.

9. The great quantity of ordnance and *matériel* for the siege of a considerable fortress requires that large and efficient means of transport should be provided. No difficulty would be experienced by a maritime Power like Great Britain, which has at its command so numerous a navy, both of ships of war and merchant vessels, in conveying a siege train to any foreign shore; but for the siege of an inland fortress, with neither railways nor rivers running near it, a very large number of transport animals and carriages would be required for the ordnance and their stores. In many countries a railway might be selected for the conveyance of a portion or the whole of the artillery *matériel* from the base of the operations to the parks. Prince Hohenlohe points out that the situation of the railway would have a 'considerable influence on the choice of the front of attack, especially in large fortresses;' and he says, 'it may be asserted that a large fortress favourably situated, which has all the resources of art at its disposal and is well defended, can only be captured by a regular attack if the besieger has a railway at disposal, because he can by its means alone provide a superiority of *matériel* over the enemy.'[3]

[3] A pamphlet, *On Sieges*, translated by Capt. F. C. H. Clarke, R.A.

When, however, a siege train has been brought to its destination near the fortress to be attacked, means of transport will be necessary for the continual conveyance of the *matériel* from the depôts to the park, and from the latter to the batteries. Strong opinions on the necessity of sending out with a siege train adequate means of transport were given after the Crimean War by several of our most distinguished artillery officers, who had experienced so many difficulties and delays from the want of such a provision.[4] The field artillery may be required to furnish a certain number of horses for the service of the siege train; but care must be taken that it is not thus rendered unfit for any operations in the field, as was the case at Sebastopol, in consequence of the reduction of its horses from such hard transport work.

Sometimes, as in General M'Clellan's operations against the lines before Yorktown, the country is intersected by streams or creeks deep enough to convey barges laden with ordnance and stores to the depôts and parks.

In the Crimea, a line of railway, about eight miles long, was constructed for the British army, and proved most useful in the conveyance of stores from Balaklava to the front. The construction of a railway is necessarily a very laborious and costly undertaking, requiring large working parties, a skilled staff, and a considerable amount of *matériel*, and would therefore only be attempted in a siege of some duration.[5] A narrow gauge (18-in.) railroad, as proposed by Mr. Fell, which would convey artillery stores and guns of seven tons weight, could be made at a comparatively small cost, and very rapidly, if the wooden framework was sent out to the seat of war from home. Traction engines, which have lately been so much improved in

[4] General Sir R. Dacres, who commanded the British artillery; Sir E. Warde and Sir J. St. George, who commanded the siege train; and Major-General Sir C. Dickson, who commanded the right attack. Sir J. (then Col.) St. George considered that not less than sixty horses should be attached to a siege train, and that 200 would have sufficed for ordinary occasions at Sebastopol.—'Memorandum on Transport,' Appendix vii. to *Artillery Operations before Sebastopol*, by Major (now Lieut.-Col.) W. E. M. Reilly, C.B.

[5] The Federals before Petersburg had a 13-in. mortar mounted on a railway truck, from which it could be fired. A steam-engine conveyed it to any required part of the lines.—*Professional Papers of Engineers*, vol. xiv. p. 55.

construction, might in many cases be employed with advantage for the conveyance of guns, ammunition, and heavy stores over rough ground.

The Prussians experienced great difficulty in organising the transport of the siege train for the attack on Paris. The road between Villacoublay, where the park was to be established, to Nanteuil-sur-Marne, the railway station nearest the S.W. front of Paris, is eleven German (= 52 English) miles long; the wagons took eight days to go and return, sometimes longer, owing to the snow and glazed ice on the roads and the occasional removal of a boat-bridge at Villeneuve. It was calculated that the 250 guns required, with 500 rounds per gun, their ammunition, and stores, would take 5,000 loads. The impossibility of trusting to the transport resources of a hostile country for the conveyance of siege stores was here shown. Four-wheeled vehicles are scarce in France, and the two-wheeled carts were found too weak for the carriage of heavy ammunition, and they required large, strong horses; the French had driven away their horses, and the German train horses were too small, and were galled by a single trip. Under these circumstances, and previous experience having shown the necessity of organising the ammunition transport on a purely military system, and without employing French labourers, 24 siege park ammunition columns, each of 40 four-horse wagons, were formed in Germany, and forwarded by rail; additional carriages were obtained by requisitions in France, but they were manned by train companies from Germany.[6]

The *matériel* of the depôts is ordinarily in the charge of the officers of the store department, the parks in that of the officers commanding the artillery.[7] The parks are kept sup-

[6] See Major Blumé's *Operations of German Armies in France*, translated by Major E. M. Jones, p. 177–180.

[7] It has, however, been laid down that, contrary to the custom and experience of our own and other armies, the park, to be termed *field arsenal*, is to be in charge of the chief military store officer (of the Control Department), and that demands for stores from the commanding-officer of artillery are to have the covering authority of the Adjutant-General of the army in the field, who might be quartered miles away from the park; such arrangements can hardly fail, as pointed out by eminent artillery officers, to cause difficulties and delays. (The above

plied with ordnance, ammunition, &c., from the depôts, and as it is from the former that the batteries receive their armament and other stores, it is essential that during a siege the depôts should keep the parks continually and amply provided with the same.

Great precautions are necessary, both in the depôts and parks, in order to avoid the chances of accident, and all persons employed in them or in their vicinity should be cautioned accordingly; as not only might much damage and loss of life be occasioned by an explosion, but there would also be a great probability of the progress of a siege being arrested by such an occurrence. There can be but little question that the terrific explosion at the Windmill Park before Sebastopol, which took place on November 15, 1855, causing heavy casualties, especially to the French siege train, was occasioned by negligence or carelessness on the part of one of their sentries. The men of the siege train always encamp near the parks, for which they usually furnish fatigues and guards.

Construction of, and Fire from, Siege Batteries.

10. The construction of siege batteries in our service does not form part of the duty of the artillery, as is the case in the French, Prussian, and most other foreign armies; their position and that of the guns should, however, be jointly determined by the commanding officers of the artillery and engineers.[8]

The distance at which the batteries should be constructed must depend upon the nature of the ground before the front selected for attack, and upon the respective armaments of the

regulations are given in *Supply of Military Stores to an Army in the Field*, pp. 21, 22.)

[8] In the French service a siege battery is usually built (with the assistance of working parties of infantry) by the same artillery troops that afterwards work the guns in it, and will therefore be sure to take every care in its construction, drainage, and repair, so as to avoid casualties and inconvenience; greater accuracy of fire is also no doubt obtained by such an arrangement than by, as in our service, constantly changing the gun-detachments from one battery to another.

fortress and besieging train. Should the former possess a large number of powerful rifled ordnance and trained gunners, the besieger's batteries would doubtless be compelled to open at very long ranges, over 2,000 yards, or, independently of heavy losses from shrapnel, they would be destroyed as quickly as formed by the elongated shells now used, which hold such large bursting charges, and penetrate so much farther than spherical shells.

At the siege of Strasburg, where the French was overpowered by the German artillery, owing chiefly to the want of regular artillerymen in the fortress, the besieger's batteries were made at very short ranges compared to those of the German batteries before the Paris forts, which were well provided with ordnance and stores, and with trained sailors and gunners to use them.[9] The batteries first made need not now be placed, as formerly, in or just in front of the parallel, the great range and accuracy of the fire from rifled guns allowing of the batteries being constructed independently of the parallels, and generally in rear of them.[1] During the war of 1870–71, the first siege batteries were placed at ranges of about 1,500 to 3,500 yards, and even the breaching batteries for curved fire at ranges of 900 yards; every advantage was taken of the formation of the ground, of woods, hedges, walls, &c. to screen the batteries from the fire of the fortress.[2]

It is now considered that the parapets should be at least 25 to 30 feet thick, and that the guns should be 36 feet apart, to prevent the liability of two being silenced by one shell

[9] At Strasburg batteries were placed at ranges of from 60 to 2,000 yds., before the Southern Paris forts from 1,100 to 5,000. (See 'Notes on some of the Siege and other Batteries used in the War of 1870–71,' by Lieut. Fraser, R.E., *R.E. Corps' Papers*, vol. xx. 1872, and Major Blumé's *Operations of German Armies.*)

[1] *Army of North German Confederation*, p. 103.

[2] Col. H. A. Smyth, R.A., in his account of the bombardment of Thionville, says of the German batteries:—' On every wooded knoll that jutted into the plain, all round the town except on its north side, at distances varying from 1,400 to 3,500 yds., was prepared a battery for four heavy guns, the trees between it and the place being only taken down at the last moment; generally the terreplein left the natural surface of the ground for a parapet; the distance, the woods, and the use of the natural surface, rendered them all but invincible to the garrison.' (*Some Observations amongst German Armies.*)

falling between them. Some interesting experiments were made at Shoeburyness to ascertain the amount of protection afforded by a blind or *screen* thrown up in front of a battery. It appeared, from the results of these experiments, that a screen consisting of a second parapet about fifteen feet thick and about forty feet in front of the battery would be of great advantage—1st, in concealing the battery during its construction; 2nd, in causing the bursting of many shells short of the battery; and 3rd, in deceiving the gunners of the enemy's artillery as to the distance, and therefore causing them to *lay* their guns incorrectly. In consequence of the extra labour and time required for such batteries, our engineer officers propose to make them half sunken, the ground forming the soles of the embrasures of the battery, the embrasures of the screens not being cut till the battery is ready to open.

The expense magazines in the batteries should not hold less than 100 rounds per gun, and there should be a separate magazine for every three or four pieces of ordnance. Besides the magazines, shell rooms are required for filling shells, boring and fixing fuzes, &c., and splinter-proof cover for the gun detachments; hollow traverses may serve as shell rooms, but expense magazines should, if possible, be placed at the side of, rather than in or behind, the battery, so that if blown up a breach be not made in the parapet, and the fire be not stopped.[3] The magazines should be in the charge of steady non-commissioned officers or men, permanently detailed for this service.

The usual form of battery constructed by the Germans during the war of 1870–71, and suited to resist the fire of rifled ordnance, has been thus described by Prince Hohenlohe. 'A depôt is organised; the batteries are commenced on the first night, the parapets having a considerably greater thickness than in the regulations (minimum thickness of 24 ft.); between every two guns a hollow traverse with a thick covering of earth, or else a bomb-proof screen between every gun; no embrasure, but merely a trough-shaped indentation on the crest, usually scooped

[3] This occurred in the 8-gun battery right British attack, Sebastopol, by the explosion of a magazine behind the battery, which rendered most of the guns temporarily useless.

out with scrapers; and a covered space for the detachment close at hand, with arrangements for keeping it warm in winter.' Such batteries would frequently be masked while being constructed, and can then be made on bad ground, in woods, gardens, on the sites of buildings, &c. The earth over the traverses and splinter-proofs should not project above the parapet, or an object will be afforded by which the enemy can be guided in laying his guns; the splinter-proofs should not be made of wood beams or planks, which give no real protection, and increase losses from the splinters. In some cases, instead of the shallow undulations in front of the gun, the parapet was sloped inwards from the crest parallel to the line of fire of the piece (10 to 14°); but this is liable to cause inundation of the battery from the rain-water draining off the parapet into it.

It has already been pointed out (p. 86) that the German siege-guns are, when in battery, raised above the carriage by means of an iron frame secured to the brackets, and that being BL. guns they can be easily loaded when run up and fired at comparatively high angles (10 to 14°). They are laid by means of pickets similar to those used for mortars. The platform is very similar to the Clerk siege platform (p. 109), and consists of two wood inclined planes faced with iron, resting on planks; the wheels of the carriage recoil up the planes and then run down again, so as to bring the gun into its former position, the trail moving upon the planks; the inclined planes are 8 or 9 ft. long, and have a slope of 1 in 6.[4]

When the besieger has advanced his works sufficiently near those of the enemy, breaching batteries are constructed for the purpose of opening a passage or passages in the revetments and parapets of the besieged fortress to admit the assaulting columns. The position and armament of breaching batteries, as well as the method of forming a breach, will however be treated separately.

11. The arming of siege batteries is carried on during the night, the guns being generally conveyed from the park across

[4] See *Observations amongst German Armies*, by Col. Smyth, R.A., who mentions the special precautions taken in sponging the bore and cleaning the BL. apparatus of the gun.

the open ground, though when the bottom of the trenches is sufficiently wide and firm they may be taken along the latter. Horses should be made use of as much as possible in this transport, as such work when added to their regular duties tells heavily upon the men; however, in arming the batteries of the third parallel, and those beyond it, this is often hardly feasible, and the pieces of ordnance, whether mounted on their own carriages or otherwise, must then be dragged by the men.[5] The conveyance of guns into the trenches, and the mounting of them in the batteries, should be conducted as silently as practicable.

Guns may be mounted during the daytime by means of luff tackles, gun tackles, &c., and in this case the embrasure should be temporarily masked; but a gyn should never be erected except at night, as the appearance of such an object above the parapet would be sure to draw down the enemy's fire upon the battery, which would very probably injure the gyn, besides creating casualties. The number of ordnance in each battery will depend upon the purpose for which the battery is erected, the nature of the ground, &c.

12. The employment in a siege of the different natures of ordnance and projectiles, as well as of the various kinds of fire, depends upon the end to be attained, and the relative position of the besieger's guns with reference to the works to be attacked. To destroy revetments, to dismount or damage guns by direct fire through embrasures, solid shot were employed. Common shells, containing large bursting charges would, however, now be employed for forming as well as for completing a breach, for dismounting ordnance, for ruining the parapets, destroying the embrasures, traverses, &c., and for causing casualties among the defenders.[6] The shell fire of the rifled guns now used is, independently of its greater accuracy and the higher velocities of the projectiles at any but very short

[5] At Belfort the guns for some German batteries, made on a ridge which had been defended by the Perches redoubts, were brought up by hand, sometimes as many as 600 men being required to draw each gun up the steep slope; the ground was very difficult, being steep, rocky, frozen hard, and covered with snow. (See Lieut. Fraser's *Notes on some of the Siege and other Batteries used in the War of* 1870–71.)

[6] The different kinds of fire have been described in Chap. VII. Part II.

ranges, much more destructive than that of the SB. pieces formerly employed, on account of the elongated shells being heavier and containing far larger bursting charges than the spherical shells. Thus :—

Shells of SB. pieces			Shells of R. pieces		
Nature	Total Weight	Bursting Charge	Nature	Total Weight	Bursting Charge
	lbs. oz.	lbs. oz.		lbs.	lbs. oz.
8-in. gun	49 1	2 9	64-pr. gun	64	7 0
32-pr. do.	23 1	1 2	40-pr. gun	40	2 4
24-pr. do.	16 15	1 0	8-in. howitzer	180	13 0
10-in. mortar	93 9	5 4			

Shrapnel shell are sometimes fired in sieges to annoy working parties, and to clear the parapets of defenders previous to an assault, which was done by some English batteries at Sebastopol; and case shot at close ranges when a sortie is made upon the batteries or trenches.

Guns placed in the prolongation of the faces of a work for enfilade and ricochet fire can often be disposed so as to admit of their being used for direct fire against the adjacent face, as with some of our batteries at Sebastopol (see Sec. 3. Chap. VIII. of this Part).

The vertical fire of shells or carcasses from mortars is chiefly used when it is required to reach those portions of the besieged town or fortress which are sheltered from direct, enfilade, or ricochet fire, such as magazines, barracks, and troops in large masses.

Vertical fire will no doubt, in spite of considerable prejudice against it, acquire additional importance in consequence of more precautions being taken to shelter troops from direct or other kinds of fire. Its great value was appreciated by both Russians and Allies in the Crimea,[7] by the Americans in their later operations,[8] and this fire appears to have been largely

[7] The author remembers three magazines being blown up by mortar shells in the English right attack, one silencing seven guns in the eight-gun battery.

[8] See General Gillmore's *Operations against Charleston Harbour*, pp. 128, 129. Brig.-General Abbot, in a paper on Siege Artillery, thus truly describes the great moral effect produced by vertical fire: 'There is much that is appalling, and, if

used by the Prussians in France.[9] The Federals employed vertical *shrapnel* with great success at Petersburg to silence some batteries previous to an assault.

In commencing a siege, the guns should not open fire until the batteries are sufficiently armed to be able to produce the desired effect, as such a proceeding would render those pieces already in battery liable to be silenced by the fire of the enemy before any result could be accomplished[1]; and in general a few guns should not be permitted to commence firing at any time by themselves.

The officers in charge of batteries, as well as the non-commissioned officers in charge of guns, should be very particular in seeing that their pieces are properly and correctly laid, as, however desirable a rapid fire may often be, accuracy is the first and most important point to be attended to, and must therefore never be sacrificed to rapidity.[2] This will apply especially to direct fire, when used for the purpose of dismounting guns, or for breaching a revetment.

When it is requisite to carry on the fire during the night, a piece of timber can be nailed down to the platform inside the felloe of each wheel of the travelling carriages (the guns being properly laid and the correct elevation ascertained during the daytime), and shorter pieces outside the cheeks at the trail.

long continued, painfully harassing to the imagination, in enduring a skilfully directed mortar fire. The dull, distant report, the long interval of expectation, the at first imagined then steadily increasing whistle of the shell, the explosion, and the hurtle of the fragments, carrying confusion in every direction, the consciousness that the trusted parapet yields no protection, and that the only security is in first constructing and then burrowing in unwholesome bombproofs—all these influences combined produce an effect upon troops which has but to be witnessed to induce a high respect for so terrible an engine of destruction.'

[9] The Prussians have rifled mortars of 21 c. m. (8-in.) calibre, the shells of which hold 15 lbs. bursting charges, and are made to explode by means of a percussion fuse.

[1] As when the French artillery opened fire on forts Issy and Vanvres, held by the Communists, with an insufficient number of batteries and guns of inferior calibre, which were consequently nearly all silenced by the concentrated fire of the forts upon them; later the forts were silenced by the fire of more powerful batteries.—Capt. H. Brackenbury, R.A.

[2] At the bombardment of Thionville the order was 'that each gun should fire but once in a quarter of an hour by day, and each battery (of four guns) once in the same time by night.'—Col. Smyth's *Observations among German Armies.*

When standing carriages are made use of, a directing bar can be employed. Clerk's, or any platform of similar description, can be made available for night firing by a proper application of scotches. Mortars, after being correctly laid, can have a piece of wood nailed down along one side of the bed, or else a chalk line drawn upon the platform on each side. Night firing, except from mortars, is of but little use, except at short distances, when it is desirable to prevent the repair of a breach, or to repulse sorties, in which case grape or canister are employed from the different natures of guns. The officers in charge of the night reliefs of artillery must, on arriving in the batteries, ascertain that all the stores, and canister or grape shot are at hand, in order that no time may be lost on the alarm of a sortie being given; and it is a good plan to have the guns loaded with cartridges, and a case shot placed in the muzzles ready to ram home if necessary.

13. On the day of the assault a certain number of gunners, under one or two officers (the whole being generally volunteers), are usually told off to form spiking parties. These should hold themselves in readiness to enter the enemy's works immediately on their being carried by the infantry, either in order to spike his guns, or turn them on any of his retreating columns. If the latter be intended, it will be necessary to carry cartridges in metal-lined cases or cartouches, with either common tubes and portfires, or friction tubes; as for projectiles, they will be found in the enemy's batteries.

Previous to an assault, it is generally the practice to endeavour as much as possible to silence the guns of the besieged place by a heavy bombardment or cannonade of some hours from all the besieger's ordnance, which should especially be directed on those of the enemy's batteries that would seem most likely to be able to annoy or cause much damage to the assaulting troops.

On the fall of a fortress, the captured ordnance and artillery *matériel* (an inventory of which should be taken) are generally handed over to the charge of the officer commanding the artillery of the victorious army, and under him to the charge of the superintendent of stores and his subordinates; should it not be the intention to dismantle the place, measures must be taken for putting it in as perfect a state of defence as possible, by repairing the batteries, magazines, and platforms, and by mounting ordnance wherever it may be considered desirable.

Breaching Revetments.

14. The formation of a breach by means of the fire of artillery, although a subject of considerable importance, has only of late years been reduced to anything like a regular system. Vauban, Bousmard, and Gassendi, indeed, gave various rules for breaching a revetment, but it was not until the present century that such experiments were instituted as could lead to any very definite results.[3]

To form a breach, it is necessary to separate that part of the masonry or revetment to be overthrown from the adjoining

Fig. 157.

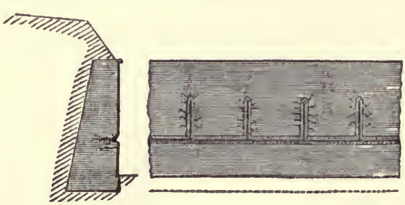
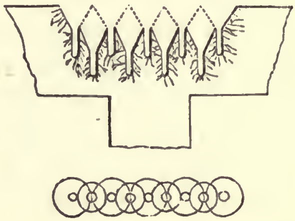


Fig. 158.



portion, in such a manner that it may be soon brought down by its own weight, and by the fire directed on it. The best method of effecting this is first to cut the wall in a horizontal direction, and then vertically, at such distances as the strength of the masonry, counterforts, &c., may require (Figs. 157, 158[4]).

[3] In 1834 a series of experiments was instituted at Metz, by the French Government, at the instance of M. Piobert, captain in the French Artillery, and again in 1844, at the same place. These, though very satisfactory, were not considered sufficiently complete, and accordingly a fresh Committee, with the Duke de Montpensier as president, was appointed in 1847, to investigate the subject at Bapaûme, a quantity of the old fortifications of that town having to be destroyed: and it is from these experiments, as well as from those at Metz, added to former knowledge, that rules for breaching a revetment under different circumstances were laid down.

[4] These figures, as well as Figs. 157 and 158, are taken from Piobert's *Cours d'Artillerie.*

The portions of masonry included between the vertical lines will then have to be broken, and this will be done nearly as much by the weight of the materials as by the shocks of the projectiles fired against them. In general, the height of the horizontal cutting should be about $\frac{1}{3}$ the total height of the escarp from the bottom, though in some cases it may be even preferable to make it as much as one-half. The length of this cutting will be regulated by the width of passage required for the assaulting party, generally from 20 to 30 yards.

The best method of forming the horizontal cutting is to divide the length of wall, designed to be cut, into as many portions as there are guns in the breaching battery, and for each gun to commence by firing a shot at the outward extremity of the portion of wall allotted to it, and then others at regular intervals until the whole of the horizontal cutting is clearly marked out. The guns will then direct their fire on points exactly between the former ones, and finish by destroying any salient parts of the masonry which may have been left uninjured throughout the line. The falling of the earth of the rampart is generally a good index for showing that the revetment has been penetrated through; as the fall of the revetment and establishment of the breach depend greatly upon the horizontal cutting, this latter is a point of considerable importance. The distances between the first series of shot will vary according to the calibre of the guns in the battery; about 4 feet was the proper space for the SB. 24-pr.

The vertical cuttings are formed by first firing a shot a certain distance above the horizontal line, and then another in the centre of this distance; the intermediate salient points are destroyed as before by further firing. A second equal length of cutting is effected in the same manner, and so on, until the length of the cutting is sufficient. The number of the vertical cuttings and the distance between them must, as has been before remarked, be determined by circumstances, such as the strength and consistency of the materials of which the revetment is composed, the absence or presence of counterforts, and the manner in which these are connected with the revetment. Should, however, this latter be of a weak nature, two vertical cuttings, as proposed by Bousmard, will suffice; for though necessary in many instances, the intermediary cuttings rather tend to diminish the weight and consequent action of the mass, and fill up the horizontal cutting and middle of the breach with rubbish.

The vertical cuttings need not, in general, be carried to a greater height than one-half the distance between the horizontal line and the cordon, nor need they always penetrate quite through the revetment, as is necessary in the case of the horizontal cutting.

After the fall of the revetment (Fig. 159), shot and shell should be fired to bring down the earth, to form a ramp or

Fig. 159.

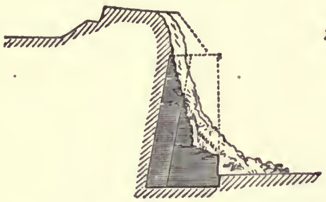
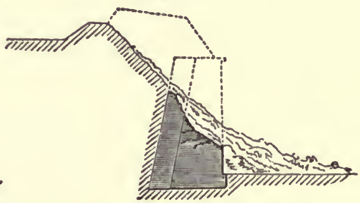


Fig. 160.



roadway into the place (Fig. 160); the ramp, to be practicable, should not be at a greater angle than 45°.

The only difference in executing a very oblique breach consists in the manner of forming the horizontal cutting. In this case, as there will be a great probability of the shots glancing, each gun must be directed at that part of its range which is nearest the breaching battery, and a first round will thus be fired. The second round must be also fired at the first holes, in the direction of the horizontal cutting, and so on, until all the openings join and form but one.

Should the masonry be very hard, it would be preferable to direct all the guns at the nearest end of the horizontal line, and work on to the farthest, in order to avoid the loss of too many shot by glancing.[5]

[5] The French used to say that a wall could be breached by the fire of SB. guns at the following angles—viz. 20°, 24°, 33°, and 43°, with charges respectively of $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, and $\frac{1}{8}$ the weight of the shot; this assertion was confirmed by the experiments carried on at Metz and Bapaûme.

In breaching a counter-arched revetment, an oblique fire should be directed on the counterforts, in order to cut them through horizontally. In this case the vertical cuttings are hardly necessary, as the fall of the arches consequent on the destruction of the piers would almost certainly cause the overthrow of the revetment even if the horizontal cutting in the outer wall were not continuous.

Should a breach be destroyed by a mine placed under its slope, a fresh fire will have to be directed on the remains of the counterforts to overthrow them, and then, by firing salvoes into the mass of the parapet, the breach may be again rendered practicable.

Breaching batteries should fire as quickly as they can with precision and with safety to the guns; about 20 rounds per hour was the average for SB. iron guns, and 12 for bronze.[6]

The proportion of the charge to the weight of the shot may vary according to circumstances, but as a general rule it may be stated, that charges of $\frac{1}{3}$ were the best for forming the horizontal and vertical cuttings with SB. guns; charges of $\frac{1}{40}$ were used with R. guns at Strasburg.

In forming a breach at long distances it is advisable to suspend the fire of the batteries during the night; but as in such a case the besieged will in all probability attempt to clear away the rubbish, and in some degree to repair the damage done, means must be taken to prevent this, by keeping up a constant fire of shells and shrapnel during the cessation from battering.

No very precise rules can be given as to the exact time and quantity of ammunition required to make a breach, as these will vary according to the distance of the breaching battery, strength of revetments and counterforts, nature of gun employed, and precision of the fire; this latter will depend chiefly upon the armament and position of the battery, and the amount of fire to which it is exposed from the besieged.[7]

[6] The advantages derived by employing iron instead of bronze guns for breaching were pointed out by Sir J. May, R.A., K.C.B., in a small work published in 1819.

[7] The difference often observable between the results of experiment and those of actual service may be accounted for by the fact that the former are obtained

15. The fire for breaching a revetment should, if possible, be direct; that is to say, it should not make with the revetment an angle measured horizontally of less than 50°; and the harder the masonry, the more perpendicular must be the fire, an essential point in breaching being that the shell shall not glance.

The position and distance of breaching batteries will depend much upon the nature of the guns employed, and upon the character of the ground near the fortress. If practicable, they were formerly placed on the crest of the glacis, near the salient of the covered way of the work to be attacked, a distance usually of from 40 to 60 yards from the salient of the ravelin to be breached.[8] This, however, could not always be done, as may be seen by reference to some of the sieges in the Peninsular War, where the distances of the breaching batteries ranged from 450 to 620 yards. With elongated shell from rifled ordnance the breach can no doubt be made in a shorter time, with a less expenditure of ammunition, and at a longer range.[9] That this is practically the case has been proved in a great measure by experiments both in England and on the Continent. An account of some experiments, carried on in this country to test the respective powers of rifled and smooth-bored guns in breaching masonry at a long range, viz. 1,032 yards, is given in the *Proceedings of the Royal Artillery Institution*, from which the following extracts are taken.

Three rifled Armstrong guns, an 80-pr., a 7-in., and a 40-pr., were fired so as to breach a Martello tower near Eastbourne, in August 1860; and four smooth-bored guns, two being 68-prs. and the others 32-prs., were afterwards, in November, fired for the same purpose at a similar Martello tower near

under the most favourable circumstances; but the latter, when the gunners are exposed to fire, when the ranges are not accurately ascertained, and the effect can only be judged from the battery.

[8] In breaching the face of a bastion, the battery would extend nearly to the re-entering angle formed by the junction of the counterscarp of the ravelin and bastion.

[9] Fort Sumter, of solid masonry, in Charleston Harbour, was silenced and seriously damaged by the Federal rifled guns at ranges of between 3,000 and 4,000 yards.

Bexhill. The respective amounts of iron and powder (including bursters) expended were :—

	Iron lbs.	Powder lbs.
With the rifled guns .	2,953	511
„ smooth-bored .	9,684	3,720

The following table, taken from the Report of the Ordnance Select Committee, represents approximately the work done upon each tower :—[1]

Tower 71.—Armstrong rifled guns			Tower 49.—Smooth-bored guns		
Nature of projectile	Took effect N°.	Work N°. by W.	Nature of projectile	Took effect N°.	Work N°. by W.
80-pr. shot. . .	19	28·88	68-pr. shot . .	40	40.00
„ shells . .	44	66·88	„ shells .	57	44·46
7-in. howitzer shells	31	44·02	32-pr. shot . .	24	10·32
40-pr. shot. . .	20	15·29	„ shells .	44	12·32
„ shells . .	44	33·44			
	158	188.51		165	107·10

'By which it appears that, irrespectively of the superior concentration of the fire of the rifled guns, and its consequently greater effect, they actually performed half as much work again as the smooth-bored guns, with the diminished expenditure of iron and gunpowder noticed in a previous paragraph.'

The great penetrations of the elongated projectiles, compared to those of the shot and shell, have been already pointed out. With regard to the accuracy of fire of the rifled guns, the remarks of the Committee were :—'The precision with which the guns could be directed upon any point it was intended to strike gave them advantages with which no smooth-bored ordnance, firing from such a distance, could compete ; and the same circumstances would have rendered it almost impossible to retrench or defend the breach, for the fire might have been continued with perfect safety to the assaulting columns until they were within a very few yards of it, sweeping away all obstacles as fast as they could be laid, and without the slightest

[1] *Proceedings of the Royal Artillery Institution*, vol. ii. p. 404.

interruption from the musketry of the defenders, the battery being quite out of their range.'

16. The following practical conclusions were drawn from the results of the experiments carried on in Prussia:[2]—

(*a*) With regard to *indirect* firing:[3]

(1) Rifled guns can be advantageously employed for *indirect* firing at a greater distance than smooth-bored guns.

(2) Breaching by *indirect* firing from rifled ordnance, can be easily accomplished without too great an expenditure of ammunition.

(3) Reduced charges may be advantageously used in *indirect* firing with rifled guns.

(4) The destructive effects produced upon masonry by shells fired from rifled guns, even with reduced charges, are so great as to render the employment of other kinds of ordnance needless.

(*b*) With reference to *direct* firing:

(5) A rifled gun of 6-lb. calibre (13-lb. shell) is sufficient to effect by means of shells, within a short time, a practicable breach in a good wall of moderate strength.

(6) A rifled gun of 12-lb. calibre (shell 27 lbs.) is sufficient to completely destroy embrasures in the strongest and most solid masonry in a short time.

(7) A 24-pr. rifled gun (shell 57 lbs.) can breach, with a comparatively small expenditure of ammunition, the strongest masonry, built of the best material and with the greatest care.[4]

The Prussians also carried on a series of breaching experiments by curved fire at Silberberg in 1869, with the short rifled 15 c.m. (6-in.) or 24-pr. gun, and the experience thus gained proved very useful at Strasburg in 1870. The following phenomena were found to be indicative of a successful breach:

[2] At Julich, in 1860, described in a paper by Lieut. Col. A. Ross, R.E., in the *Professional Papers of the Royal Engineers*, vol. x. p. 167 (New Series).

[3] By *indirect* is here meant *curved* fire at an object which is covered by a parapet, glacis, or wall, so that it cannot be seen from the battery; it has been fully described in Chap. VII. Part II.

[4] The angle at which the 27-lb. shells were fired, to breach the block-house that was not visible from the battery, was about $6\frac{1}{4}°$, so that the angle of descent would be about $8\frac{1}{4}°$.

(1) The concussion and explosion of a shell has a hard, sharp sound if it hits solid masonry; on the other hand, it has a hollow and faint sound if it hits masonry either wholly or partly broken through—in this latter case the shell exploding in the earth behind the wall.

(2) Fragments of stone are hurled into the air as long as masonry resists.

(3.) The smoke from the explosion of the projectile soon rises above the wall, is of a bluish tinge, and forms a *ball* if the masonry remains intact. If the masonry has been broken through, the smoke appears after some delay, is darkish gray in colour, and rises slowly, as if coming from a chimney-pot.[5]

During the war of 1870 breaches were made by curved fire at Strasburg at ranges of 900 yds.

[5] 'Artillery Lessons from the Siege of Strasburg, 1870,' by Capt. F. C. H. Clarke, R.A., in *Proceedings of R. A. Institution*, vol. viii. Col. H. H. Maxwell, R.A., in a paper on 'Breaching by Indirect Fire,' in vol. vii. of the *Proceedings*, gives the following particulars of the short R. 24-pr. gun:—

Weight of piece, 29 cwt.	No. of grooves, 24
Length „ 14·4 cals.	Pitch of rifling, $\frac{1}{45}$
Calibre „ 5·866 ins.	Weight of shell, 61·07 lbs.
Charge (maximum) of piece 3·3 lbs.	Bursting charge, 4·4 lbs.

CHAPTER VIII.

SIEGE ARTILLERY.

1. Examples to illustrate remarks.—2. Antwerp.—3. Sebastopol.—
4. Charleston.—5. Strasburg.

1. The following brief accounts of the artillery operations in several of the sieges of recent times will serve to illustrate the preceding remarks, affording as they do important examples of the effects produced by the fire of different kinds of ordnance, of the gradual increase in the destructive power of artillery fire from heavy pieces, owing to the introduction and improvement of rifled guns, and of the various methods of employing siege artillery.

2. *Antwerp.*—The siege of Antwerp by the French in 1832 was remarkable for the regularity of proceeding, the trenches and batteries being constructed in succession, according to the rules laid down in treatises on fortification. The opposition offered was but feeble, owing to the great preponderance of the French artillery.[1] With regard to the artillery operations two circumstances are worthy of notice.

(1) The large and unprecedented use of horizontal shell fire by the French, the effects of which were, according to General Chassé, irresistible, the shells penetrating bombproofs and exploding magazines.

(2) The employment of a monster mortar, which, being only mounted towards the end of the siege, fired but a few rounds and did little execution.

The moral effect produced by these few rounds may, however, be judged from the following extracts from the Journal of the Defence :—

[1] One hundred and forty-three guns against thirty-nine in the front attacked.

'At midnight the enemy put the finishing stroke to his barbarous manner of acting, in firing the great mortar so long before announced. The projectile, which is two feet in diameter, fell at the side of the grand powder magazine; the explosion was terrible, but caused no damage.'

And on the following day 'The enemy again threw some shells of 60 c. m. (23·2626 inches), but they fell into the passages, where there was nothing to damage. If chance had caused one of these projectiles to fall on the grand powder magazine, it is certain that it could not have resisted the shock.'[2]

It was curious that while the Journal was being printed, this monster mortar was burst at practice with a charge of 9 kil. (about 20lbs.).[3]

In this siege the destructive effects of horizontal shell firing from SB. ordnance were exhibited, but which were small compared to what may be accomplished by the fire of the large common shells of rifled guns; also an instance is afforded of the terrible effect that may be produced by vertical fire from very powerful mortars. It may safely be asserted, as pointed out some years ago, that 'a few such shells as were fired from Mallet's mortar would, in all probability, have rendered the Malakoff, the Redan, or any other of the Sebastopol works, perfectly untenable.'[4]

3. *Sebastopol.*—From the siege of Sebastopol—the masterly offensive defence by the Russians, under the direction of General Todleben, and the persevering and at last successful attempts of the allies, during eleven months, to capture a fortress only half invested, and defended not alone by a powerful army constantly reinforced, but by a fleet which could sweep most of the town and works, and reach some of the besieger's positions with its fire, as well as supply a large amount of

[2] Pp. 137 and 138, *Journal des Opérations de l'Artillerie au Siége de la Citadelle d'Anvers.* Paris, 1833.

[3] The remark made upon this circumstance in the *French Journal*, p. 56, is—'This accident proves how important it is to invoke experience before adopting new ordnance, especially if of cast iron.'

[4] *Motion of Projectiles*, by Major (now Lieut.-Col.) C. H. Owen, R.A., p. 87.

matériel and trained gunners for the defence—many important artillery lessons may be drawn respecting the employment of siege artillery. Space will only allow of some of these being briefly examined; but it may be observed that other points, such as the following, to which allusions have been made, are well worth attentive consideration.

The difficulties of transport due to the neglect of any proper provisions for moving a siege train, and to the fact of the siege being continued through a very severe winter at a great distance from home, where most of the necessary *matériel* and stores could alone be obtained.

The selection of positions for batteries in very difficult ground, hard, and intersected by many deep ravines.

The unprecedented amount of vertical fire brought to bear upon the besieged, and the consequent construction of massive splinter-proof cover in all the Russian works.

The extensive employment of horizontal shell fire from powerful guns.

The large use of rifle-pits as a protection from fire, and as a means, not only of annoyance to batteries, but, by their extension into trenches, of making an advance upon an enemy.

The ravages made in wooden vessels by the fire of large shells from guns.[5]

Although, with the exception of a few Lancaster R. guns, the ordnance employed were SB., yet both their numbers and weights were so formidable compared to those of the pieces employed at any former siege, and the resources developed on both sides for such a length of time were so enormous, that this siege was doubtless one of the most important operations of the time.

Instead of the old 18 and 24-prs., the British siege guns were 32-prs. and 8-in., besides 10-in. and 68-prs. procured from

[5] Warned by the fate of the Turkish fleet at Sinope, and the effects produced upon that of the allies in the attack on Sebastopol, both British and French Governments constructed iron-clad floating batteries during the Crimean War. The French floating batteries were very successful in their attack upon the fortress of Kinburn. (*See* Sir H. Douglas' *Naval Gunnery*, fifth edition, p. 395, and Major (now Lieut.-Col.) Owen's *Motion of Projectiles*, p. 93.)

the fleet, and four 68-prs. rifled on the Lancaster system;[6] 13-in. mortars were obtained from Malta during the siege. The French armaments were lighter, and in the first bombardment less numerous, than ours, although more so towards the end, some heavy guns being, however, borrowed from the English. The Russians mounted their heavy ship guns in their works.[7]

In the first bombardment (October 17, 1854) the English took the right and the French the left (see Fig. 161). It was arranged that the French should make the principal attack on the Bastion du Mat; that the English, who, in consequence of

[6] Lieut.-Col. Elphinstone, R.E., gives 10 in. as the calibre of the Lancaster R. guns, and Todleben and other writers appear to have copied the mistake. Some of the 8-in. 54 cwt. guns had Lancaster Bores, but three of them bursting when firing the elongated shells, the rest were fired with spherical projectiles. The so-called Lancaster guns weighed 95 and 84 cwt., the major diameter of the bore being 8·78 in. and the minor 8·08, windage ·15; shells from 56 to 90 lbs., bursting charges of the largest 10lbs.

[7] ARMAMENTS AT FIRST BOMBARDMENT.

In English Batteries.

Guns	Lancaster R.	4
	68-pr.	5
	32-pr.	7
	24-pr.	30
	8-in.	16
10-in. mortars		10
	Total	72

In French Batteries.

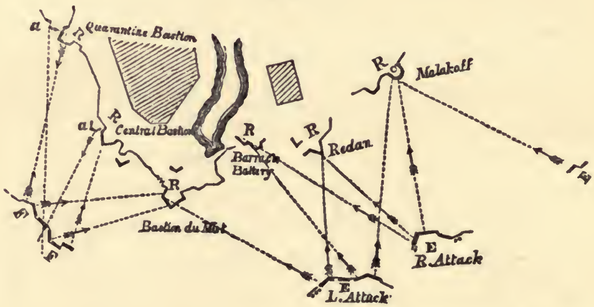
50-pr.		1
30-pr.		13
24-pr.		12
16-pr.		2
Canon obusier 80 c.		9
Obusier 22 c.		4
Mortars	27 c.	4
	22 c.	4
	Total	49

In Russian Batteries.

		Against French	Against English
Shell 3 poud		5	—
Guns	68-pr.	1	4
	36-pr.	13	8
	24-pr.	11	18
	12-pr.	6	—
Carronades	36-pr.	—	3
	24-pr.	10	11
	18-pr.	—	4
Licornes	1 poud	10	5
	½ poud	4	—
Mortars	5 poud	1	1
	2 poud	3	—
	Total	64	54

the nature of the ground, which was very rocky, and intersected by deep ravines, could not get so near, were to keep by their fire the Barrack Battery, the Redan, and the Malakoff employed; while the fleet was to engage the harbour forts simultaneously with the opening of the land batteries. It has been objected that the British batteries were too distant—about 1,600 to 1,700 yards from the Russian works; but, besides the unfavourable nature of the ground, had they been placed nearer, they would have been flanked by the Inkerman Ridge, which there were not sufficient troops to occupy, but which was patrolled by Russian outposts with field guns.

Fig. 161.



The French made the mistake of placing their batteries (FF) too close together, about 1,000 yards from the Russian works, and of disposing them so that, instead of *concentrating* their fire upon the Russian works, they had to *diverge* it; whereas the Russian fire was *concentrated* upon them—an inversion of the principle to be followed in a siege to ensure success. Todleben, the Russian engineer, had the enterprise, when he discovered the French works, to throw out a counter-battery (*a*) in advance of Quarantine Bastion, so as to enfilade the right faces of the French batteries. It is, then, easily understood why the latter were reduced to silence in about four hours—a result the superiority in number of the Russian guns (sixty-four to forty-nine) would not alone have obtained.

The English batteries were more skilfully placed, so as to batter some faces and enfilade others of the Russian works (see Fig. 159, EEE), while their fire was concentrated from different positions. They had the advantages of command and superior armament over the works properly opposed to them; but after the French collapse, they had to sustain the brunt of the fire from all the Russian guns that could be brought to bear on them. Nevertheless, with a loss of eight guns dismounted, they quickly destroyed the Malakoff tower, and dismounted the five guns below it; and by evening reduced the Redan to ruins, dismounting twenty out of its twenty-two guns. Altogether, they dismounted thirty Russian guns. Todleben lays stress upon the superiority of the English mortar fire.[8]

The fleet did not attack as early as had been intended; but when it had retired, as Todleben says: 'After this the English batteries alone continued the cannonade, keeping it up almost until night, principally against the third Bastion (Redan). Of the twenty-two guns on this work only two remained: the whole bastion was a wreck; the earthen breastwork was almost demolished, and platforms, guns, and bodies of the killed were scattered about in confusion. The silence on the bastion was only now and then interrupted by the discharge of a gun, or the groans of the wounded, begging for water. On the whole bastion there remained only five artillerymen, who stuck to the two guns which had remained uninjured till they had fired their last charge.'[9] Such were the effects accomplished by the fire of SB. guns at ranges of from 1,600 to 2,000 yards.

In the subsequent bombardments, the numbers and weights of the ordnance in the allied batteries were gradually increased,[1] so that although the Russians contrived to construct fresh batteries, and even to advance towards the besiegers on the right, their fire was easily reduced although not silenced by that of the besiegers; and the losses of the besieged, especially from vertical fire, were very great. The Russian

[8] The above account is based upon the strong testimony of Todleben, in his *Defence of Sebastopol.*

[9] Russell's translation, in his Review of Todleben's *Defence of Sebastopol*, p. 276. Dr. Russell has omitted much that is stated above respecting the positions of the batteries.

[1] The following table will show the description and number of ordnance used by

embrasures were well protected from the accurate fire of the rifled small arms by heavy rope mantlets; and these being of the same colour as the parapets, the allied gunners had often difficulty in distinguishing the points upon which to lay their pieces. The total number of British ordnance employed, from October 1854 to September 1855, was 401. The French are said to have been provided with 644 siege and 605 naval pieces, but nothing like such numbers were employed or could have been available when wanted, as 140 guns were borrowed from the Arsenal at Constantinople, besides a number of 68-pr. and 32-pr. guns, and 13-in. and 10-in. mortars from the English; and on the day of assault they had but 620 guns in battery. Their guns had fired during the siege more than 1,100,000 projectiles, and 3,000,000 kilogrammes of powder.[2] The British guns were of much heavier metal than those of the French;[3] and it must not be forgotten that the French left attack, although it still had numerous batteries, was practically abandoned as an attack in 1855, the real attack being then, as Sir J. Burgoyne had pointed out it should have been at first, on the Malakoff; also that the French, in their retention of the Mamelon and afterwards of the Malakoff, were greatly assisted by the fire of the British Quarry battery just

the English at the siege of Sebastopol, and the armament of their batteries at the commencement of each bombardment:—

Bombardments	Mortars				Guns							Total
	13-in.	10-in.	8-in.	5½-in.	Lancaster	68-pr.	32-pr.	24-pr.	9-pr.	10-in.	8-in.	
1st—Oct. 17, 1854	—	10	—	—	4	5	7	30	—	—	16	72
2nd—Apr. 9, 1855	20	16	—	—	—	6	42	20	—	4	15	123
3rd—June 6, 1855	26	17	—	—	—	8	49	—	—	8	46	154
4th— „ 17, 1855	30	17	8	—	—	8	49	—	—	8	46	166
5th—Aug. 17, 1855	33	24	7	20	1	4	53	—	—	8	46	196
6th—Sept. 8, 1855	34	27	10	20	2	6	61	—	3	7	37	207

[2] *See* Marshal Vaillant's Report, *Proceedings of R.A. Institution*, vol. i. p. 410.

[3] The French siege guns consisted of 24, 16, and 12-pr. guns, and of howitzers of 22, 16, and 12 centimètres, all of which were of bronze. They obtained some heavier pieces from their ships, viz. 50 and 30-pr. guns, and some heavy 80-pr. shell guns. The mortars were of 32, 27, 22, and 15 c. m. calibre.

below the Redan, at a distance of 380 yards from it, which enfiladed some of the Russian works and swept the approach to the entrance of the Malakoff.

It is worthy of notice that constant complaints were made by our engineers of the interruption of working parties and consequent delays from the fire of light balls, 'which burn for nearly half an hour,' and from that of grape and grenades thrown from mortars at high angles, causing a great many casualties.[4]

A considerable number of rockets were fired during the siege on both sides. By the British, from both attacks, into the town; from the right attack—against the flank of the Russian army at Inkerman; and from the Quarry battery—to enfilade the streets of the Karabelnaia, across which men and stores passed on their way to the Malakoff. The French had an improved rocket, which ranged to very long distances; they generally fired them into the town from the heights above, but they fired some of them at the Russian cavalry at the battle of the Tchernaya.

General Bormann, in his work, 'The Shrapnel Shell,' published at Brussels in 1859, says that the shrapnel shell was not fired by the English, except on September 8, 1855, by a naval detachment on the left attack against the Redan. He gives credit to the naval officers for initiating such practice, and states that the Russians, who mounted the parapet of the Redan for defence, *were literally mowed down each time by this fire.* He is in error, as the table giving the expenditure of ammunition will show; and the writer of this work well remembers firing shrapnel from the 5-gun battery right attack on the Russians who gallantly mounted the parapet of the proper left flank of the Redan to repel our assaulting column.

The British batteries fired during the siege 251,872 projectiles; and the proportions of different natures were as follows:—

[4] *R. E. Journal of Operations, Sebastopol,* part ii. pp. 327, 354, 373.

		Round Shot	Common Shells	Shrapnel Shells	Case Shot
Guns	68-pr. . . .	3,510	891	746	12
	32-pr. . . .	38,311	2,931	663	4
	24-pr. . . .	32,175	425	254	83
		Hollow Shot	Common Shell		
	10-in. . . .	2,101	1,491		
	8-in. . . .	25,543	17,979		
	Lancaster		224		
		Shells	Carcasses		
Mortars	13-in. . . .	39,174	40		
	10-in. . . .	38,827	161		
	8-in. . . .	3,777	404		
	5½-in. . . .	4,319			

Besides over 500 9-pr. shot, and some 38,000 rounds not reported.[5]

4. *Charleston.*—The next example is taken from the land attack on the defences of Charleston Harbour in 1863, where rifled guns were employed to breach uncovered masonry at very long ranges. The great object was to silence Fort Sumter, the main obstacle to the entry of the fleet into the harbour; and to effect this it was determined to land on Morris Island and capture Forts Wagner and Gregg, from which batteries it was conceived that Fort Sumter might be disabled.

'The batteries of Sumter were especially dreaded, on account of their height above the water and the comparative vulnerability of the monitors' decks to a plunging fire.'

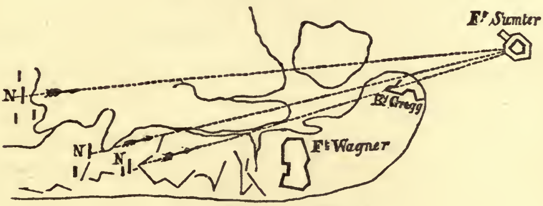
Fort Wagner and Battery Gregg were mere outposts of Sumter, the former designed, as stated, 'to prevent the erection of breaching batteries against that work. It was valueless to the enemy if it failed to accomplish that end, for the fleet, in entering, was not obliged to go within effective range of its guns.' Should the fleet not succeed in forcing its way into

[5] For further artillery details of this siege *see* Major (now Lieut.-Col.) Reilly's *Artillery Operations before Sebastopol;* Marshal Vaillant's report in *Proceedings of R. A. Institution*, vol. i. p. 410; *Siége de Sébastopol,* par le Général Niel; and Todleben's *Défense de Sébastopol.*

the harbour, Morris Island would still be valuable as a means of securing the blockade of the port, by allowing a portion or all of the squadron to lie inside the bar.

The landing on Morris Island—a hazardous undertaking in the face of an enemy—was skilfully executed on July 10, 1863; but the strength of Fort Wagner was underrated, for, after two unsuccessful assaults on July 11 and 18, it was found necessary to advance by regular approaches. The first parallel was commenced immediately after the repulse of the last assault, and the work of constructing trenches and batteries was vigorously pushed on from day to day; but, as some time must have elapsed before Wagner could be reached by such means, it was determined to attempt the demolition of Sumter by firing

Fig. 162.



at it over Wagner from breaching batteries in the trenches (Fig. 162).

A few years ago this would have been impossible, as the ranges of the batteries from Sumter varied from 3,428 to 4,290 yards; nevertheless, by the fire of nine 100-pr., four 200-pr. and one 300-pr. rifled guns during a seven-days' bombardment (from August 17 to 23), Fort Sumter was much damaged. General Gillmore describes its state as follows:—

'The barbette fire of the work was entirely destroyed. A few unserviceable pieces still remaining on their carriages were dismounted a week later. The casemates of the channel fronts were more or less thoroughly searched by our fire, and we had trustworthy information that but one serviceable gun remained in the work, and that pointed up the harbour toward the city. The fort was reduced to the condition of a mere infantry outpost, alike incapable of annoying our approaches to Fort Wagner or of inflicting injury upon the ironclads.'

At this stage of the siege, when Sumter had been practically silenced, the admiral should, according to General Gillmore, have again attempted to force an entrance into the harbour. No attempt was, however, made with the ironclads, and the siege of Wagner proceeded in face of great difficulties, owing to the sandy nature of the ground, the encroachments of the spring tides, which, aided by a storm, submerged the trenches to a depth of two feet in many places, and the heavy fire in front from Wagner, and in flank from the James Island batteries.[6]

So little progress was now made with the works that it was decided to bombard Fort Wagner vigorously with vertical fire (called in the report curved), and at the same time to endeavour with the rifled guns to breach the splinter proof which afforded cover to the enemy, the co-operation of the famous ironclad *Ironsides* being also secured. This bombardment is thus described:—

'For forty-two consecutive hours the spectacle presented was of surpassing sublimity and grandeur. Seventeen siege and coëhorn mortars unceasingly dropped their shells into the work, over the heads of our sappers and the guards of the advanced trenches. Thirteen of our heavy Parrott rifles—100, 200, and 300-prs.—pounded away at short though regular intervals at the south-west angle of the bombproof, while

[6] The following description of the Marsh battery, or 'Swamp Angel,' as it was characteristically called, will give an idea of some of the difficulties overcome by the skill and perseverance of the Federals:—

The Marsh battery consisted of a sandbag parapet with a return or epaulment of the same material at each end; the whole supported by a broad grillage, composed of round timbers in two layers, crossing each other at right angles and resting directly on the surface of the marsh. In this grillage, in rear of the parapet, there was a rectangular opening through both layers of logs, exactly of the proper size to receive the platform of the gun, and surrounded by closely fitting sheathing piles. These piles reached from the upper surface of the grillage entirely through the stratum of mud into the solid substratum of sand. Within this rectangular space thus closely confined latterly by the piles, layers of marsh grass, canvas, and sand were placed directly on the mud, to the aggregate depth of several inches, the sand being on top. On the sand rested a compact sub-platform of planks. On these planks the gun platform was placed.

during the daytime the new *Ironsides*, with remarkable regularity and precision, kept an almost incessant stream of 11-in. shells from her eight-gun broadside, ricocheting over the water against the sloping parapet of Wagner, whence, deflected upward with a low remaining velocity, they dropped nearly vertically, exploding within or over the work, and rigorously searching every part of it except the subterranean shelters. The calcium lights turned night into day, and, while throwing around our own men an impenetrable obscurity, they brilliantly illuminated every object in front, and brought the minutest details of the fort into sharp relief.'

The sappers, now relieved from the converging fire of Wagner on the head of the sap, were enabled to advance until they arrived so near the fort that the James Island batteries were compelled to discontinue their fire for fear of injuring the defenders. The works could therefore be continued with entire immunity. On the night of September 6 the crest of the counterscarp was crowned, and an assault ordered; but at midnight it was discovered that the enemy was evacuating the fort, which was accomplished so rapidly that only seventy prisoners were made by the Federals.

On September 8 a naval force assaulted Sumter, but was repulsed. On October 26 Sumter was again bombarded, in order to destroy the south-east face. The heavy rifled breech-loading ordnance were this time mounted in Forts Wagner and Gregg (now called Putnam), and the result of the firing was that—'In a few days the south-east face was more completely a ruin than the gorge wall. The *dêbris* formed a continuous and practicable ramp, reaching from the summit of the breach to the level of the water. The two faces of the work seen from Morris Island were both in ruins.'

Those who followed these operations with the aid of the reports in the newspapers were surprised and disappointed that after the apparently effectual reduction of Sumter another attempt was not made to enter the harbour. As before observed, General Gillmore was clearly of opinion that such an attempt would, in all probability, have been successful after the first bombardment, and that it was still practicable; but

Admiral Dahlgren states that the delay in capturing Wagner gave the enemy time to replace Sumter by an interior position. A lengthy correspondence between the general and the admiral was carried on, but a perusal of it does not show that there existed any insurmountable obstacles to the entry of the fleet; the general affirms that 'the concurrent testimony of prisoners, refugees, and deserters represented the obstacles in the way as by no means insurmountable.'

A kind of mitrailleuse was used at the siege of Charleston, called a *Requa rifle battery.* It consists of twenty-five rifle barrels, each 24 in. long, arranged horizontally and held in position upon a light field carriage by an iron frame. Upon this frame, in the rear of the barrels, is fitted a sliding bar worked by two levers (one at each side), by which the cartridges are forced to the rear of the chambers. By a lever under the frame the barrels may be diverged so as to scatter the balls 120 yards in a distance of 1,000. The weight of the battery complete is 1,382 lbs.

'When served by three men the battery is readily fired seven volleys, or 175 shots per minute. 1,300 yards is probably its effective range.'

The *Requa battery* is in fact an improvement upon the *ribaudequin*, or *organ gun.* The general thus reports upon its efficiency:—

'I feel quite satisfied that it is adapted to the defence of earthworks, particularly in a flat country like this, where the horizontal line of dispersion afforded by the fire of this piece is more effective than the cone of dispersion of the howitzer. It should be noted that the angle of dispersion can be varied to suit the case in this battery, which is not true of the howitzer.'

The following remarks on vertical (which throughout General Gillmore's work is erroneously termed curved) fire are very important, as illustrating the value of mortars for both siege and garrison service; especially as, notwithstanding our Crimean experience, which fully confirms them, this kind of fire is very often greatly underrated. One fault in the defence of Fort Wagner was that—

'Curved (vertical) fire was not used enough. The armament of the work contained but two mortars (one 8-in. and one 10-in.). These, when earnestly served, caused the most serious delay in the progress of our work, and on one occasion suspended it entirely.'

But, on the contrary, one of the assigned conditions for the success achieved by the Federals was—

'An overpowering mortar fire from our batteries, particularly towards the end of the siege of Fort Wagner, opposed by a weak mortar fire from the enemy.'[7]

5. *Strasburg.* In the many sieges carried on by the Prussians in France, but few places were defended with vigour, and although the bombardment of works with field guns produced little result, twelve French fortresses were taken by bombardment with siege pieces.[8] As the siege of Strasburg afforded some valuable artillery lessons, it has been selected for examination.

The investment of Strasburg, commenced after the battle of Woerth, was completed on 15th August, 1870. The front selected for attack was that on the N.W., including Bastions 11 and 12, with Lunettes 53 and 52 in front of them. The ground on the south of the place could be inundated, and difficulties would have been caused on the north and east by the river Ill and its tributaries intersecting the ground in so many directions.

The place was unprepared to resist the attack of a strong force provided with a modern siege train. No detached works had been constructed; and, with the exception of some hollow traverses, little had been done to afford bomb-proof cover, or to strengthen the defences. Moreover, the fortifications were so close to the town, that the projectiles passing over them must cause great destruction among the streets and buildings. The garrison was weak, there being only about 3,000 regular troops, with some 10,000 newly-formed battalions and mobiles; and the force

[7] The above account, an abridgment of one written by the author for the *Times* newspaper, is taken from the *Engineer and Artillery Operations against the Defences of Charleston Harbour in* 1863. By Major-General Gillmore. New York: D. Van Nostrand, 1865.

[8] Niemann's *French Campaign*, pp. 230 and 242.

of artillery was entirely inadequate to serve the requisite number of pieces, which were for the most part manned by the sailors of a flotilla intended to act on the Rhine. Niemann states[9] that there were two battalions of artillery; and, with the pontoon train and sailors of the Rhine flotilla, about 3,000 artillerymen in the place. But a French writer, an inhabitant of the place,[1] says that the guns were served by some artillerymen who had escaped from Froschweiler, by artillery of the mobile and national guard, and by sailors. The number of ordnance in the fortress was amply sufficient for its defence, about 1,200;[2] but only about 440 pieces were mounted, and these were very scantily provided with ammunition and stores. Many of the guns were not rifled, and it is difficult to arrive at an estimate of the proportions of the different natures employed; but the pieces consisted of

Rifled 24-prs. and 12-prs.,
SB. 16-prs. and 12-prs.,
SB. Mortars.

The German siege corps consisted latterly of about 50,000 men, including 37 companies of siege artillery (about 7,400 men), with the following formidable siege train:—

Rifled	58	24-prs. (12 short, adapted for curved fire),	
	80	12-prs.,	
	20	6-prs.,	
	2	21-c.m. (8-in.) mortars.	
Smooth-bored	8	60-pr. mortars.	
	19	50-pr.	do.,
	24	25-pr.	do.,
	30	7-pr.	do.,
Total .	241	pieces of ordnance.	

[9] *The French Campaign*, 1870–71 (translated by Col. E. Newdigate), p. 226.

[1] A. Schnéegans, in *La Guerre en Alsace*, gives:—

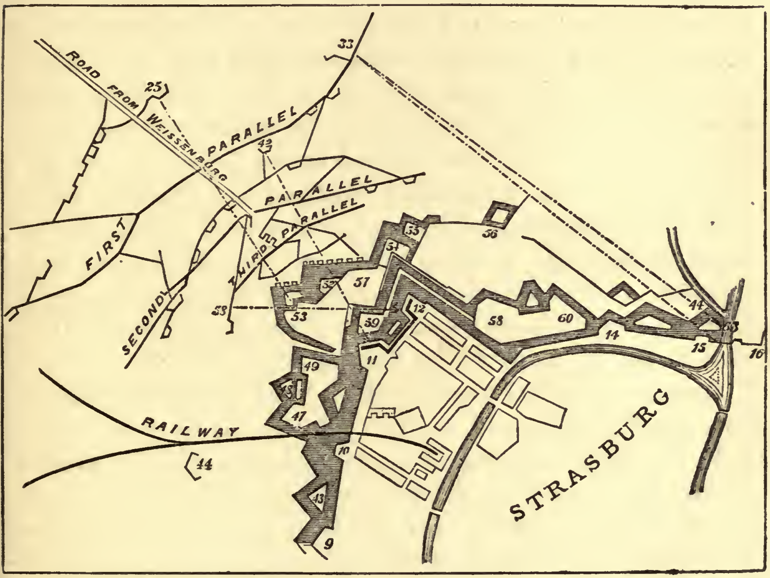
5 Floating batteries each with a crew of 45 men.
2 „ carriages „ „ 6 „

making a total of 237 men, but of these all had not arrived. There were also 100 dockyard workmen, some marine artillery on leave, and 65 artillery recruits.

[2] Rüstow says that 1,070 pieces, and Niemann that about 1,200, were given over by the French to the Germans. For particulars respecting the French and German ordnance, see Appendix II.

Previous to the arrival of the siege train a cannonade was kept up by the German field guns to disturb the French working parties, but when a sufficient number of heavy pieces could be placed in batteries General von Werder determined to try the effect of a bombardment, in hopes that the inhabitants, intimidated by the destruction of buildings and loss of life, would force General Uhrich to surrender. Accordingly on August 24th, a bombardment was opened, and continued with several

Fig. 161.



interruptions for three days, from 40 siege pieces (R. 24-pr. guns and 50-pr. SB. mortars) and the field artillery placed in batteries at 900 to over 2,000 yds. from the *enceinte* on the north-west; and from 36 Baden siege guns in batteries on the far side of the Rhine at Kehl, against the citadel. The bombardment failing to effect its object, or being stopped for other reasons, regular siege works were commenced, the first parallel (see Fig. 161) being made on the night of 29th to 30th August, from 600 to 700 yds. from the works in the north-west, and ten fresh batteries constructed some 150 to 250 yds. in rear. These, with the bombarding batteries, opened on the morning of the 30th August, and quickly overpowered the French guns. The superiority of the German fire was no doubt partly owing to the efficiency of their artillerymen and their better *matériel*, but also in a great degree to the comparatively harmless character of the French fire, in consequence of the scarcity of trained gunners in the fortress and of an accident which had deprived them of their fuses. On August 24, the stores of fuses (35,000) and quickmatch in the citadel were burnt, and although the latter could be replaced, the new fuses of wood made by the artificers only served to render the French fire, as General Uhrich remarked, ridiculous; some burst long, others short, and a number were blind.[3] A boat with a supply of fuses from Schlestadt drifted among the willows and brushwood bordering the Ill, and was captured by the Germans. Schnéegans says that this catastrophe paralysed the French gunners and was the beginning of the end, and was the reason why the Germans suffered so little annoyance in pushing on their approaches. Lunette 44, which disturbed the siege works by a flank fire, was bombarded with short 24-prs. from Battery 33 and with R. 21-c.m. mortars from Battery 35.

A second and third parallel with a large number of batteries were rapidly constructed, so that by September 24 the Germans had 229 pieces, including 83 mortars, playing upon the French works. The garrisons of Lunettes 53 and 52 were driven out by the terrible artillery fire; the former was abandoned, and occupied by the Germans on the 20th, and the latter was taken, with some loss from the fire from the ramparts, on the following night. A breach in Bastion 11 being nearly practicable, another in Bastion 12 requiring but little more fire to bring down the masses of earth, the interiors of them and the adjoining works being reduced to shapeless heaps and ruins, the white flag was hoisted at 5 p.m. on September 27.

The most interesting artillery operations in this siege were the breaching of the revetments of Lunette 53 and of Bastions 11 and 12, and the attempt to cut two sluices, which retained the water in the ditches and on the ground on the left of the

[3] *La Guerre en Alsace*, p. 250.

attack, by means of curved fire, and the use of rifled mortars for bombarding. Experiments had been made in this country and in Germany both in curved fire and vertical fire from rifled pieces, but neither had before been practised in actual warfare. The position and objects of the batteries used for these purposes may be seen in Fig. 161. No. 25 battery was armed with 4 guns to breach the right face of Lunette 53 at a range of 900 yds.; No. 42 with 6 guns to breach the right face of Bastion 11 at 900 yds.; and No. 58 with 4 guns to breach the left face of Bastion 12 at 600 yds. range. The pieces used for breaching were the short 15-c.m. (6-in.) or 24-pr. gun, which had been lately adopted for this purpose.[4] Three of the eight 15-c.m. steel guns in Battery 33 were used to cut the sluices, one in front of Curtain 15, and the other in front of Lunette 63, at a range of about 1,950 yds.

The breaches were made by horizontal and vertical cuts in the usual way; but as the object could not be seen, the angle of elevation, the charge, and the deflection required were obtained in the following way:—'The distance of the battery from the work being known from the map, and profiles of the fortress being at hand, the amount of charge, &c. due to the required "angle of descent" necessary could be found from the range tables. The next thing to be done was to select some visible part of the work, and by firing a number of rounds, to find the *point of mean impact* of the group. By consulting the plans of the fortress, data could be obtained by which the necessary amount of decrease of elevation of the gun and of deflection could be calculated, so as to hit the part where the breach was to be made. In this way the *point of mean impact* of the first group of hits was transferred to a terminal point of the horizontal cut in the case of Lunette 53, and to the face of the sluice in the other.'[5] The starting point for the horizontal cut being thus obtained, the *point of mean impact* could be transferred to the other end. The

[4] The short R. 24-pr. throws a special shell of about 61 lbs., which holds a bursting charge of 4·4 lbs. (*See* Note, p. 483).

[5] 'Artillery Lessons from the Siege of Strasburg,' by Capt. F. C. H. Clarke, R.A. *Proceedings of R.A. Institution*, vol. viii. p. 141.

visible point chosen for the breach in the Lunette 53 was the parapet at the head of the work; for the sluice in front of Curtain 15, a turret known (by an engineer officer) to be near it; and for the sluice in front of Lunette 63, the exterior slope of the left face of the latter. The result of the fire in breaching was observed by a range party in the advanced trenches, the effect produced being judged by the sound made by the shell on striking, by the fragments of stone thrown up, and by the colour and form of the smoke from the shell after bursting.[6] In firing at the sluices, it could be seen from the battery 'whether the shells hit the water by the *sheaf* of water which was thrown in the air; and by a comparison of the position and height of the *sheaf* with the position of known objects in the fortress, inferences could be drawn as to where the shot struck. With a good glass, it could be seen whether this sheaf of water was accompanied with a shower of wood or stone splinters. When this occurred, it was concluded that the sluice was hit.'[7]

The breach in Lunette 53 took four days and 1,CC0 rounds of ammunition. When the horizontal cut in the escarp was about half completed, the countermines in front of the lunette were penetrated by a gallery from the third parallel, and the results of the fire could then be observed from the counterscarp. The angle of the line of fire with the face of the lunette was 55°, and the angle of descent of the shell, to hit the wall two feet above the water level, was 7° 45′, the charge of the gun being 1·7 lb.; the completion of the breach was delayed by bad weather and want of training in the gunners. The breach in the right face of Bastion 11 took 18 hours and 600 rounds, or six to seven rounds per foot run. For the sluices, the angle of descent was 7°, and the charge of the gun 5 lbs.

The 21-c.m. (8-in.) rifled mortars, used first for vertical fire upon Lunette 44, and afterwards on Bastions 11 and 12, weighed about 150 cwt., and fired a shell of 160 lbs., holding a bursting charge of 15 lbs., and provided with a percussion fuse. Schnéegans said of the Prussian artillery fire

[6] *See* page 483.

[7] Capt. F. C. H. Clarke's 'Artillery Lessons from the Siege of Strasbu g.'

that it was 'incessant, most destructive, and mathematically accurate;' and that 100 French pieces, including a large mortar battery in the citadel, were dismounted by it. He mentions that, in firing on the sluices, their positions were exactly determined by means of plans and calculations, and that it required a party of sailors to be kept perpetually repairing the dyke. Quoting the account of a naval officer, he said:—Seven rounds were fired by the Prussians to one by the French, who were inundated from morning till night with projectiles of all kinds. Towards noon the parapet was thrown down (*était à terre*), the embrasures demolished, and nothing but stone revetment exposed to the Prussians, for the French ceased fire, and waited till night to repair as well as they could with sand-bags.[8]

The German artillery had thrown during the siege 193,722 projectiles into the town and fortress: 6,249 each day, 269 in the hour, 4 to 5 a minute. The expenditure of ammunition in the German batteries Rüstow gives as follows:[9]—

	Common shell	Shrapnel	Mortar shell
Long R. 24-pr.	28,000	5,000	
Short R. 24-pr.	3,000	—	
R. 12-pr.	45,000	11,000	
R. 6-pr.	8,000	4,000	
R. 21-c.m. mortars			600
50-pr. SB. mortars . 15,000			
25-pr. „ „ . 20,000			58,000
7-pr. „ „ . 23,000			

[8] The officer says, 'Ce n'est qu'avec des prodiges de gymnastique que nous évitions les éclats; des factionnaires veillaient la lueur du coup et criaient *casse-cou!* tout le monde s'abritait alors pour ressauter sur la pièce et continuer le feu.'

[9] *Der Krieg um die Rheingrenze*, 1870, vol. i. p. 159.

CHAPTER IX.

ARTILLERY FOR GARRISON AND COAST SERVICE.

Garrison Artillery: 1. Objects.—2. Armament.—3. Ammunition.—4. Carriages and platforms.—5. Gyns, sheers, &c.—6. Men.—7. Employment of garrison artillery. Coast Batteries: 8. Purposes.—9. Ordnance.—10. Ammunition.—11. Carriages and platforms.—12. Employment of coast artillery.—13. Position of coast batteries. 14. Batteries combined with obstructions.—15. Vertical fire in coast defence.

Garrison Artillery.

1. Artillery is employed in the defence of fortresses, for the purpose of retarding and injuring the besieger's works, of counteracting and silencing the fire of his batteries, of creating casualties among his troops, and of repulsing such assaults as may be made by him.

2. The armament of fortresses and garrisons is governed in a great measure by the size and description of the works, as well as by the nature of the locality on which they are situated, and is not based upon those principles which regulate the armament of a battering train, the question of transport, which influences in so great a degree the latter, being as regards the arming of fortresses of but little importance.

For the defence of fortresses, the French employ the long R. 12-pr. and the long R. 24-pr. throwing shells of about 26 and 53 lbs. with maximum charges of 3 and 5½ lbs. respectively;[1] also the SB. 16-pr. gun, the SB. 22-c.m. (8·79-in.) howitzer, and the SB. 32-c.m. (12·78-in.) mortar. The Prussians use the long R. 15-c.m. or 24-pr., which fires a shell of about 56 lbs. with a maximum charge of 4½ lbs., and the R.

[1] At the siege of Paris by the Germans heavier guns than the 24-prs. were used, but, according to Lieut. Fraser, R.E., none heavier than the 6½-in. or 16-c.m. gun, which would throw a projectile of about 70 lbs.

12-pr., throwing a shell of 29 lbs. with a 2 lbs. charge; they have also 7, 9, and 11-in. SB. mortars, and the R. 21-c.m. (8-in.) mortar before mentioned.[2]

All our great fortresses, such as Portsmouth, Plymouth, Malta, Gibraltar, &c., are on the coast, and it is therefore necessary to class their armaments into those for *land fronts* and *sea fronts* respectively, the latter will be referred to under the heading of coast batteries, and the heavy ordnance, from the ML. R. 7-in. gun and upwards, will not therefore be noticed in this section. The SB. 68, 42, 32, 24, and 18-prs., and the 8 and 10-in. shell guns, are still mounted in large numbers, but they are being gradually replaced by rifled guns, such as the converted ML. R. 80 and 64-prs.,[3] and the BL. R. 7-in. and 40-pr. ordnance. The SB. 8-in. howitzer and carronades are mounted for the defence of short flanks. Some field pieces are required to defend covert ways, for sorties, and, as they can be kept under cover till the last moment, for repelling assaults;[4] for these purposes, machine guns, such as the Gatlin battery, would prove most formidable. Of the mortars, the 13 and 10-in. have chiefly been made use of, though the 8-in., as well as the small brass mortars, are also of service, the fire of the latter being very annoying to the working parties of a besieger.[5] Experiments are being made with a view to the introduction of a 10-in. rifled howitzer, which would doubtless be a most formidable piece for vertical fire.

At the siege of Paris by the Germans in 1870-71, armour-plated railway wagons were used by the French. In two of these the gun was mounted with its carriage on a traversing platform, *en barbette* over the end of the wagon; but in the other two, the upper portion of the wagon, forming a low turret with embrasure, could be made to revolve, by means of a winch and pinion, on a large central pin. The plating of the wagons

[2] For fuller particulars respecting Foreign Ordnance, see Appendix. Lieut.-Col. Reilly, in his *Notes of a Visit to Berlin*, gives a new siege 24-pr. which fires a shell of 61 lbs. with the very large charge of 13½ lbs.

[3] Only a few BL. R. 64-prs. are mounted in garrisons.

[4] The Russians used a field gun against our troops in the Redan at Sebastopo on September 8, 1856.

[5] See p. 491.

consisted of 5 thicknesses of $\frac{2}{5}$-in. plates = 2 in. The wagons were drawn by *motors* (or small engines) plated like the wagons, or by ordinary engines provided with a screen of one $\frac{2}{5}$-in. iron plate; they were armed with BL. R. 14 and 16-c.m. guns.

These wagons were engaged on several important occasions, viz.:—

Near Brie-sur-Marne, to support the Champigny sortie; at Choisy-le-Roi, for the sortie preceding the above; at Le Bourget, in an attempt to recapture the position. At Malmaison, to support the Montretout sortie. On the last occasion they are said to have caused great inconvenience to the Prussian artillery. The wagons were struck by shells from field guns, some of the hits being made at the junction of the plates, but although indented were not penetrated. Neither *motors* nor engines received damage, and only one man was killed, and by a shell which passed through the screen above the plating. Each wagon had a crew of 7 marines and a naval lieutenant.[6]

The French divide their fortresses into three classes, and apportion the number of pieces accordingly; the quantity requisite for the immediate security of a place is laid down at 10 pieces per bastion, this number providing for the armament of the salients and flank defences, and also allowing for the heavy mortars; but that required to sustain a siege must depend on the extent of the works generally. Thus, fortresses of the

1st class,	consisting of	10 sides and upwards,	require	110 pieces,
2nd	„	6 to 10 sides	„	70 „
3rd	„	4 to 6 sides	„	30 „

in addition to the 10 per bastion.

Piobert gave from 300 to 400 pieces for the larger fortresses, and set down the armament of Paris at upwards of 2,000 ordnance.[7] It will therefore be seen that the extent and positions

[6] See Lieut. Fraser's paper on 'Armour-plated Railway Waggons,' in the *R. E. Corps' Papers*, vol. xx. Drawings of these carriages are given.

[7] The moveable defence (of Paris in 1870) was represented by 92 field batteries and 4 mountain batteries—say, 2,627 guns in position and 576 moveable guns; together 3,203. These guns were on the average provided with 400 rounds each, and the reserve of powder in barrels amounted to 2,600,000 kilogrammes (5,720,000 lbs.). (*The French Artillery before and since the War*, by General Susane, p. 22, translated by H. H. An interesting pamphlet showing the ample

of the works to be defended must be the ruling principle as regards the arming of a fortress or garrison.

3. The quantity of ammunition required for the defence of a fortress is regulated by its extent, the nature and number of pieces of ordnance mounted in the works, and also in some measure by the probable duration of any siege it may have to sustain. In the defence of a maritime fortress containing an arsenal and a fleet, such as Sebastopol, or of a city, like Paris, defended by an *enceinte* with numerous strong detached works, and with immense supplies of ordnance and stores and the means of manufacturing them, there could be scarcely any limit to the quantity of shot and shell available for use; but it is generally considered that in ordinary fortresses no more ammunition should be stored than that necessary for a vigorous defence.[8]

provision of artillery *matériel* existing at the time in France, and which had been gradually accumulated notwithstanding the very small sums voted annually for the conversion of SB. into R. guns.) General Súsane says that, in July 1870, there were 3,216 rifled guns of 4, 8, and 12, making, with 190 mitrailleuses, 3,406 pieces; besides 581 rifled mountain guns, bringing up the total to 3,987 pieces. Hence the ease with which fresh batteries were armed after such enormous losses in the early part of the war. Of heavy pieces there were 12,336, including 4,407 rifled guns of 30, 24, and 12 land service, and of 19 and 16-c.m. naval service.

[8] The proportion of ammunition per piece has been laid down by the French according to the class of fortress to be defended and the position of the pieces, that is to say, as to whether they are mounted on such faces of the fortress as are susceptible of a regular attack or not. The following Table of Ammunition is taken from the *Aide-mémoire à l'usage des Officiers d'Artillerie*, ed. 1856.

Class of Fortresses	No. of rounds (not including case)					Case shot		
	Per gun	Per howitzer, and canon-obusier of 80	Per mortar			Per gun		Per howitzer, and canon-obusier of 80
			32c and 27c	22c	15c	30 24 16	12 and 8	
For the fronts exposed to regular attack								
1st	1,000	800	800	1,200	800	25	60	30
2nd	830	600	600	900	800	29	40	25
3rd	600	500	400	800	600	20	40	25
For the fronts not exposed to regular attack								
1st	300	250	180	250	...	12	30	15
2nd	250	200	130	200	...	10	20	12
3rd	200	150	90	150	...	10	20	12

Common shell are obviously required for damaging siege works, dismounting guns, and killing or wounding the defenders. Shrapnel shell are also of great use for the latter purpose; light balls, pound shot, and hand grenades should be provided for the mortars; the first for discovering the besieger's working parties, and the others being very efficacious against the defenders of the advanced trenches when the besieger has arrived at short distances from the place.

The quantity of powder is calculated in the same manner as for siege equipments. Powder is kept in gun ammunition barrels or in metal-lined cases.

The numbers of rounds to be maintained in Land Fronts[9] are:—

	Home	Abroad
ML.R. 64-pr. . . .	100	200
BL.R. 7-in. . . .	75	200
BL.R. 40-pr. . . .	100	200

The proportions of the different projectiles are:—

ML.R. 80 and 64-prs. and BL.R. 7-in. and 40-pr.	10 Case shot 60 Common shell 30 Shrapnel for ML.; Segment for BL.

	Solid Shot	Case Shot	Common Shell	Diaphragm Shell
SB. 10-in. . . .	0	15	85	0
SB. 8-in. . . .	0	15	60	25
SB. 68, 42, 32, 24, and 18-prs. .	50	10	25	15

For flanks—the pieces, including 10 and 8-in. howitzers, are supplied with 30 rounds of common shell and 70 rounds of case and grape. The proportions of fuses are:—

ML.R. 80 and 64-prs.	R.L. Percussion		60
	M.L. Wood Time	20 seconds	25
		9 "	50
		5 "	25
BL.R. 7-in. and 40-pr.	BL. Wood Time	20 "	35
		9 "	65

	Com. Time	Diaphragm	Pettman LS.
10-in.	52	—	42
8-in.	36	30	30
68, 42, 32, 24, and 18-prs. . . .	15	18	12

9 Part I., *Corps Equipment*, Section I., Artillery for Garrison Service. Jan. 1873.

Service LG. powder is supplied for the cartridges, shell LG. for the bursters of shells, and pistol or FG. powder for bursters of shrapnel. The number of tubes is 1 per round and 10 per cent. spare, besides which slow-match and portfires are provided. Grummet wads are issued according as circumstances may require their use for the SB. guns; the BL. R. guns are provided with lubricators, and the 7-in. also with tin cups.

4. The guns of a fortress are generally mounted on wooden or iron standing garrison carriages, though all the natures of naval as well as siege carriages may be employed if desirable, or if there be not a sufficient number of the first-named description. The ML. R. 80-pr., the BL. R. 7-in., and the SB. 68-pr. and 10-in. guns, are generally mounted on sliding carriages; the ML. R. 64-pr. the BL. R. 40-pr. and the SB. 8-in. and 32-pr. on wrought iron standing, and the other SB. pieces on wood standing carriages. (See Part I. Chap. VII.) Spare carriages in the proportion of from $\frac{1}{3}$ to $\frac{1}{4}$ the number of guns should also be furnished, as a great number are almost sure to be rendered unserviceable during a siege. Mortars are provided with beds. A piece on a standing, rear-chock, or carronade carriage has a ground platform, constructed sometimes of wood, but usually of stone; the dwarf traversing platform is chiefly used for mounting guns in the salients of works; but in casemated batteries, the casemate traversing platform must be made use of. The Moncrieff carriage would be well adapted to garrison service. For the transport of ordnance in a garrison, the sling wagon and drug are employed, the latter being intended for confined localities; they are not both issued, except in extensive and important districts. Traversing platforms and gun carriages are moved by means of transporting axletrees with wheels and limber (dilly).[1] For the 10 and 8-in. mortars, trench carts are also very useful; indeed, most of the carriages used for siege purposes are applicable for the transport of guns in fortresses and coast batteries. In large fortresses it is of great advantage to have a railway to connect the different works and thus facilitate the transport not only of troops but of the large amount of heavy *matériel* now used. At Paris, both a military road

[1] See p. 111 and Fig. 57.

and a railway run round the interior of the *enceinte*, the latter uniting all the lines entering the city from different directions; and at the Russian fortress of Modlin, Todleben has laid down within the exterior lines two railways, in connection with one another and by branch lines with the citadel.[2]

5. The artillery *matériel* provided for the defence of a fortress must include a certain number of triangle gyns[3] (complete), as well as the spars, tackle, &c. for sheers, though no definite proportion of each can be laid down. Sheers are especially useful when it is requisite to mount guns on towers, or to perform any work for which the gyn might not be considered adequate; the cheeks of the gyn may, however, in many cases be made to supply the place of sheers. In casemates or galleries, such as those at Gibraltar, the Gibraltar gyn is applicable; for although a more tedious method of mounting guns than by making use of skidding and luff tackle, it can be more easily managed by men not perfectly drilled in the service and shiftings of heavy ordnance.

6. The works armed and manned by artillery are united into *districts* at home or *stations* abroad, a district or station constituting an artillery command with usually a brigade of garrison artillery. The proportion of gunners allowed per piece of ordnance in the defence of a fortress or garrison will generally be less than that calculated for the attack. In France, three men per gun, estimating for three reliefs, has been the number laid down, the rest of the detachment being made up of soldiers of the line. In our service, however, although some line regiments are drilled with heavy ordnance, their numbers are usually merely sufficient for their own duties, and a large proportion of artillerymen would be required in order that the guns might be worked efficiently. The militia and volunteer artillerymen would, doubtless, be of great service in assisting to work the guns in home garrisons.

In our service each garrison brigade has seven batteries, but

[2] See a description of this fortress by Capt. C. Brackenbury, R.A., in his *Foreign Armies and Home Reserves*, p. 112.

[3] If batteries are contiguous, one gyn would suffice for two or even three batteries (*Corps Equipment*).

the establishment of the battery varies according to its station. The different establishments of garrison batteries laid down for 1872-3 are given in the Table below.[4]

Rank	At home	Mediterranean	America and West Indies	S. Africa and the East	India
Major . .	1	1	1	1	1
Captain . .	1	1	1	1	1
Lieutenants .	2	2	2	2	3
Battery Staff-Sergts.	1	1	1	1	1
Sergeants . .	5	5	4	4	4
Trumpeters .	2	2	2	2	2
Corporals . .	5	4	4	4	4
Bombardiers .	5	4	4	3	4
Gunners . .	128	142	98	85	72
Total . .	150	162	117	103	92

The Staff of a Brigade quartered in a large fortress, such as Malta or Gibraltar, consists of a Colonel, 2 Lieut.-Colonels, Paymaster, Adjutant, Quartermaster, and Surgeon, with eight N.-C. Officers.

7. In the defence of a fortress the guns should be placed so as to defend all the approaches to it, the positions of the different descriptions of ordnance being determined by their respective powers and natures. Previous to the investment by an enemy, and indeed at all times, the artillery officers should make themselves acquainted with the exact distance from their guns of every object in the surrounding country, such as trees, hillocks, buildings, &c., which may happen to be within range; this will enable the fire of the besieged to be executed with precision at the time when the besiegers are laying out their batteries, and to maintain a superiority in this respect over that of the enemy after his batteries are armed; at all events, until such time as he may have ascertained the different ranges. On the investment of the fortress, the artillery of the besieged should endeavour to annoy and harass the enemy as much as possible and hinder his progress, and on the night on which it is supposed he is first breaking ground, a heavy

[4] *Army Circular*, August 1872, and *Details of Equipments*, Sept., 1872.

fire of common and shrapnel shell should be kept up across the ground where his working parties are engaged; light balls being also employed to ascertain the position of the latter.

The fire of the ordnance mounted in a fortress ought for some time at least to be far more powerful than that of the guns of the attacking army. Much larger ordnance than siege pieces can be employed in permanent works, where there is no difficulty, with proper arrangements, in transporting very heavy guns and their ammunition, or in mounting the former on durable platforms of suitable construction. The ordnance in a fortress can be disposed in situations most favourable to the peculiar effect of their fire; and the garrison are always acquainted with the ranges of the objects on the ground around the fortress. These advantages should enable a fortress, supplied with heavy rifled ordnance throwing large shells, to cover the ground in front of the works with so deadly a fire as to render the establishment of siege batteries, except at very long distances, impracticable.[5] This was the case at Paris in 1870, where German batteries were thrown up against Mont Avron at ranges of 3,000 to 4,600 paces, and against the Southern works at ranges of 2,300 to 5,000 paces;[6] other instances have been given in Chap. VIII. of this Part.

Until the besieger's batteries are fully armed, the artillery of the place is paramount and usually undisturbed by the fire of guns or mortars; this advantage should not therefore be thrown away, but every effort should be made to dismount the enemy's guns, destroy his magazines, &c., and thus delay the progress of the siege. When the fire of the besieger is in full force, the ordnance in the salients and covert ways should be withdrawn and placed in the most advantageous interior positions, the dismounted pieces removed, and the ammunition economised for the last effort, viz. the attempt to destroy the breaching batteries, and impede the final advance of the besiegers, by a new disposition of the flank defences. In opposing the enemy's assaults, grape and case shot may be employed with the greatest advantage, and previous to this

[5] See *Motion of Projectiles from Rifled Arms*, p. 88.
[6] Major Blumé's *Operations of German Armies in France*, pp. 175 and 180.

period guns should be so disposed as to obtain a very heavy cross fire on those parts of the glacis over which the besieger's attacking columns may have to pass. Finally, should it be desirable, and at the same time feasible, to evacuate the fortress, all the ordnance and artillery *matériel* left in the place should be rendered unserviceable and damaged in such a manner that the enemy on taking possession may be able to make no further use of, or derive any benefit from, their acquisition.

Coast Batteries.

8. Artillery is used in coast batteries and defences to protect the entrances of harbours and ports, to defend the different dockyards, to oppose the landing of an enemy on any part of the coast, and to prevent the approach of his vessels, either for any aggressive purposes, or for taking soundings, observations, &c.

Coast batteries are usually erected on important situations commanding the mouth of a river or harbour, which it is requisite to defend. Should the mouth be very wide, intermediate batteries must be placed between the opposite shores on islands, breakwaters, &c., or floating batteries must be moored in favourable positions, so that any vessel endeavouring to force an entrance shall, in doing so, be compelled to pass within comparatively short ranges of the batteries. A vessel propelled by steam power might in some cases run past such batteries, but would hesitate to do so if there was a risk of the ship being disabled by artillery fire, and therefore rendered incapable of retiring. Floating iron-clad batteries will doubtless in future play an important part in the defence of harbours and coasts, but they must be supported by torpedoes and by shore batteries, under the guns of which they may retire when crippled. Towns and dockyards can be bombarded from a distance of 4,000 yards, even with the shells of the ordinary sea-service 13-in. mortars, and therefore it is necessary that hostile ships shall not be allowed to anchor outside such harbours as Portsmouth, Plymouth, &c., within at least this range.

Another purpose for which guns are required in the defence of a coast, is to prevent troops landing from vessels in boats. Field or position artillery would generally be employed when the coast offers many beaches well adapted for the disembarkation of troops, but when there are but few landing places, so that the enemy must choose one of them, guns would be placed in field works, or permanent batteries erected in such situations as will enable the fire of the battery to flank the beach.[7]

9. The armament of coast batteries depends chiefly on the nature of the coast which they are required to defend, and the facilities afforded by it for the landing of an enemy; the depth of water in shore; and the object of such battery or batteries, whether this object be to command the approach to a harbour or landing place, to cover a roadstead, &c.

In batteries liable to attack by iron-plated ships, the heaviest rifled guns, ML. 7 to 12-in., should be mounted; but against wooden vessels the BL.R. 7-in. and 64-pr., the ML.R. 80 and 64-prs., and the heavy SB. guns, would be sufficiently powerful—their common shells and the hot shot of the latter being capable of setting such vessels on fire. Large mortars should also be used for the defence of dockyards or other important stations; for, although their inaccuracy of fire may cause many shells to be wasted, the chance of one or two shells falling upon the deck of any vessel, plated or not, would usually prevent its coming within short ranges. Position batteries of R. 40-prs. might be employed to connect a line of batteries or forts erected along the coast, and to defend those situations where permanent batteries do not exist; for which purpose heavy batteries, or batteries of horse and field artillery, might also be used, as they could be quickly transported by railway to any required point.

10. Coast batteries should be provided with sufficient ammunition for at least one day's firing, the general proportion of made-up ammunition being laid down for SB. guns at 200 rounds per gun.[8] The proportions of the different kinds of projectiles must depend, to a great extent, upon the situation

[7] See *Motion of Projectiles from Rifled Arms*, p. 96.
[8] *Report of Committee on Coast Batteries*, July 1860.

of the battery and the purposes for which the fire of its guns is required. Against iron-plated vessels—Palliser or steel projectiles must be fired; at wooden ships—common shells; and from SB. guns, hot shot. As before pointed out, mortar shells—against either class of vessel; to repel a boat attack—shrapnel, grape, and case; and the first might also be very effective in clearing the decks of ships at considerable ranges. Solid shot or common shell might be fired to sink boats.

The number of rounds *per gun* to be kept in coast defences for rifled ordnance[9] are:—

		Home	Abroad
ML.R.	12-in.	100	250
	11-in.	100	250
	10-in.	100	250
	9-in.	100	300
	7-in.	100	300
	64-pr.	100	200
BL.R.	7-in.	75	200
	40-pr.	100	200

The proportions in 100 rounds have been laid down for SB. cast-iron ordnance; the guns being intended to command the approaches to works by land and sea, the howitzers and carronades being confined to flanking defences. Those for *land fronts* have been given (see p. 508); the following are for *sea fronts*:—

	Solid Shot	Case Shot	Common Shell	Diaphragm Shell
10-in.	0	15	85	0
8-in.	0	15	70	15
68-pr.	50	10	30	10
42, 32, 24, and 18-prs.	45	15	30	10

BL. R. 7-in. and 40-pr. guns have 60 common shell, 30 segment shell, and 10 case.

The following proportions in 100 rounds for the heavy ML. R. guns 'assume that, for the present, guns of this description will be placed only on sea defences approachable by iron-clad vessels; that the occasions where their fire might be required to aid in the land defence would be exceptional;

[9] The numbers of rounds and proportions of different kinds of projectiles, &c., &c., are taken from *Part I. Corps Equipment: Ordnance, Ammunition, and Stores for Garrison Service.*

that they might be opposed to wooden as well as to iron ships; and that they would always be associated with lighter ordnance, capable of maintaining a rapid fire, and suitable for repelling the landing of troops within short ranges.'

		7-in.	9-in.	10, 11, and 12-in.
Shell	Common	26	31	20
	Double	5	0	0
	Palliser	32	32	42
Shot	Case	5	5	3
	Palliser	32	32	35

'Batteries situated behind others more advanced, or further than 300 yards in-shore, will be supplied with additional Palliser shell in lieu of case.'

The special proportions for batteries in the Thames, Medway, &c., are:—

		Flanking Fire up or down river	Direct Fire
Shell	Common	20	10
	Palliser	42	50
Shot	Case	6	0
	Palliser	32	40

The proportions of fuses are:—

	Common	Diaphragm	Pettman LS.
10-in.	52	0	42
8-in.	42	18	35
68, 42, 32, 24, and 18-pr.	18	12	15

	BL. Wood Time 9 sec.	BL. Wood Time 20 sec.	Pettman GS.
BL.R. 7-in. / 40-pr.	30	20	60
ML.R. 7 and 9-in.	0	0	31
ML.R. 10, 11, and 12-in.	0	0	20

All coast batteries armed with solid shot SB. guns should be provided with Addison's shot furnaces.

The powder should generally be made up into cartridges, and kept in gun-ammunition barrels or metal-lined cases; but the filled cartridges for the heavy ML. R. guns, 7-in. and over, are kept in zinc cylinders, of which a sufficient number are issued for 75 rounds per gun at home, and for 100 rounds per gun abroad; a small proportion of loose powder (one barrel per gun), with the requisite number of flannel cartridges, is also recommended. A certain proportion of rockets might be found useful for the protection of beaches, but they are not to form any portion of the equipment of fortresses.[1]

11. The common standing and rear-chock carriages, and the sliding carriage for traversing platforms, have been generally used for coast batteries, though all the natures of naval carriages may be made available, as in the defence of garrisons and fortresses. Where rapidity of fire is not needed, the common ground platform of wood or stone may be used; but for quick firing at vessels in motion, traversing platforms are essential. The naval slide may also be used on an emergency for the same purpose; and in some cases turntables may be laid for heavy R. guns. Batteries armed with heavy ML. R. guns are now provided with training and running-in-and-out gear; shell-lifts, and other appliances for facilitating the service of the pieces, are also supplied.

The Moncrieff carriage will no doubt be extensively used for coast defence, where its peculiar advantages will be especially valuable in low batteries, situated a little above the water. Against batteries placed on elevated positions, the fire of ships produces but small effect.

12. The objects against which the guns of coast batteries are employed being generally moveable, very great accuracy and rapidity of fire are essential; well-trained gunners, and ordnance which can be readily laid and traversed, are therefore required. But in the defence of harbours or channels, certain lines of fire, which vessels must pass, should be chosen and marked on the platform; so that instead of attempting to follow up a ship in rapid movement, the gun may, after it has fired the first shot, be quickly traversed and ready for the vessel when she passes the next line; hence the necessity of providing training gear for heavy guns, and in some cases turntables. It will also be necessary, in most cases, to have guns of great power as regards range, for it is very desirable to prevent a vessel from closing with the battery, by disabling her when at a considerable distance. Long range gives comparative immunity to forts, but not to ships, as shown at Sebastopol, where the French and English ships at long range suffered

[1] Army Circular, clause 129.

considerably, but inflicted little loss on the Russian batteries. A vessel can, by selecting her position, sometimes bring a greater number of guns than a battery to bear upon a given point; but the advantages of the battery are—that the guns are fired from a steady platform; that the battery, unless it be on a level with the water, does not present so good an object as the vessel, and that the ranges would generally be known to the gunners in the former; it cannot be set on fire like a ship, and the effect of shells upon the former, especially if it be an open earthwork, is comparatively trifling to the destruction caused by their bursting inside a vessel; moreover, a battery possesses the numerous advantages which choice of position can give.

Many instances might be taken from the late American War of engagements between land forts and iron-clad squadrons, in some of which the latter were repulsed; as at Charleston, on April 6, 1863, where, with a loss of only two men killed, the Confederate artillery sank a monitor, the *Keokuk*, besides damaging other vessels and killing and wounding a considerable number of men in the squadron.[2]

In order that guns may be employed with the greatest advantage in coast batteries, the different depths of water within range should be ascertained, as in the case of an attack it can be judged approximately, from the size and class of the attacking ships, to within what distance from the shore they are likely to be able to approach; buoys may also be anchored to indicate the several ranges.

13. The choice of position for a coast battery, in order that its guns may be most effectively employed, and that it may suffer as little as possible from the fire of any vessel that can approach within range, is a point of much importance. An able 'Treatise on Coast Defence,' based on the experience of the American War of 1861–65, by Lieut.-Col. von Scheliha, chief engineer of the Confederate Army in the Gulf of Mexico, contains many valuable facts and suggestions on this subject. He says: 'Wherever the position will allow, a scattering of the

[2] Lieut.-Col. Fletcher's *History of the American War*, vol. ii. p. 301.

guns is preferable to placing them close together. A disposition of this kind does not exclude a concentration of the fire from all guns, while it renders it more difficult for the enemy to effect a concentration of his fire on any one battery.' And: 'The accurate and plunging fire from rifled pieces, placed at a certain elevation over the level of the water, must have a most destructive effect on the decks of iron-clads; and for these reasons a combination of low water-batteries, armed with 11-in. and 15-in. smooth-bore guns, and of higher placed batteries armed with rifled pieces of heavy calibre, appears to be the most judicious theory, wherever the ground will allow its being carried into effect.'[3]

The following extracts from Admiral Porter's Report on the Confederate batteries at Vicksburg are quoted to show the little effect produced by the fire of guns from vessels on properly constructed and well-placed earthworks:—'On the morning when the ram *Queen of the West* went by the batteries, I had officers stationed all along, to note the places where guns fired from, and they were quite surprised to find them firing from spots where there were no indications whatever of any guns before. The shots came from banks, gulleys, from railroad depôts, from clumps of bushes, and from hill-tops 200 feet high. A better system was never devised.' 'Not that the number of guns is formidable, but the rebels have placed them out of our reach, and can shift them from place to place in case we should happen to annoy them (the most we can do) in their earthworks.' 'The people of Vicksburg are the only ones who have, as yet, hit upon the method of defending themselves against our gun-boats, viz., not erecting water-batteries, and placing the guns some distance back from the water, where they can throw a plunging shot which none of our iron-clads could stand.'[4]

The advantages of placing batteries above the sea-level were clearly shown at Sebastopol, where an earth battery (the Telegraph) of only five guns, on a cliff about 100 feet high, inflicted, at ranges of 700 and 800 yards, heavy losses on four

[3] *Treatise on Coast Defence*, p. 44.
[4] *Ibid*, pp. 30, 31,

powerful English ships, disabling two of them, without any loss to itself in men or guns; on the other hand, at 800 to 1,200 yards, three English vessels, assisted by steam frigates, shelling from 1,600 yards, ruined, in ten minutes, the top (open) battery of the stone fort Constantine, placed at the water's edge.[5]

It may be here remarked that, although batteries placed in very high situations, like some of those in Gibraltar, would lose as regards accuracy of fire (from its plunging nature), they would have a good chance of damaging vessels seriously, by the projectiles passing through the decks, and even in some cases taking the side plating in reverse. Capt. J. B. Richardson, in a very interesting paper on the 'Re-armament of Gibraltar,'[6] contends that for such a fortress there should be two general lines of guns: one low, for accurate horizontal fire against ships' sides; the other high, from which vessels could be watched, and good practice (the distances being taken by instruments), giving the advantages of vertical fire, be made upon their decks. The fire of the first would penetrate or rack the iron armour on the near side of a ship, while that of the high line would plunge projectiles through the deck, and knock off plates on the far side. The guns on the low line would necessarily require strong and costly protection; those on the high line would be secure from ship fire. An intermediate line Capt. Richardson considered a mistake, as it fulfils neither object perfectly, although of course capable of doing a certain amount of execution.

14. Lieutenant-Colonel von Scheliha insists very strongly on the necessity of combining shore and floating batteries with obstructions and torpedoes, in order to secure a perfect system of coast defence. He instances the passing of Forts Jackson and St. Philip on the Mississippi, and of the batteries of Vicksburg by the Federal fleet, to show that forts cannot keep out a fleet unless the channel is obstructed; the passing of Fort Morgan by the Federal fleet to illustrate the inutility of

[5] See Kinglake's account of the attack of the fleet on Sebastopol, in his *Invasion of the Crimea*, vol. iii.

[6] *Proceedings of R.A. Institution*, vol. vii.

partial obstruction; and the first attack on Fort Sumter to establish the principle, that 'no fleet can force a passage if kept under the fire of heavy batteries by properly constructed obstructions.'

The truth of the last proposition, as well as that of another which is stated—that vessels can silence barbette batteries by concentrated fire—was proved at Sebastopol as far as wooden vessels and SB. guns were concerned; but in the American War both iron-plated vessels and rifled guns of considerable power were largely employed, and although the strength of the former and the power of the latter have been since much increased, the relations of offence to defence have little altered.

15. With regard to vertical fire, which the Americans appear to consider essential to harbour defence, Brigadier-General R. J. Abbott, U.S.A., points out that with plated vessels which possess sufficient speed to escape the impact of rams, the deck and bottom are the only vulnerable points; and that, leaving torpedoes to deal with the latter, vertical fire is the best mode of injuring the former; and therefore that every effort should be made to secure maximum accuracy of fire, and to supply large numbers of mortars of the largest calibre, moderate sized shells not possessing sufficient *energy*. Speaking of the absence of vertical fire allowing Admiral Porter to anchor his iron-clads within easy range of Fort Fisher, he says: 'The fatal damage to the works was done by the iron-clads. Thirty 13-in. mortars could have kept up a discharge of one shell every ten seconds, any one of which, striking a monitor on her deck, would have penetrated it. No horizontal fire—we had no mortars available, and under no circumstances are mortars afloat to be much dreaded—could have prevented brave men from serving these mortars behind a sand parapet like that of Fort Fisher (twenty feet high). Hence, if such mortars had been properly served, the iron-clads would not have been anchored within a range which commanded the accuracy of fire necessary to seriously damage the work from the unstable decks of a vessel.'[7]

[7] Paper on 'Siege Artillery' in *Professional Papers, Corps of (U.S.) Engineers*, No. 14, p. 46.

The following results of practice with 13, 10, and 8-in. mortars show the proportion of shell which fell in a circle of thirty feet radius—an area nearly equal to that of a ship's deck:[8]—

Range	No. of Rounds fired	Fell within radius
1,000 yds. . . .	28	6
1,100 . . .	20	5
1,000 . . .	28	6
1,000 . . .	16	3
	92	20

Or about 20 per cent. at 1,000 yds.

With rifled mortars, or 8-in. and 10-in. R. howitzers, a much larger proportion would fall within the area.

For the effect of vertical fire upon shore batteries, the bombardment of Forts St. Philip and Jackson may be taken as an instance. The object of the bombardment was to prepare for, and assist in, the passage of Admiral Farragut's squadron. The mortars were in schooners, which were towed into positions selected at known ranges (2,850 to 3,680 yds.) from a survey made of the river. The schooners were in three divisions, the 1st and 3rd (13 vessels) being in line close together on the south shore, under the lee of a thick wood, so that, the masts being dressed with bushes, they could not be seen from the forts;[9] the other division (6 vessels) was on the north-east shore of the river at the longer range. The fire was opened on April 16, 1862, and lasted 6 days, 1,500 shells being thrown from each division in 24 hours. One of the schooners was sunk, with its mortar, by a shell from a rifled gun passing down through her; a large rifled gun in St. Philip was dismounted by a mortar shell, and two other guns were dismounted by one shell, but the latter were not injured.[10] The fleet passed the forts on the 24th; the steamers which had been used to tow

[8] General Lefroy's *Handbook for Field Service*, p. 105.

[9] The mortars in the schooners on the south shore were pointed by means of sights fixed to the mastheads, and many curious expedients were resorted to in order to obtain accurate firing.

[10] The bombardment and its effects are described in the *Treatise on Coast Defence*, pp. 20 and 57.

the mortars enfiladed a heavy water-battery of 6 guns, and the barbette guns commanding the approach to the forts; the mortars drove the men from their guns by bursting shells rapidly over the parapets; and the ships of the admiral's squadron plied the casemated batteries with shrapnel and grape. The bombardment was re-opened after the fleet had passed; but the forts surrendered, and their casemated batteries were found to be in a very ruinous state, the walls and roofs being cracked from end to end; and although the losses in men were not great, the defenders were demoralised and driven into the casemates.

APPENDIX I.

Table I.—*Selection from the large number of SB. Ordnance still in the Service.*

Nature of ordnance	Length	Weight	Windage	Calibre	Charges: Service	Charges: Saluting	Fire Proof: Charge	Fire Proof: Shot	Fire Proof: Wad
Cast-iron Ordnance:—	ft. in.	cwt.	in.	in.	lbs. oz.	lbs. oz.	lbs. oz.		
10-in. gun	9 4	86	·16	10	12 0	6 0	20 0	1 hollow	1 stick
8-in. „	9 0	65	·125	8·05	10 0	5 0	20 0	1 solid	1 junk
do. „	8 0	54	·125	...	8 0	5 0	16 0	1 „	1 „
68-pr. „	10 10	112	·2	8·12	18 0	8 0	30 0	1 „	2 „
do „	10 0	95	·2	...	16 0	8 0	28 0	1 „	2 „
42-pr. „	10 0	84	·2	6·97	14 0	8 0	25 0	1 „	2 „
do. „	9 6	67	·2	6·93	12 0	8 0	25 0	1 „	2 „
32-pr. „	9 6	58	·198	6·375	10 0	6 0	21½ 0	1 „	2 „
do. „	9 6	56	·233	6·41	10 0	6 0	21½ 0	1 „	2 „
do. (A)	9 0	50	·198	6·375	8 0	5 0	18 0	1 „	1 „
do. (B)	8 6	45	·173	6·35	7 0	5 0	16 0	1 „	1 „
do. (C)	8 0	42	·173	6·35	6 0	5 0	14 0	1 „	1 „
24-pr. „	9 6	50	·211	5·823	8 0	5 0	18 0	1 „	2 „
do. „	9 0	48	·211	...	8 0	5 0	18 0	1 „	2 „
18-pr. „	9 0	42	·193	5·292	6 0	4 0	15 0	1 „	2 „
do. „	8 0	38	·193	...	6 0	4 0	15 0	1 „	2 „
10-in. howitzer	5 0	42	·16	10	...	4 0	12 0	1 hollow	1 stick
8-in. „	4 0	22	·14	8	3 0	3 0	8 0	1 „	1 „
SS. 13-in. mortar	4 4·8	100	·16	13	20 0	...	21 11	1 cylinder of 4½ cwt.	...
SS. 10-in. „	3 9·6	52	·16	10	9 8	...	9 8	1 solid	...
LS. 13-in. „	3 3·6	36	·16	13	9 0	...	9 0	1 „	...
LS. 10-in. „	2 7·5	18	·16	10	4 0	...	4 0	1 „	...
LS. 8-in. „	2 1·2	9	·14	8	2 0	...	2 0	1 „	...
Bronze Ordnance:—									
12-pr. gun	6 6·6	18	·1	4·62	4 0	3 0	5 0	1 „	...
9-pr. „	6 0	13	·1	4·2	2½ 0	1½ 0	3½ 0	1 „	...
6-pr. „	5 0	6	·1	3·66	1½ 0	1 0	2 0	1 „	...
3-pr. „	3 0	2½	·1	2·91	0 10	0 10	1 0	1 „	...
32-pr. howitzer	5 3	17	·123	6·3	3 0	2 0	4 0	1 „	...
24-pr. „	4 8·6	13	·125	5·72	2½ 0	1½ 0	2½ 0	1 „	...
12-pr. „	3 9·2	6½	·126	4·58	1¼ 0	1 0	1¼ 0	1 „	...
4⅖ in. „	1 10·6	2½	·066	4·52	0 8	0 4	1 0	1 „	...
5½-in. mortar	1 3·1	1¼	·025	5·62	0 7	...	0 7	1 „	...
4⅖-in. „	1 0·7	0¾	·066	4·52	0 5	...	0 5	1 „	...
Built-up Ordnance:—		tons							
150-pr.	12 3	12	·1	10·5	40 0 35 0 20 0	...	50	Cylinder of 225	...
100-pr.	10 3	6¼	·1	9	25 0 20 0 12 0	...	31¼	Cylinder of 150	...

The weights given in the above table are the *nominal* weights. The *actual* weights of guns of the same nature, especially of those of large calibre, may vary as much as 2 per cent. under or over the *nominal* weights, according to the density of the metal employed. The 56-pr. has been withdrawn from the service. List of Ordnance retained and abolished (C in P, § 1140).

Table II.—*Projectiles, SB. Guns.*

Nature			Mean Diameter	Mean Thickness	Weight: Empty with plug lbs.	oz	dr	Bursting charges lb	oz	dr	Total weight lbs.	oz.	Remarks
			in.	in.	lbs.	oz	dr	lb	oz	dr	lbs.	oz.	
Solid shot...		150-pr.	10·4	...	...	...	...	...	...	...	150	0	
		100 „	8·9	...	...	...	...	...	...	...	94	6	
		68 „	7·925	...	...	...	...	...	...	...	66	2	
		56 „	7·48	...	...	...	...	...	...	...	55	15	
		42 „	6·765	...	...	...	...	...	...	...	41	0	
		32 „	6·177	...	...	...	...	...	...	...	31	7	
		24 „	5·6115	...	...	...	...	...	...	...	23	8	
		18 „	5·099	...	...	...	...	...	...	...	17	11	
		12 „	4·5225	...	...	...	...	...	...	...	12	5	Wood bottoms attached (12 to 3)
		9 „	4·1	...	...	...	...	...	...	...	9	4	
		6 „	3·568	...	...	...	...	...	...	...	6	0	
		3 „	2·823	...	...	...	...	...	...	...	3	0	
Shells	Mortar	13-in.	12·84	2·146	196	9	0	10	15	...	207	1	
		10 „	9·85	1·646	88	9	0	5	4	...	93	9	
		8 „	7·86	1·39	45	11	0	2	9	...	47	15	
	Common	10-in.	9·85	1·35	77	13	5	6	12	...	84	1	
		8-in. or 68-pr.	7·86	1·39	46	13	6	2	9	...	49	1	
		56-pr.	7·48	1·25	38	15	10	2	7	...	40	15·5	
		42 „	6·765	1·132	28	12	15	1	12	...	30	3	
		32 „	6·177	1 034	21	14	14	1	2	...	23	1	
		24-pr. or 5½-in.	5·595	0·936	16	1	15	1	...	...	16	15	
		18-pr.	5·099	0·853	12	5	8	...	12	...	12	15·5	
		12-pr. or 4⅗-in.	4·454	0·746	8	0	12	...	6	...	8	6·75	
	Naval	150-pr.	10·4	1·7	104	8	...	6	14	...	111	3	
		100 „	8·9	1·5	66	3	...	3	13	...	69	13	
		10-in.	9·85	1·35	77	1	8	6	5	...	83	5·5	
		8 „	7·925	1·35	47	1	11	2	9	...	49	5	
		32-pr.	6·177	1·034	21	10	2	1	5	...	22	12	
	Diaphm.	150-pr.	10·4	1·225	85	5	4	...	12	0	141	5	802 bullets (16 per lb.)
		100 „	8·9	1·06	53	4	...	...	6	0	85	6	484 musket bullets, 2 carbine, and 1 pistol
													Musket — Carbine (All have in addition one bullet and one buckshot)
		8-in. or 68-pr.	7·95	·99	36	12	...	...	...	80	60	13	338 — 1
		56 „	7·48	·84	...	...	...	...	...	70	52	5	284 — 1
		42 „	6·765	·795	...	...	...	...	...	60	38	5	210 — 1
		32 „	6·177	·74	17	8	...	...	...	50	28	15	151 — 1
		24 „	5·595	·65	12	13	...	...	...	40	21	5	110 — 1
		18 „	5·099	·59	9	12	...	...	...	30	15	5	77 — 1
		12 „	4·454	·45	6	2	...	...	...	24	10	12	... — 72
		9 „	4·08	·40	4	9	...	...	...	18	7	14	... — 52
		6 „	3·55	·35	3	6	...	...	...	10	5	13	... — 29
Hand grenades		6 „	3·476	·379	3	9	...	...	5	...	3	13	
		3 „	2·758	·465	1	10	...	...	3	...	1	12	
Carcasses...		13-in.	12·84	2·9	220	...	...	...	...	...	234	0	
		10 „	9·85	2·11	96	...	...	...	...	...	105	0	
		8 „	7·86	1·68	48	...	...	...	...	...	53	0	
		56-pr.	7·48	1·6	...	...	...	...	...	...	...	...	None yet made
		42 „	6·77	1·45	...	...	...	...	...	...	30	8	
		32 „	6·177	1·32	...	...	...	...	...	...	26	12	
		24 „	5·595	1·2	15	...	...	...	...	...	19	4	
		18 „	5·099	1·09	...	...	...	...	...	...	14	12	
		12 „	4·454	0·95	8	...	...	...	...	...	9	8	

Note.—The weights of the common and naval shells and carcasses, and of those round shot which have not the words 'wood bottoms attached' are given exclusive of the bottom. Mortar shells and hand grenades never have wood bottoms attached, and are therefore weighed without them. The bursting charges, except for the diaphragm shells, are approximate.

Table III.—*Projectiles, SB. Guns.*

Nature			Mean Diameter	Mean Length*	Balls: No. in each	Balls: Weight of each		Total weight		Remarks
			in.	in.		lb.	oz.	lb.	oz.	
Case...	Gun	10-in.	9·82	7·05	{34 / 50}	1 / ...	... / 13⅛	80	5	The respective case for carronades and guns of like nature have the same sized sand shot, but with the exception of the 68-pr. which has the same number, there are fewer balls in the carronade case, and consequently it is lighter than the gun case.
		8 ,,	7·82	7·6	90	...	8	48	3	
		42-pr.	6·735	8·7	85	...	8	44	6½	
		32 ,,	6·147	8·65	66	...	8	34	13	
		24 ,,	5·57	7·6	46	...	8	24	12½	
		18 ,,	5·074	7·6	46	...	6	19	0½	
		12 ,,	4·432	9·4	41	...	6½	16	15¼	
		9 ,,	4·06	8·15	41	...	5	13	9	
		6 ,,	3·332	7·25	41	...	3¼	8	5¾	
		3 ,,	2·808	6·0	41	...	1½	4	7	
	Howitzer	10-in.	9·82	8·5	170	...	8	89	0¾	
		8 ,,	7·82	5·3	258	...	2	34	12½	
		32-pr.	6·147	6·2	105	...	3¼	21	7	
		24 ,,	5·57	5·4	100	...	2	13	13	
		12 ,,	4·432	5·05	50	...	2	7	13½	
Grape	Gun	10-in.	9·82	8·1	24	3	...	81	7	The grape shot for a carronade has the same sized balls, and an equal number of them, as that for a gun of like nature, but for a carronade the balls are packed in a tin cylinder.
		68-pr.	7·82	9·38	15	3	...	65	9	
		56 ,,	7·45	10·26	12	4	...	69	7	
		42 ,,	6·735	9·76	9	4	...	48	11	
		32 ,,	6·147	8·78	9	3	...	36	12	
		24 ,,	5·57	7·68	9	2	...	25	3	
		18 ,,	5·074	6·86	9	1	8	18	13	
		12 ,,	4·402	6·18	9	1	...	12	15	
		9 ,,	4·06	5·78	9	...	13⅛	10	12	
		6 ,,	3·532	4·76	9	...	8	6	11	
Light balls		10-in.	9·375	14·1	...	...	...	63	10½	
		8 ,,	7·5	11·25	...	...	...	32	15	
		5½ ,,	5·4	7·625	...	...	...	10	9½	
		4⅖ ,,	4·125	6 25	...	...	...	5	2	

Note.—The 100-pr. and 150-pr. guns have each, instead of a grape and a case shot, a projectile called a *grape case*, similar to the 10″ grape; in this shot, ½ of the balls weigh 1 lb.; ¼ of the balls weigh 2 lbs.; ¼ of the balls weigh 3 lbs.; and the balls are, as before stated, placed in an iron cylinder with iron top and bottom. The substitution of a *grape case* instead of a grape and a case shot for all SB. ordnance was in contemplation.

Table IV.—*Service Breech-loading Rifled Guns.*

Nature		Length		Nominal weight	Calibre	No. of grooves	Twist of rifling	Charge	
		ft.	in.	cwt.	in.			lbs.	oz.
Screw	7-in. heavy . . .	10	0	82	7	76	1 turn in 37 cals.	11	0
	,, light . . .	9	10	72	7	76	,, ,,	10	0
	40-pr. (G pattern)	10	1	35	4·75	56	,, 36½ ,,	5	0
	,, (old pattern)	10	0	32	4·75	56	,, ,,	5	0
	20-pr. LS. . .	8	0	16	3·75	44	,, 38 ,,	2	8
	,, SS. . .	5	6	15	3·75	44	,, ,,	2	8
	,, SS. . .	5	6	13	3·75	44	,, ,,	2	8
	12-pr. (shortened)	6	0	8	3	38	,, ,,	1	8
	9-pr.	5	2	6	3	38	,, ,, ,,	1	2
	6-pr.	5	0	3	2·5	32	,, 30 ,,	0	12
Wedge	64-pr.	9	2	61	6·4	70	,, 40 ,,	8	0
	40-pr.	8	2	32	4·75	56	,, 36½ ,,	5	0

The grooves of 7″, 64, 40, and 20-prs. are ·166″ wide, and ·06′ deep.
,, 12 and 9-prs. ,, ·148″ ,, ·04″ ,,
,, 6-prs. ,, ·145″ ,, ·04″ ,,
The lands of 7″ guns are ·1233″ wide.
,, other natures ·1″ ,,

* The length given in this column to the case of bronze guns and howitzers includes the wooden bottom.

TABLE V.—Service ML. Rifled Ordnance.

Nature of Gun	Nominal weight	Preponderance	Length: Gun	Length: Bore	Length: Rifling	Calibres	Grooves: Number	Grooves: Twist in Calibres	System	Charges: Battering	Charges: Service	Remarks
	tons	cwt.	in.	in.	in.	in.				lbs.	lbs.	
12-in. Gun .	35	1 to 3	191·75	162·5	135	12	9	0 to 1 in 35	Woolwich Increasing	110	85	
12-in.* . .	23 / 25	5½	171·5	145	127	12	9	1 in 100 to 1 in 50	,,	85	55	Pebble powder † (12-in.*, 11-in., 10-in.)
11-in. . .	25	2¼	171	145	119	11	9	0 to 1 in 35	,,	85	60	
10-in. . .	18	8½	170	145·5	118	10	7	1 in 100 to 1 in 40	,,	70	44	
9-in. . .	12	0	147	125	107·5	9	6	0 to 1 in 45	,,	43	30	Pellet or pebble powder for all charges of 50 lbs. and upwards
8-in. . . .	9	0	136·5	118	102	8	4	0 to 1 in 40	,,	30	20	64 lbs. of pellet = 60 lbs. R.L.G. powder
7-in. . . .	7	4½	142·1	126	112·5	7	3	1 in 35	Woolwich Uniform	22	14	Windage of all ML. R. guns = ·08″
7-in. . . .	6½	5½	125·25	111	97·5	7	3	1 in 35	,,	22	14	Preponderance in future to be—
80-pr. (Palliser cnvtd)	5	9¾	120	113·25	106·25	6·29	3	1 in 40	,,	—	10	7-in. guns . . . 3 cwt.
	cwt.											8-in. ,, . . . 4 ,,
64-pr. . .	64	7	111·5	98	90·5	6·3	3	,,	Shunt	—	8	9-in. ,, . . . 3 ,,
64-pr. (Palliser cnvtd)	71	6½	108	103·27	96·2	6·29	3	,,	Woolwich Uniform	—	8	Guns over 18 tons 3 ,,
,, . .	58	6	114	108·45	101·45	6·29	3	,,	,,	—	—	
40-pr. . .	35	¼	96	85·5	71·5	4·75	3	1 in 35	,,			
		lbs.									lb. oz.	
Wrgt. Iron 16-pr. .	12	7	74·45	68·4	58·04	3·6	3	1 in 30	French Uniform	—	3 0	
Do. 9-pr. .	8¼	7	68·5	63·5	59·8	3	3	,,	,,	—	1 12	
Do. do. . .	6					3	3	,,	,,	—		
Bronze 9-pr.	8	8	67	63·5	59·8	3	3	1 in 30	French	—	1 12	
,, 7-pr.	2	40	36	34·15	31·15	3	3	1 in 20	Woolwich	—	oz. 10	
	lbs.											
Steel ,,	150	3	26½	24	·22	3	3	,,	Woolwich Uniform	—	6	
		cwt.									los.	
8-in. howtzr.	46	2	61·125	48	35·5	8	4	1 in 16	,,	—	1½ to 10	
10-in. ,,												

Table VI.—*Projectiles, BL. Rifled Guns.*

Nature	Length	Diameter								Segments					Shot			Mean Weight Empty		Weight of Bursting Charge		Weight of Iron Burster	Total Weight		Remarks
		Lead Coated				Case Shot				Large		Small		Tot.											
		Body		Back end		Body		Band or Studs								Weight									
		High	Low	High	Low	High	Low	High	Low	No.	Weight	No.	Weight	Number	No.	lbs.	oz.	oz.	lbs.	lbs.	oz.		lbs.	oz.	
	in.	in.	in.	in	in.	in.	in.	in.	in.		oz.		oz.									oz.			
7-in. Shell Common	15·8	7·046	7·026	7·095	7·08	..	..	..	..	..	..	..	..	..	..	..	..	83	4	6	8	..	89	12	
7-in. Shell Segment	13·98	”	”	”	”	..	..	..	..	112	3·36	..	..	112	..	..	..	98	8	3	2	..	101	10	
7-in. Shot Case	10·35	..	..	..	..	6·92	6·86	7·1	7·095	..	..	..	..	..	77	..	8	..	..	..	..	..	69	..	
7-in. Shot Drill	13·98	6·975	6·945	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	90	..	
64-pr. Shell Common	13·88	6·437	6·423	6·493	6·482	..	..	..	..	..	..	..	..	..	..	..	..	64	8	4	8	..	69	..	
64-pr. Shell Segment	11·91	”	”	”	”	..	..	..	..	84	2·71	..	..	84	..	..	..	64	8	2	12	..	67	4	
64-pr. Shot-Case	9·1	..	..	..	..	6·33	6·27	6·493	6·482	..	..	..	..	..	56	..	8	..	..	..	..	..	49	12	
40-pr. Shell Common	13·56	4·787	4·773	4·84	4·83	..	..	..	..	..	..	..	..	..	..	..	..	38	5	2	4	..	40	9	
40-pr. Shell Segment	10·62	”	”	”	”	..	..	..	..	72	2·47	..	..	72	..	..	..	39	..	..	13	..	39	13	Bullets
40-pr. Shell Shrapnel	12·4	”	”	”	”	..	..	..	..	..	..	..	..	..	162	..	1	39	..	..	..	..	39	3	
40-pr. Shot Solid	10·28	”	”	”	”	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	41	8	
40-pr. Shot Case	10·25	..	..	..	..	4·73	4·7	4·84	4·83	..	..	..	..	..	37	..	8	..	..	..	..	..	31	..	
40-pr. Shot Drill	10·28	4·73	4·7	4·84	4·83	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	40	12	
20-pr. Shell Common	10·9	3·787	3·773	3·846	3·836	..	..	..	..	..	..	..	..	..	..	..	..	20	8	1	2	..	21	10	
20-pr. Shell Segment	8·125	”	”	”	”	..	..	..	..	56	1·7	14	1·06	70	..	..	..	19	10	..	700 grs	7¼	20	3¼	
20-pr. Shot Solid	8·28	”	”	”	”	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	9	
20-pr. Shot Case	9·4	..	..	..	..	3·72	3·69	4·846	3·836	..	..	..	..	..	41	..	4	..	..	..	..	..	15	12	
20-pr. Shot Drill	8·28	3·71	3·69	3·846	3·836	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20	..	
12-pr. Shell Common	8·5	3·034	3·024	3·074	3·067	..	..	..	..	..	..	..	..	..	..	..	..	10	7	..	9·8	..	11	8 drs	
12-pr. Shell Segment	6·75	”	”	”	”	..	..	..	..	42	1·32	6	0·86	48	..	..	..	10	8	..	550 grs	6¼	10	15¼	Bullets {42, 18 per lb. 14, 34 do.
12-pr. Shell Shrapnel	8·415	”	”	”	”	..	..	..	..	..	..	..	..	..	56	..	..	6	4½	..	12 drs	..	10	11	
12-pr. Shot Solid	7·05	”	”	”	”	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11	9	
12-pr. Shot Case	8·6	..	..	..	..	2·97	2·95	3·12	3·115	..	..	..	..	..	48	..	2	..	..	..	..	..	9	8	
12-pr. Shot Drill	7·10	2·97	2·95	3·074	3·067	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11	10	
9-pr. Shell Common	6·6	3·034	3·024	3·074	3·067	..	..	..	..	..	..	..	..	..	..	..	..	8	4	..	6·8 drs	..	8	10·8 drs	
9-pr. Shell Segment	5·35	”	”	”	”	..	..	..	..	35	1·5	7	1·2	42	..	..	..	8	5	..	300 grs	4½	8	9¾	Bullets {21, 18 per lb. 21, 34 do.
9-pr. Shell Shrapnel	7·15	”	”	”	”	..	..	..	..	..	..	..	..	..	42	..	..	5	4	..	12 drs	..	8	11	
9-pr. Shot Solid	5·63	”	”	”	”	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8	13	
9-pr. Shot Case	6·95	..	..	..	..	2·97	2·95	3·074	3·067	..	..	..	..	..	36	..	2	..	..	..	..	..	6	13½	
9-pr. Shot Drill	5·6	2·97	2·95	3·074	3·067	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
6-pr. Shell Segment	5·02	2·536	2·526	2·574	2·567	..	..	..	..	12	1·0	18	0·8	30	..	..	..	5	7	..	200 grs	2½	5	9¾	
6-pr. Shot Solid	5·3	2·536	”	”	”	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	3	
6-pr. Shot Case	6·6	..	..	..	..	2·48	2·45	2·57	2·567	..	..	..	..	..	44	..	1	..	..	..	..	..	4	12	
6-pr. Shot Drill	5·3	2·48	2·46	2·574	2·567	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	15	

TABLE VII.—*Projectiles ML. Rifled Ordnance.*

Natures			Dimensions: Length	Dimensions: Diameter: Over Body	Dimensions: Diameter: Over Studs	Composition of Studs—Parts of: Copper	Composition of Studs—Parts of: Tin	Contents	Bursting Charge: lbs.	Bursting Charge: ozs.	Total average Weight: lbs.	Total average Weight: ozs.
			Inches	Inches	Inches							
12-in. 35 tns.	Shell	Common	34·45	11·92	12·35	10	1	.. ..	38	4	616	0
		Shrapnel	..	..	..	..	..	.. ..	..		..	
		Palliser	31·3	11·925	12·35	10	1	.. ..	9	14	701	14
	Shot	Case (II.)	11·35	11·88	..	..	..	258 8-oz. sand-shot (clay and sand) ..	..		246	0
12-in. 25 „	Shell	Common (I.)	30·0	11·92	12·35	10	1	.. ..	36	10	495	10
		Shrapnel (II.)	29·75	..	..	7	1	276 4-oz. sand shot	1	15	497	0
		Palliser (II.)	29·2	11·92	12·35	7	1	.. ..	14	0	600	0
	Shot	Palliser (IV.)	28·15	11·925	12·35	10	1	.. ..	7	12	600	0
		Case (II.)	11·35	11·88	..	..	..	258 8-oz. sand-shot (clay and sand) ..	..		246	0
11-inch	Shell	Common (I.)	34·2	10·92	11·35	10	1	.. ..	28	12	530	0
		Shrapnel	..	..	..	..	..	.. ..	..		..	
		Palliser (II.)	28·3	10·925	11·35	10	1	.. ..	6	7	536	7
	Shot	Case (I.)	10 9	10·88	..	..	..	210 8-oz. sand shot (clay and sand) ..	..		200	0
10-inch	Shell	Common (I.)	32·5	9·92	10·35	10	1	.. ..	27	6	401	2
		Shrapnel (II.)	31·88	9·92	10·35	10	1	306 4-oz. sand shot	1	9	405	0
		Palliser (II.)	25·8	9·925	10·35	10	1	.. ..	6	14	400	0
	Shot	Palliser (IV.)	25·8	9·925	10·35	10	1	.. ..	4	0	404	0
		Case (II.)	9·6	9·915	..	..	..	139 8-oz. sand shot (clay and sand) ..	..		143	0
9-inch	Shell	Common (V.)	26·75	8·92	9·31	10	1	.. ..	20	0	252	0
		Shrapnel (II.)	26·25	8·92	9·31	10	1	374 2-oz. sand shot	1	5	255	0
		Palliser (IV.)	21·45	8·92	9·31	10	1	.. ..	5	8	250	0
	Shot	Palliser (V.)	20·85	8·925	9·31	10	1	.. ..	3	12	250	0
		Case (IV.)	9·1	8·88	..	..	..	113 8-oz. sand shot (clay and sand) ..	..		107	0
8-inch	Shell	Common (III.)	24·17	7·92	8·31	10	1	.. ..	14	9	181	9
		Shrapnel (II.)	23·23	7·92	8·31	10	1	300 2-oz. sand shot	1	0	181	0
		Palliser (IV.)	19·25	7·92	8·31	10	1	.. ..	4	8	180	0
	Shot	Palliser (IV.)	18·8	7·925	8·31	10	1	.. ..	2	10	180	0
		Case (II.)	8·4	7·88	..	..	..	75 8-oz. sand shot (clay and sand) ..	..		74	0
7-inch	Shell	Common (V.)	20·4	6·92	7·31	9	1	.. ..	9	4	116	0
		Shrapnel (III.)	19·72	6·92	7·31	..	..	192 2-oz. sand shot	0	12	118	0
		Palliser (III.)	16·5	6·92	7·31	..	..	.. ..	2	8	115	0
		Double (III.)	27·2	6·92	7·31	9	1	.. ..	13	12	159	15
	Shot	Palliser (VI.)	16·1	6·925	7·31	..	..	.. ..	1	10	115	0
		Case (IV.)	10·25	6·89	7·007	..	..	70 8-oz. sand-shot (clay and sand) ..	..		69	0
80-pounder	Shell	Common (I.)	19	6·22	6·53	All	..	.. ..	8	12	80	0
		Shrapnel	15·8	6·22	6·53	„	..	288 mixed metal balls, 14 per lb. ..	0	9	78	0
	Shot	Case	9·6	6·22	..	..	..	49 8-oz. sand shot (clay and sand) ..	..		51	0
64-pounder	Shell	Common (IV.)	16·0	6·22	6·47	All	..	.. ..	7	0	64	9
		Shrapnel (III.)	14·02	6·22	6·47	„	..	234 mixed metal balls, 14 per lb. ..	0	9	65	0
	Shot	Case (II.)	9·6	6·22	..	..	..	49 8-oz. sand shot (clay and sand) ..	..		51	0
16-pounder	Shell	Common (I.)	10·0	3·54	3·8	10	1	.. ..	1	0½	15	13
		Shrapnel (I.)	10·0	3·54	3·8	10	1	63 at 18 and 56 at 84 balls per lb. with rosin	0	1½	16	5
	Shot	Case (I.)	7·1	3·54	..	..	..	176 mixed metal balls 16½ per lb. (clay and sand)	..		15	3
9-pounder	Shell	Common (II.)	7·93	2·94	3·2	Zinc	..	.. ..	0	8	9	0
		Shrapnel (III.)	7·93	2·94	3·2	„	..	28 at 18 and 35 at 34 balls per lb. ..		12 drs.	9	4
	Shot	Case (III.)	7·4	2·94	..	..	..	108 bullets of 16½ per lb. (clay and sand)	..		9	13
7-pounder	Shell *	Common (III.)	6·75	2·94	3·17	..	..	.. ..	0	7 oz.	7	5
		Double (III.)	13·15	2·94	3·17	..	..	.. ..	1	0	12	0
		Shrapnel (IV.)	6·5	2·94	3·17	..	..	21 of 18 and 21 of 34 mixed metal balls to the lb.	0	8 drs.	7	5

The following Table gives the initial velocities of projectiles fired from service SB. ordnance, and has been made out from the results of numerous experiments carried on by Capt. A. Noble, late R.A., and Capt. W. H. Noble, R.A., for the late Ordnance Select Committee.

Table VIII.

	Nature of Ordnance	Charge	Projectile Nature	Projectile Weight		Initial velocity
		lbs.		lbs.	oz.	
Cast iron	10″ gun, 87 cwt.	12	Hollow shot	88	5	1292
	,, ,,	8	Martin's shell	117	0	940
	68-pr. gun, 95 cwt.	16	Solid shot	66	4	1579
	,, ,,	,,	Naval shell	51	8	1809
	,, ,,	10	Martin's shell	60	0	1308
	8″ gun, 65 cwt.	10	Common shell	49	14	1464
	,, ,,	,,	Martin's shell	51	8	1506
	32-pr. gun, 58 cwt.	10	Solid shot	31	6	1690
	,, ,,	8	,,	,,		1618
	,, ,,	6	,,	,,		1447
	24-pr. gun, 50 cwt.	8	,,	23	8	1720
	18-pr. gun, 38 cwt.	6	,,	17	11	1690
Bronze	12-pr. gun	4	,,	12	10½	1769
	9-pr. gun	2½	,,	9	5¾	1613
	6-pr. gun	1½	,,	6	3¾	1484
	24-pr. howitzer	2½	Common shell	16	11½	1252
	12-pr. howitzer	1¼	,,	8	12	1163
Cast iron	13″ mortar	7	Mortar shell	204	8	506
	,,	3½	,,	,,		328
	10″ mortar	4	,,	91	7	521
	,,	2	,,	,,		325
Built-up iron	150-pr. gun, 12 tons	40	Solid shot	149	14	1726
	,, ,,	30	,,	,,		1569
	,, ,,	20	,,	,,		1344
	100-pr. gun, 125 cwt.	25	,,	102	0	1653
	,, ,,	20	,,	,,		1547

Table IX.—*Initial Velocities of Projectiles fired from Rifled Ordnance, from experiments made by Capt. W. H. Noble, R.A.*

Nature of gun	Calibre	Length of bore in calibres	Charge: Nature of powder	Charge: Weight	Projectile: Nature	Projectile: Mean Weight	Projectile: Mean Diameter	Mean initial velocity
Rifled muzzle-loading:	inches			lbs. ozs.		lbs.	inches	f. s.
12-inch of 35 tons	12·0	13·5	P.	110 0	Palliser	700	11·92	1300
12-inch of 25 tons	12·0	12·0	,,	85 0	,,	600	11·92	1300
			,,	85 0	Com. shell	495	11·92	1358
			,,	55 0	,,	495	11·92	1142
			R.L.G.	67 0	Palliser	600	11·92	1180
			,,	67 0	Com. shell	495	11·92	1271
			,,	50 0	,,	495	11·92	1140
11-inch of 25 tons	11·0	13·2	P.	85 0	Palliser	535	10·92	1315
			,,	85 0	Com. shell	535	10·92	1315
			R.L.G.	70 0	Palliser	535	10·92	1217
			,,	70 0	Com. shell	535	10·92	1217

TABLE IX.—*continued.*

Nature of gun	Calibre	Length of bore in calibres	Charge		Projectile			Mean initial velocity
			Nature of powder	Weight	Nature	Mean Weight	Mean Diameter	
Rifled muzzle-loading—*cont.*	inches			lbs. ozs.		lbs.	inches	f.s.
10-inch of 18 tons . . .	10·0	14·5	P.	70 0	Palliser	400	9·92	1364
			,,	70 0	Com. shell	400	9·92	1340
			,,	44 0	,,	400	9·92	1125
			R.L.G.	60 0	Palliser	400	9·92	1298
			,,	40 0	Com. shell	400	9·92	1117
9-inch of 12 tons . . .	9·0	13·9	P.	50 0	Palliser	250	8·92	1420
			,,	50 0	Com. shell	250	8·92	1420
			R.L.G.	43 0	Palliser	250	8·92	1336
			,,	43 0	Com. shell	250	8·92	1336
			,,	30 0	,,	250	8·92	1192
8-inch of 9 tons . . .	8·0	14·8	P.	35 0	Palliser	180	7·92	1413
			,,	35 0	Com. shell	180	7·92	1413
			R.L.G.	30 0	Palliser	180	7·92	1330
			,,	30 0	Com. shell	180	7·92	1330
			,,	20 0	,,	180	7·92	1163
7-inch of 7 tons . .	7·0	18·0	P.	30 0	Palliser	115	6·92	1561
			,,	30 0	Com. shell	115	6·92	1561
			R.L.G.	22 0	Palliser	115	6·92	1458
			,,	22 0	Com. shell	115	6·92	1458
			,,	14 0	,,	115	6·92	1258
7-inch of 6½ tons . .	7·0	15·9	P.	30 0	Palliser	115	6·92	1525
			,,	30 0	Com. shell	115	6·92	1525
			R.L.G.	22 0	Palliser	115	6·92	1430
			,,	22 0	Com. shell	115	6·92	1430
			,,	14 0	,,	115	6·92	1230
80-pr. of 101 cwt. converted from 68-pr. smooth-bored gun . .	6·3	18·0	L.G.	10 0	,,	80	6·22	1240
64-pr. wrought iron of 64 cwt. . . .	6·3	15·5	R.L.G.	8 0	,,	64	6·22	1252
			L.G.	8 0	,,	64	6·22	1229
64-pr. of 58 cwt., converted from 32-pr. smooth-bored gun . .	6·3	17·2	R.L.G.	8 0	,,	64	6·22	1245
64-pr. of 71 cwt., converted from 8-inch smooth-bored gun . .	6·3	16·4	,,	8 0	,,	64	6·22	1230
40-pr. of 35 cwt.* . . .	4·75	18·0	,,	8 0	,,	40	4·69	1357
			,,	7 0	,,	40	4·69	1336
			,,	6 0	,,	40	4·69	1305
25-pr. of 21 cwt.* . . .	4·0	18·0	,,	5 0	,,	25	3·94	1355
			,,	4 8	,,	25	3·94	1320
			,,	4 0	,,	25	3·94	1278
16-pr. of 12 cwt.	3·6	19·0	,,	3 0†	,,	16	3·54	1352
			,,	2 8	,,	16	3·54	1273
			,,	2 0	,,	16	3·54	1167
9-pr. of 8 cwt. . . .	3·0	21·3	,,	1 12†	,,	9	2·94	1381
			,,	1 8	,,	9	2·94	1325
			,,	1 4	,,	9	2·94	1203
9-pr. of 6 cwt. . . .	3·0	17·5	,,	1 12	,,	9	2·94	1262
			,,	1 8†	,,	9	2·94	1234
7-pr. of 220 lbs. (bronze)	3·0	11·3	F.G.	0 12†	,,	7·25	2·94	955
			,,	0 10	,,	7·25	2 94	854
7-pr. of 150 lbs. (steel)	3·0	8·0	,,	0 6	,,	7·25	2·94	673
Rifled breech-loading:								
7-inch of 82 cwt. . . .	7·0	14·2	R.L.G.	10 0	,,	110	7·09	1013
			,,	11 0	,,	90	7·09	1165
64-pr. of 61 cwt.	6·4	10·9	,,	9 0	,,	64	6·48	1200
40-pr. of 35 cwt.	4·75	22·4	,,	5 0	,,	41	4·8	1180
20-pr. of 16 cwt. (land service) . . .	3·75	22·4	,,	2 8	,,	21	3·8	1130
20-pr. of 13 cwt. (sea service) . . .	3·75	14·5	,,	2 8	,,	21	3·8	1000
12-pr. of 8 cwt.	3·0	20·5	,,	1 8	Segt. shell	11·75	3·07	1150
9-pr. of 6 cwt.	3·0	17·7	,,	1 2	,,	9·25	3·07	1057
6-pr. of 3 cwt.	2·5	21·2	,,	0 12	,,	6·6	2·57	1046

* These guns are not yet finally approved of. † Service charge.

P. represents pebble; R.L.G., rifle large grain; L.G., large grain; and F.G., fine grain powders.

TABLE X.—*Table showing the Energy of Projectiles fired with Battering Charges of P. Powder from heavy Rifled ML. Guns. Calculated by Capt. W. H. Noble, R.A.*

Range	12-in. ML.R. of 25 tons Charge 85 lbs. Projectile 600 lbs.			11-in. ML.R. of 25 tons Charge 85 lbs. Projectile 535 lbs.			10-in. ML.R. of 18 tons Charge 70 lbs. Projectile 400 lbs.			9-in. ML.R. of 12 tons Charge 50 lbs. Projectile 250 lbs.			8-in. ML.R. of 9 tons Charge 35 lbs. Projectile 180 lbs.			7-in. ML.R. of 6½ tons* Charge 30 lbs. Projectile 115 lbs.		
	v.	Total energy	Energy per inch of shot's circumference	*v.*	Total energy	Energy per inch of shot's circumference	*v.*	Total energy	Energy per inch of shot's circumference	*v.*	Total energy	Energy per inch of shot's circumference	*v.*	Total energy	Energy per inch of shot's circumference	*v.*	Total energy	Energy per inch of shot's circumference
yds.	ft.	ft. tons	ft. tons	ft.	ft. tons	ft. tons	ft.	ft. tons	ft. tons	ft.	ft. tons	ft. tons	ft.	ft. tons	ft. tons	ft.	ft. tons	ft. tons
0	1300	7030	188	1315	6415	187	1364	5160	165·6	1420	3496	124·7	1413	2492	100·2	1525	1855	85·3
200	1273	6750	181	1289	6165	180	1336	4950	158·9	1379	3297	117·6	1369	2339	94·0	1467	1716	78·9
400	1248	6480	174	1265	5935	173	1308	4745	152·3	1341	3117	111·2	1327	2198	88·3	1409	1583	72·8
600	1224	6230	167	1242	5720	167	1280	4575	146·8	1304	2948	105·2	1286	2064	83·0	1356	1466	67·5
800	1201	6000	161	1220	5520	161	1254	4360	140·0	1270	2796	99·8	1248	1944	78·1	1307	1362	62·7
1000	1179	5780	155	1199	5335	156	1228	4185	134·2	1236	2648	94·5	1213	1837	73·8	1261	1268	58·3
1200	1157	5570	149	1179	5155	150	1204	4020	129·0	1204	2513	89·7	1180	1738	69·9	1217	1181	54·3
1400	1137	5380	144	1159	4985	145	1181	3870	124·1	1174	2389	85·3	1150	1651	66·3	1177	1105	50·8
1600	1118	5200	139	1139	4815	140	1159	3725	120·0	1147	2281	81·4	1122	1571	63·2	1141	1038	47·8
1800	1101	5040	135	1122	4670	136	1138	3590	115·3	1121	2178	77·7	1097	1502	60·4	1108	979	45·0
2000	1085	4890	131	1106	4540	132	1118	3470	111·2	1097	2086	74·4	1074	1440	57·9	1078	927	42·6
2200	1069	4750	127	1090	4410	129	1099	3350	107·5	1075	2003	71·5	1052	1381	55·5	1053	884	40·7
2400	1055	4630	124	1075	4285	125	1082	3245	104·2	1055	1930	68·9	1032	1329	53·4	1030	846	38·9
2600	1041	4510	120	1061	4175	122	1066	3150	101·1	1037	1864	66·5	1014	1283	51·6	1009	812	37·3
2800	1028	4400	117	1048	4075	119	1052	3070	98·5	1020	1804	64·4	996	1238	49·8	990	782	36·0
3000	1016	4300	115	1036	3980	116	1038	2990	95·9	1004	1747	62·4	980	1199	48·2	973	755	34·7
3200	1004	4200	112	1024	3890	113	1025	2915	93·5	990	1699	60·6	965	1162	46·7	958	732	33·7
3400	993	4100	110	1012	3800	111	1013	2845	91·3	978	1658	59·2	952	1131	45·5	945	712	32·8
3600	984	4030	108	1002	3725	109	1002	2785	89·4	966	1618	57·7	940	1103	44·3	934	696	32·0
3800	976	3960	106	994	3665	107	992	2730	87·6	955	1581	56·4	930	1080	43·4	924	681	31·3
4000	968	3900	104	986	3605	105	982	2675	85·8	945	1548	55·2	920	1056	42·5	916	669	30·8

* The energy per inch of the shot's circumference of projectiles fired from the 7-inch R.ML. of 7 tons is about 5 per cent. more than the above figures.

Tables showing the connection between Initial Velocity and Weight of Charge, obtained from the results of Experiments with the Bashforth Chronograph.

Table XI.—3-*in*. *Gun*.

Charge	12 lb. shot	9 lb. shot	6 lb. shot	Charge	12 lb. shot	9 lb. shot	6 lb. shot
	Initial velocity	Initial velocity	Initial velocity		Initial velocity	Initial velocity	Initial velocity
lb. oz.	f.s.	f.s.	f.s.	lb. oz.	f.s.	f.s.	f.s.
0 12	614	693	815	1 7	1021	1146	1357
0 13	658	745	876	1 8	1050	1176	1394
0 14	700	794	935	1 9	1077	1205	1429
0 15	741	841	991	1 10	1103	1233	1463
1 0	782	886	1044	1 11	1127	1260	1495
1 1	820	928	1095	1 12	1151	1285	1525
1 2	857	969	1144	1 13	1173	1309	1554
1 3	893	1008	1191	1 14	1194	1333	1582
1 4	927	1045	1235	1 15	1213	1356	1609
1 5	960	1080	1277	2 0	1231	1378	1634
1 6	991	1114	1318				

Table XII.—5-*in*. *Gun*.

Charge	47·68 lb. shot	23·84 lb. shot	Charge	47·68 lb. shot	23·84 lb. shot	Charge	47·68 lb. shot	23·84 lb. shot
	Initial velocity	Initial velocity		Initial velocity	Initial velocity		Initial velocity	Initial velocity
lbs.	f.s.	f.s.	lbs.	f.s.	f.s.	lbs.	f.s.	f.s.
3	...	1179	4·75	1131	1543	6·5	1277	1715
3·25	...	1246	5	1158	1577	6·75	1292	1730
3·5	...	1308	5·25	1182	1608	7	1306	1743
3·75	...	1364	5·5	1205	1635	7·25	1319	1755
4	1039	1416	5·75	1225	1659	7·5	1331	1766
4·25	1072	1463	6	1244	1680	7·75	1342	1776
4·5	1103	1505	6·25	1261	1698	8	1353	1785

Table XIII.—7-*in*. *Gun*.

Charge	123·125 lb. shot	61·156 lb. shot	Charge	123·125 lb. shot	61·156 lb. shot	Charge	123·125 lb. shot	61·156 lb. shot
	Initial velocity	Initial velocity		Initial velocity	Initial velocity		Initial velocity	Initial velocity
lbs.	f.s.	f.s.	lbs.	f.s.	f.s.	lbs.	f.s.	s.
5	...	879	10·5	1023	1402	15·5	1235	...
5·5	...	942	11	1050	1435	16	1251	...
6	...	1002	11·5	1075	1466	16·5	1265	...
6·5	...	1058	12	1099	1495	17	1279	...
7	...	1111	12·5	1122	1522	17·5	1293	...
7·5	828	1161	13	1143	1549	18	1307	...
8	865	1208	13·5	1163	1575	18·5	1320	...
8·5	900	1252	14	1182	1601	19	1333	...
9	933	1293	14·5	1200	1626	19·5	1346	...
9·5	965	1331	15	1218	1651	20	1357	...
10	995	1367						

Table XIV.—9-*in. Gun.*

Charge	250 lb. shot Initial velocity	Charge	250 lb. shot Initial velocity	Charge	250 lb. shot Initial velocity	Charge	250 lb. shot Initial velocity
lbs.	f.s.	lbs.	f.s.	lbs.	f.s.	lbs.	f.s.
20	959	27	1137	34	1238	40	1290
21	990	28	1155	35	1248	41	1298
22	1019	29	1171	36	1257	42	1306
23	1046	30	1187	37	1266	43	1314
24	1071	31	1202	38	1274	44	1322
25	1095	32	1215	39	1282	45	1329
26	1117	33	1227				

Professor Bashforth's Tables showing the Velocities of the Service Shot (ogival head) for the 7-in., 8-in., and 9-in. ML. R. Guns at intervals of 100 ft., supposing the Shot to move in a straight Line.

Table XV.

7-in. ML. Rifled Gun. Diameter of Shot, 6·92 *in.*
Weight of Shot, 115 *lbs.*

Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity
ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.
0	1717·2	2300	1490·1	4600	1296·1	6900	1139·6	9200	1031
100	1706·1	2400	1481	4700	1288·4	7000	1134·2	9300	1027·7
200	1695·2	2500	1472·1	4800	1280·9	7100	1128·6	9400	1024·4
300	1684·5	2600	1463·2	4900	1273·4	7200	1123·1	9500	1021·1
400	1673·8	2700	1454·5	5000	1266	7300	1117·7	9600	1017·8
500	1663·3	2800	1445·8	5100	1258·7	7400	1112·7	9700	1014·6
600	1653	2900	1436·8	5200	1251·5	7500	1107	9800	1011·3
700	1642·7	3000	1427·9	5300	1244·4	7600	1101·7	9900	1008·1
800	1632·6	3100	1419	5400	1237·2	7700	1096·5	10000	1004·9
900	1622·6	3200	1410·3	5500	1230·1	7800	1091·3	10100	1001·8
1000	1612·8	3300	1401·7	5600	1223·1	7900	1086·2	10200	998·6
1100	1603	3400	1393·2	5700	1216·2	8000	1081·1	10300	995·6
1200	1593·4	3500	1384·9	5800	1209·4	8100	1076	10400	992·4
1300	1583·9	3600	1376·6	5900	1202·6	8200	1071	10500	989·3
1400	1574·5	3700	1368·4	6000	1195·9	8300	1066·1	10600	986·2
1500	1565·1	3800	1360·2	6100	1189·3	8400	1061·2	10700	983·2
1600	1555·7	3900	1352	6200	1182·8	8500	1056·3	10800	980·1
1700	1546·3	4000	1343·8	6300	1176·3	8600	1051·5	10900	977·1
1800	1536·9	4100	1335·7	6400	1169·9	8700	1048·1	11000	974·1
1900	1527·4	4200	1327·6	6500	1163·6	8800	1044·6	...	...
2000	1518	4300	1319·6	6600	1157·3	8900	1041·2	...	...
2100	1508·6	4400	1311·6	6700	1151·1	9000	1037·8	...	...
2200	1499·3	4500	1303·8	6800	1145·3	9100	1034·4	...	...

Table XVI.

8-in. ML. Rifled Gun. Diameter of Shot, 7·92 in. Weight of Shot, 180 lbs.

Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity
ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.
0	1700	3000	1459	6000	1254	9000	1098·2	12000	999·2
100	1691·4	3100	1451·6	6100	1248	9100	1094	12100	996·6
200	1682·8	3200	1444·2	6200	1241·9	9200	1089·9	12200	993·9
300	1674·4	3300	1436·7	6300	1235·9	9300	1085·8	12300	991·4
400	1666	3400	1429·3	6400	1230	9400	1081·8	12400	988·7
500	1657·7	3500	1421·9	6500	1224·1	9500	1077·8	12500	986·2
600	1649·3	3600	1414·5	6600	1218·3	9600	1073·9	12600	983·6
700	1640·9	3700	1407·3	6700	1212·5	9700	1070·2	12700	981·1
800	1632·4	3800	1400·1	6800	1206·8	9800	1066·4	12800	978·5
900	1624	3900	1392·9	6900	1201·1	9900	1062·8	12900	976
1000	1615·7	4000	1385·8	7000	1195·5	10000	1059·3	13000	973·4
1100	1607·5	4100	1378·9	7100	1190	10100	1055·8	13100	971
1200	1599·3	4200	1371·9	7200	1184·4	10200	1052·4	13200	968·4
1300	1591·3	4300	1365·1	7300	1179	10300	1049	13300	966
1400	1583·3	4400	1358·3	7400	1173·6	10400	1045·6	13400	963·5
1500	1575·4	4500	1351·6	7500	1168·3	10500	1042·3	13500	961·1
1600	1567·5	4600	1344·9	7600	1163·1	10600	1039·1	13600	958·6
1700	1559·6	4700	1338	7700	1157·9	10700	1035·9	13700	956·2
1800	1551·7	4800	1331·1	7800	1152·9	10800	1032·8	13800	953·7
1900	1543·8	4900	1324·3	7900	1148	10900	1029·8	13900	951·4
2000	1535·9	5000	1317·6	8000	1143·2	11000	1026·8	14000	948·9
2100	1528	5100	1311	8100	1138·4	11100	1023·8	14100	946·6
2200	1520·2	5200	1304·4	8200	1133 6	11200	1020·9	14200	944·6
2300	1512·3	5300	1297·9	8300	1129	11300	1018·1	14300	942·6
2400	1504·4	5400	1291·4	8400	1124·4	11400	1015·3	14400	940·6
2500	1496·7	5500	1285	8500	1119·9	11500	1012·6	14500	938·6
2600	1489	5600	1278·7	8600	1115·5	11600	1009·9	14600	936·7
2700	1481·4	5700	1272·4	8700	1111·1	11700	1007·2	14700	934·7
2800	1473·8	5800	1266·2	8800	1106·8	11800	1004·5	14800	932·8
2900	1466·4	5900	1260·1	8900	1102·5	11900	1001·9	14900	930·8

Table XVII.

9-in. ML. Rifled Gun. Diameter of Shot, 8·92 in. Weight of Shot, 250 lbs.

Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity
ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.
0	1400	1000	1338	2000	1281·2	3000	1229·1	4000	1181·1
100	1393·5	1100	1332·1	2100	1275·8	3100	1224·1	4100	1176·5
200	1387·1	1200	1326·2	2200	1270·5	3200	1219·2	4200	1171·9
300	1380·8	1300	1320·4	2300	1265·2	3300	1214·3	4300	1167·4
400	1374·5	1400	1314·7	2400	1259·9	3400	1209·4	4400	1162·9
500	1368·3	1500	1309	2500	1254·6	3500	1204·6	4500	1158·5
600	1362·1	1600	1303·3	2600	1249·5	3600	1199·8	4600	1154·1
700	1356	1700	1297·8	2700	1244·3	3700	1195·1	4700	1149·7
800	1349·9	1800	1292·2	2800	1239·2	3800	1190·5	4800	1145·4
900	1343·9	1900	1286·7	2900	1234·1	3900	1185·7	4900	1141·1

Table XVII.—*continued.*

Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity	Distance	Velocity
ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.	ft.	f.s.
5000	1136·8	6500	1077	8000	1024·5	9500	979·7	11000	943·1
5100	1132·5	6600	1073·2	8100	1021·4	9600	976·9	...	...
5200	1128·3	6700	1069·6	8200	1018·3	9700	974·4	...	...
5300	1124·2	6800	1066	8300	1015·2	9800	971·9	...	...
5400	1120·1	6900	1062·4	8400	1012·1	9900	969·4	...	...
5500	1116	7000	1058·8	8500	1009·1	10000	966·9	...	...
5600	1112	7100	1055·3	8600	1006·1	10100	964·5	...	...
5700	1108	7200	1051·8	8700	1003·1	10200	962·1	...	...
5800	1104	7300	1048·3	8800	1000·1	10300	959·7	...	...
5900	1101·1	7400	1044·8	8900	997·1	10400	957·3	...	...
6000	1096·2	7500	1041·4	9000	994·1	10500	954·9	...	...
6100	1092·3	7600	1037·9	9100	991·3	10600	952·6	...	...
6200	1088·4	7700	1034·5	9200	988·3	10700	950·2	...	...
6330	1084·6	7800	1031·2	9300	985·4	10800	947·9	...	...
6400	1080·8	7900	1027·8	9400	982·5	10900	945·4	...	...

Table XVIII.

Professor Bashforth's Table showing the Velocities of Spherical Solid Shot for the undermentioned Guns at intervals of 100 ft., supposing the Shot to move in a straight Line, subject only to the Resistance of the Air.

Distance	Velocities											Distance
	15-in. Rodman	150-pr. (chilled shot)	100-pr. (chilled shot)	68-pr.	32-pr.	24-pr.	18-pr.	12-pr.	9-pr.	6-pr.	3-pr.	
ft.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.
0	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	0
100	2079	2072	2067	2059	2048	2043	2038	2030	2022	2011	1990	100
200	2058	2044	2033	2019	1998	1988	1978	1962	1947	1926	1886	200
300	2037	2016	2001	1980	1948	1935	1920	1896	1875	1845	1788	300
400	2017	1988	1970	1942	1900	1883	1863	1833	1806	1768	1696	400
500	1996	1962	1938	1905	1854	1833	1808	1772	1742	1694	1606	500
600	1976	1935	1907	1868	1809	1784	1755	1713	1679	1623	1527	600
700	1956	1909	1877	1832	1764	1737	1704	1656	1618	1555	1450	700
800	1937	1883	1848	1797	1721	1691	1654	1601	1560	1490	1377	800
900	1917	1858	1819	1763	1679	1646	1606	1548	1504	1429	1309	900
1000	1898	1833	1790	1729	1637	1602	1559	1497	1450	1371	1245	1000
1100	1879	1808	1762	1696	1598	1559	1514	1448	1398	1316	1186	1100
1200	1860	1784	1734	1664	1559	1518	1470	1401	1349	1264	1131	1200
1300	1842	1760	1707	1632	1521	1478	1428	1356	1302	1215	1081	1300
1400	1823	1737	1680	1601	1484	1439	1388	1313	1257	1169	1035	1400
1500	1805	1714	1654	1571	1449	1402	1349	1272	1215	1126	994	1500
1600	1787	1691	1628	1541	1415	1366	1311	1233	1175	1086	957	1600
1700	1769	1668	1603	1512	1381	1331	1275	1196	1137	1009	925	1700
1800	1752	1645	1578	1484	1349	1297	1241	1161	1101	1015	897	1800
1900	1735	1623	1553	1456	1318	1265	1208	1128	1068	984	873	1900
2000	1717	1601	1529	1429	1288	1234	1176	1097	1036	956	...	2000
2100	1700	1580	1505	1403	1258	1204	1146	1068	1007	930	...	2100
2200	1683	1559	1482	1377	1230	1175	1117	1040	980	906	...	2200
2300	1667	1538	1459	1352	1203	1147	1090	1014	955	884	...	2300
2400	1650	1518	1437	1327	1176	1121	1065	990	932	...	...	2400
2500	1633	1498	1415	1303	1151	1096	1041	968	991	...	...	2500
2600	1617	1479	1394	1280	1127	1072	1018	946	892	...	...	2600

Table XVIII.—*continued.*

Distance	Velocities											Distance
	15-in. Rodman	150-pr. (chilled shot)	100-pr. (chilled shot)	68-pr.	32-pr.	24-pr.	18-pr.	12-pr.	9-pr.	6-pr.	3-pr.	
ft.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	f.s.	ft.
2700	1601	1459	1373	1257	1104	1050	997	926	874	...	...	2700
2800	1585	1440	1352	1235	1082	1029	977	907	...	...	...	2800
2900	1570	1422	1331	1214	1061	1009	958	889	...	...	...	2900
3000	1554	1403	1311	1193	1041	990	940	871	...	...	...	3000
3100	1539	1385	1292	1172	1022	972	922	854	...	...	...	3100
3200	1524	1367	1273	1152	1004	955	905	...	...	...	...	3200
3300	1509	1349	1254	1133	987	938	888	...	...	...	...	3300
3400	1494	1332	1236	1115	971	922	872	...	...	...	...	3400
3500	1479	1316	1219	1097	955	906	857	...	...	...	...	3500
3600	1465	1299	1201	1080	940	891	...	...	...	...	...	3600
3700	1451	1282	1184	1064	925	...	...	...	...	...	...	3700
3800	1437	1267	1168	1048	911	...	...	...	...	...	...	3800
3900	1423	1251	1152	1033	897	...	...	...	...	...	...	3900
4000	1409	1235	1136	1019	884	...	...	...	...	...	...	4000
4100	1396	1220	1121	1005	...	...	...	...	...	...	...	4100
4200	1382	1205	1106	992	...	...	...	...	...	...	...	4200
4300	1369	1191	1092	979	...	...	...	...	...	...	...	4300
4400	1356	1177	1078	966	...	...	...	...	...	...	...	4400
4500	1343	1163	1065	954	...	...	...	...	...	...	...	4500
4600	1330	1149	1052	942	...	...	...	...	...	...	...	4600
4700	1318	1136	1040	930	...	...	...	...	...	...	...	4700
4800	1305	1123	1028	919	...	...	...	...	...	...	...	4800
4900	1293	1110	1016	908	...	...	...	...	...	...	...	4900
5000	1281	1098	1005	898	...	...	...	...	...	...	...	5000
5100	1269	1086	994	...	...	...	...	...	...	...	...	5100
5200	1258	1075	983	...	...	...	...	...	...	...	...	5200
5300	1246	1064	972	...	...	...	...	...	...	...	...	5300
5400	1235	1053	962	...	...	...	...	...	...	...	...	5400
5500	1223	1042	952	...	...	...	...	...	...	...	...	5500
5600	1212	1032	943	...	...	...	...	...	...	...	...	5600
5700	1201	1022	933	...	...	...	...	...	...	...	...	5700
5800	1191	1012	924	...	...	...	...	...	...	...	...	5800
5900	1180	1002	915	...	...	...	...	...	...	...	...	5900
6000	1170	993	906	...	...	...	...	...	...	...	...	6000
6100	1160	984	...	...	...	...	...	...	...	...	...	6100
6200	1150	975	...	...	...	...	...	...	...	...	...	6200
6300	1140	966	...	...	...	...	...	...	...	...	...	6300
6400	1130	958	...	...	...	...	...	...	...	...	...	6400
6500	1120	950	...	...	...	...	...	...	...	...	...	6500
6600	1111	941	...	...	...	...	...	...	...	...	...	6600
6700	1102	933	...	...	...	...	...	...	...	...	...	6700
6800	1093	925	...	...	...	...	...	...	...	...	...	6800
6900	1084	917	...	...	...	...	...	...	...	...	...	6900
7000	1076	910	...	...	...	...	...	...	...	...	...	7000
7100	1068	...	...	...	...	...	...	...	...	...	...	7100
7200	1059	...	...	...	...	...	...	...	...	...	...	7200
7300	1051	...	...	...	...	...	...	...	...	...	...	7300
7400	1043	...	...	...	...	...	...	...	...	...	...	7400
7500	1036	...	...	...	...	...	...	...	...	...	...	7500
7600	1028	...	...	...	...	...	...	...	...	...	...	7600
7700	1021	...	...	...	...	...	...	...	...	...	...	7700
7800	1013	...	...	...	...	...	...	...	...	...	...	7800
7900	1006	...	...	...	...	...	...	...	...	...	...	7900
8000	999	...	...	...	...	...	...	...	...	...	...	8000

TABLE XIX.

Table showing the Resistance of the Air in lbs. to Spherical Shot from 1 in. to 15 in. in diameter, at Velocities varying from 900 to 2,100 f. s.

Velocity	Resistance															Velocity
	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.	12 in.	13 in.	14 in.	15 in.	
f.s.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	f.s.
900	3·1293	13	28	50	78	113	153	200	254	313	379	451	529	613	704	900
950	3·6964	15	33	59	92	133	181	237	299	370	447	532	625	725	832	950
1000	4·3827	18	39	70	110	158	215	281	355	438	530	631	741	859	986	1000
1050	5·2533	21	47	84	131	189	257	336	426	525	636	757	888	1030	1082	1050
1100	6·2592	25	56	100	156	225	307	401	507	626	757	901	1058	1227	1408	1100
1150	7·2560	29	65	116	181	261	356	464	588	726	878	1045	1126	1422	1633	1150
1200	8·2335	33	74	132	206	296	403	527	667	823	996	1186	1392	1614	1853	1200
1250	9·1666	37	82	147	229	330	449	587	743	917	1109	1320	1549	1797	2063	1250
1300	10·0860	40	91	161	252	363	494	646	817	1009	1220	1452	1705	1977	2269	1300
1350	11·0582	44	99	177	277	398	542	708	896	1106	1338	1592	1869	2167	2488	1350
1400	12·0432	48	108	193	301	434	590	771	976	1204	1457	1734	2035	2361	2710	1400
1450	13·0393	52	117	209	326	469	639	835	1056	1304	1578	1878	2204	2556	2934	1450
1500	14·0579	56	126	225	351	506	689	900	1139	1406	1701	2024	2376	2755	3163	1500
1550	15·1293	60	136	242	378	545	741	968	1226	1513	1831	2179	2557	2965	3404	1550
1600	16·2213	65	146	260	406	584	795	1038	1314	1622	1963	2336	2741	3179	3650	1600
1650	17·3157	69	156	277	433	623	849	1108	1403	1732	2095	2494	2926	3394	3896	1650
1700	18·4314	74	166	295	461	664	903	1180	1493	1843	2231	2655	3115	3613	4148	1700
1750	19·5433	78	176	313	489	704	958	1251	1583	1954	2365	2814	3303	3831	4397	1750
1800	20·6871	83	186	331	517	745	1014	1324	1676	2069	2503	2979	3496	4055	4655	1800
1850	21·8890	88	197	350	547	788	1073	1401	1773	2189	2649	3152	3699	4290	4925	1850
1900	23·1583	93	208	371	579	834	1135	1482	1876	2316	2802	3335	3914	4539	5211	1900
1950	24·4823	98	220	391	612	881	1200	1567	1983	2448	2962	3526	4138	4799	5509	1950
2000	25·8179	103	232	413	645	929	1265	1652	2091	2582	3124	3718	4363	5060	5809	2000
2050	27·1609	109	244	435	679	978	1331	1738	2200	2716	3287	3911	4590	5324	6111	2050
2100	28·5355	114	257	457	713	1027	1398	1826	2311	2854	3453	4109	4823	5593	6421	2100

TABLE XX.

Table showing the Resistance of the Air in lbs. to Elongated Projectiles with ogival heads, from 1 in. to 15 in. in diameter, at Velocities of from 900 to 1700 f.s.

Velocity	Diameter of Projectile															Velocity
	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.	12 in.	13 in.	14 in.	15 in.	
f.s.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	f.s.
900	1·4584	5·8	13·1	23·3	36·5	52·5	71·5	93·3	118	146	176	210	246	286	328	900
950	1·7951	7·2	16·2	28·7	44·9	64·6	88	115	145	180	217	258	303	352	404	950
1000	2·3299	9·3	21	37·3	58·2	83·9	114	149	189	233	282	336	394	457	524	1000
1050	3·3373	13·3	30	53·4	83·4	120	164	214	270	334	404	481	564	654	751	1050
1100	4·3829	17·5	39	70	110	158	215	281	355	438	530	631	741	859	986	1100
1150	5·1121	20·4	46	82	128	184	250	327	414	511	619	736	864	1002	1150	1150
1200	5·8457	23·4	53	94	146	210	286	374	474	585	707	842	988	1146	1315	1200
1250	6·5952	26·4	59	106	165	237	323	422	534	660	798	950	1115	1293	1484	1250
1300	7·3641	29·5	66	118	184	265	361	471	596	736	891	1060	1245	1443	1657	1300
1350	8·1322	32·5	73	130	203	293	398	520	659	813	984	1171	1374	1594	1830	1350
1400	8·8650	35·5	80	142	222	319	434	567	718	887	1073	1277	1498	1738	1995	1400
1450	9·5556	38·2	86	153	239	344	468	612	774	956	1156	1376	1615	1873	2150	1450
1500	10·1902	40·8	92	163	255	367	499	652	825	1019	1233	1467	1722	1997	2293	1500
1550	10·7585	43	97	172	269	387	527	689	871	1076	1302	1549	1818	2109	2421	1550
1600	11·3245	45·3	102	181	283	408	555	725	917	1132	1370	1631	1914	2220	2548	1600
1650	11·9174	47·7	107	191	298	429	584	763	965	1192	1442	1716	2014	2336	2681	1650
1700	12·8050	51·2	115	205	320	461	627	820	1037	1281	1549	1844	2164	2510	2881	1700

The following Table of ranges, given by a 68-pr. 95 cwt., carefully laid and fired at 2°, 5°, and 10° of elevation (by quadrant), shows clearly the inaccuracy of fire of SB. guns, and the consequent difficulty of making accurate Range Tables. This gun is one of the most accurate SB. pieces.

Table XXI.

Round	Elevation	1st Graze	Round	Elevation	1st Graze	Round	Elevation	1st Graze
		yds.			yds.			yds.
1	2°	1207	21	5°	2100	41	10°	3118
2	,,	1233	22	,,	1992	42	,,	3156
3	,,	1302	23	,,	2059	43	,,	2975
4	,,	1208	24	,,	2228	44	,,	3272
5	,,	1146	25	,,	2049	45	,,	2950
6	,,	1236	26	,,	2092	46	,,	3074
7	,,	1310	27	,,	2081	47	,,	3000
8	,,	1157	28	,,	1990	48	,,	3204
9	,,	1198	29	,,	2109	49	,,	3059
10	,,	1254	30	,,	2112	50	,,	2911
11	,,	1261	31	,,	2148	51	,,	2981
12	,,	1366	32	,,	1980	52	,,	2992
13	,,	1219	33	,,	1996	53	,,	3000
14	,,	1240	34	,,	2000	54	,,	2985
15	,,	1246	35	,,	1998	55	,,	3004
16	,,	1288	36	,,	2118	56	,,	3105
17	,,	1214	37	,,	2150	57	,,	3090
18	,,	1345	38	,,	1994	58	,,	3140
19	,,	1200	39	,,	2000	59	,,	3064
20	,,	1272	40	,,	2098	60	,,	3204

This Table, and those giving the ranges of heavy rifled ordnance and carcasses, are taken from the Range Tables in the *Manual of Artillery Exercises*, 1870.

Table XXII.—*Ranges, &c., for SB. Cast-Iron Ordnance.*

Nature	Weight	Charge	Elevation P.B	1°	2°	3°	4°	5°	6°	8°	Remarks
	cwt.	lbs.	yds.	yds.	yds.	yds.	yds.	yds.	yds.	yds.	
68-pr.	112	18	370	900	1170	1660	1860	2140	2400	2740	Solid shot
			s.	s.	s.	s.	s.	s.	s.	s.	
			...	2·25	3·25	4·25	5·25	6·25	7·75	9·75	
,,	95	16	320	700	1070	1410	1710	1930	2140	2540	
			s.	s.	s.	s.	s.	s.	s.	s.	
			...	2	3	4·25	5·5	6·5	7·5	9	
32-pr.	58 }	10	{ 400	820	1200	1520	1810	2050	2250	2610	
,,	56 }		{ 370	779	1160	1460	1690	1910	2110	2460	
,,	50	8	346	747	1173	1435	1698	1900	2127	2443	
			s.	s.	s.	s.	s.	s.	s.	s.	
			...	2	3	4	3·25	6·25	7·25	8·75	
24-pr.	50	8	360	750	1120	1440	1630	1840	1950	2230	
18-pr.	38	6	350	690	990	1270	1500	1710	1890	2130	
10-in.	86	12	315	635	935	1205	1450	1665	1825	2095	Hollow shot
			s.	s.	s.	s.	s.	s.	s.	s.	
			...	2·2	3·4	4·2	5	6·4	7	8·7	
8-in.	65	10	320	660	960	1250	1500	1720	1910	2220	Common shell naval
			s.	s.	s.	s.	s.	s.	s.	s.	
			...	2	3	4·5	5·2	6·2	7·2	9·2	
,,	52	8	290	530	820	1080	1340	1550	1860	2080	Hollow shot

(s) stands for seconds, and refers to time of flight.
With common shells a little less elevation is required than for solid shot at short ranges, but at long ranges about the same, at very long ranges more.

The following Table is compiled from the results of practice, carried on in Woolwich marshes by the Gentlemen Cadets of the Royal Military Academy, during the years 1857 to 1864.

Table XXIII.

Nature	Weight	Charge	Range in yards 900		1000		1100		1200		1300		1400		Remarks
	cwt	lb.	°	fu.	°	fu.	°	fu.	°	fu.	°	fu.	°	fu.	
Round Shot:—															
10-in. gun . . .	86	12	...		2½	0	2¾	0	3	0	3½	0	4	0	Hollow
8-in. " . . .	65	10	...		2¼	0	2½	0	2¾	0	3¼	0	3¾	0	
32-pr. " . . .	56	10	...		1¾	0	2	0	2¼	0	2⅝	0	3	0	Solid
" " . . .	"	7½	...		2	0	2¼	0	2½	0	2¾	0	3½	0	Hot
Common Shell:—															
10-in. gun . . .	86	12	1⅞	·5	2½	·6	2¾	·7	3	·8	3⅜	·8	3⅝	·9	
8-in. " . . .	65	10	1¾	·4	2¼	·5	2⅝	·6	2⅞	·7	3¼	·8	3½	·9	
32-pr. " . . .	56	10	1½	·4	1⅝	·5	1⅞	·5	2	·6	2½	·7	3	·8	
Diaphragm Shrapnel Shell:—															
8-in. gun . . .	65	8	...		3	·5	3½	·6	4	·7	4¾	·8	5½	·9	
32-pr. " . . .	56	10	...		2	·4	2¼	·5	2⅝	·6	3	·7	3½	·8	

Table XXIV.

Ranges, &c., for the 150-*pr. and* 100-*pr. Built-up SB. Guns.*

Range	150-pr. 12-ton gun		100-pr. ML. wrought-iron gun of 6¼ tons									
	Common shell		Solid shot			Common shell						
	Charge 40 lbs.		Charge 25 lbs.	Charge 20 lbs.	Charge 12 lbs.	Charge 25 lbs.		Charge 20 lbs.		Charge 12 lbs.		
	Elevation	Time of flight	Elevation	Elevation	Elevation	Elevation	Time of flight	Elevation	Time of flight	Elevation	Time of flight	
yds.	° ′	″	° ′	° ′	° ′	° ′	″	° ′	″	° ′	″	
100	0 5	0·2	0 6	0 8	0 10	0 5	0·2	0 6	0·2	0 8	0·2	
200	0 11	0·4	0 14	0 16	0 20	0 12	0·4	0 14	0·4	0 18	0·5	
300	0 18	0·6	0 22	0 25	0 30	0 19	0·6	0 22	0·6	0 30	0·8	
400	0 25	0·8	0 30	0 34	0 42	0 27	0·8	0 31	0·9	0 42	1·1	
500	0 32	1	0 38	0 43	0 54	0 36	1·1	0 40	1·2	0 54	1·4	
600	0 40	1·2	0 47	0 53	1 6	0 45	1·4	0 50	1·5	1 8	1·7	
700	0 49	1·5	0 57	1 3	1 20	0 55	1·7	1 1	1·8	1 23	2	
800	0 58	1·8	1 7	1 13	1 34	1 5	2	1 12	2·1	1 39	2·3	
900	1 8	2·1	1 18	1 24	1 49	1 16	2·3	1 24	2·4	1 55	2·6	
1000	1 18	2·4	1 30	1 36	2 5	1 28	2·6	1 37	2·7	2 12	2·9	
1100	1 30	2·7	1 43	1 49	2 22	1 40	2·9	1 52	3	2 30	3·2	
1200	1 42	3	1 56	2 4	2 41	1 52	3·2	2 8	3·3	2 49	3·5	
1300	1 55	3·3	2 10	2 19	3 0	2 6	3·5	2 24	3·7	3 9	3·9	
1400	2 8	3·6	2 24	2 35	3 21	2 21	3·8	2 42	4·1	3 30	4·3	
1500	2 22	4	2 39	2 51	3 43	2 38	4·2	3 1	4·5	3 53	4·7	
1600	2 38	4·4	2 55	3 8	4 6	2 55	4·6	3 21	4·9	4 18	5·1	
1700	2 54	4·8	3 12	3 26	4 31	3 12	5	3 42	5·3	4 43	5·5	
1800	3 11	5·2	3 30	3 45	4 56	3 31	5·4	4 4	5·7	5 10	5·9	
1900	3 30	5·6	3 49	4 5	5 22	3 52	5·8	4 28	6·1	5 38	6·3	
2000	3 49	6	4 9	4 25	5 49	4 14	6·2	4 53	6·5	6 8	6·7	
2100	4 10	6·4	4 29	4 47	6 18	4 37	6·6	5 19	7	...	...	
2200	4 32	6·8	4 50	5 9	6 48	5 0	7	5 46	7·4	...	...	
2300	4 55	7·2	5 12	5 32	7 18	5 25	7·5	6 14	7·9	...	...	
2400	5 19	7·6	5 35	5 56	...	5 52	8	6 43	8·4	...	...	
2500	5 44	8	5 58	6 21	...	6 20	8·5	7 13	8·9	...	...	

The following Table has been taken from the practice carried on by the Gentlemen Cadets of the Royal Military Academy during the years 1857 to 1864.

Table XXV.—*Ricochet Practice from SB. Ordnance.*

Range 600 yds.

Nature of Ordnance	Charge		Elevation	Fuze	Projectile
	lbs. oz.	prop.	deg.	in.	
8-inch gun, 52 cwt.	2 0	$\frac{1}{24}$	$5\frac{3}{4}$	...	Hollow shot
32-pr. gun, 25 cwt.	1 8	$\frac{1}{21}$	$4\frac{7}{8}$	...	Solid shot
do. do.	1 5	$\frac{1}{24}$	$5\frac{1}{4}$	...	
10-inch howitzer	3 0	$\frac{1}{29}$	$6\frac{1}{2}$	...	Hollow shot
do. do.	3 9	$\frac{1}{24}$	$5\frac{1}{2}$	·8	Com, shell
8-inch howitzer	2 0	$\frac{1}{24}$	$6\frac{1}{4}$	·8	

When the charges are very small, and the velocities of projectiles consequently low, wind is found to decrease greatly the accuracy of fire at a range of 600 yds.

Table XXVI.—*Ranges of Mortar Shells.*

At 45°.

Range	13-inch		10-inch		8-inch		$5\frac{1}{2}$-inch		$4\frac{2}{5}$-inch	
	charge	fuze	charge	fuze	charge	fuze	charge	fuze	charge	fuze
yds.	lbs. oz.	in.	lbs. oz.	in.	lbs. oz. dr.	in.	oz. dr.	in.	oz. dr.	in.
200	...	...	...	...	...	...	...	...	2 0	1·55
250	...	...	...	...	...	...	...	...	2 3	1·6
300	...	...	...	...	...	...	4 8	1·65	2 6	1·65
350	...	...	...	...	...	...	4 12	1·7	2 9	1·7
400	1 12	1·8	0 15	1·8	0 9 8	1·8	5 0	1·75	2 12	1·75
450	1 15	1·9	1 0	1·9	0 9 12	1·9	5 4	1·8	3 0	1·8
500	2 1	2	1 2	2	0 10 12	2	5 8	1·85	3 4	1·85
550	2 3	2·1	1 3	2·1	0 12 8	2·1	5 12	1·9	3 8	1·9
600	2 5	2·2	1 $4\frac{1}{2}$	2·2	0 13 12	2·2	6 0	1·95	3 12	1·95
650	2 7	2·3	1 6	2·3	0 14 10	2·3	6 4	2	4 0	2
700	2 9	2·4	1 $7\frac{1}{2}$	2·4	0 15 4	2·4	6 8	2·1	4 5	2·1
750	2 $11\frac{1}{2}$	2·45	1 $8\frac{1}{2}$	2·45	0 15 14	2·45	6 12	2·2	4 10	2·2
800	2 $13\frac{1}{2}$	2·5	1 10	2·5	1 0 10	2·5	7 1	2·3	4 15	2·3
850	3 0	2·55	1 11	2·55	1 1 4	2·55	7 6	2·4		
900	3 2	2·6	1 12	2·6	1 2 0	2·6	7 11	2·45		
950	3 4	2·65	1 13	2·65	1 2 12	2·65	8 0	2·5		
1000	3 7	2·7	1 14	2·7	1 3 8	2·7	8 6	2·55		
1050	3 9	2·75	2 0	2·75	1 4 0	2·75				
1100	3 11	2·8	2 $1\frac{1}{2}$	2·8	1 4 12	2·8				
1150	3 14	2·85	2 $2\frac{1}{2}$	2·85	1 5 4	2·85				
1200	4 0	2·9	2 $4\frac{1}{2}$	2·9	1 6 0	2·9				
1300	4 5	3	2 $6\frac{1}{2}$	3						
1500	4 15	3·2	3 0	3·2						
1700	5 10	3·4	3 4	3·4						
2000	...	...	...	...	2 0 0					
2400	...	...	4 0							
2900	9 0									

$5\frac{1}{2}$-inch at 15°	$4\frac{2}{5}$-inch at 15°
6 0 350 yards 0·7 in.	4 8 450 yards 0·8 in.
7 0 400 yards 0·75 in.	4 12 500 yards 0·85 in.
7 8 450 yards 0·8 in.	**at 25°**
8 0 500 yards 0·85 in.	4 0 540 yards 1·1 in.

Range	BL. 40-pr.			BL. 20-pr.			BL. 12-pr.			BL. 9-pr.			64-pr. ML. gun of 64 cwt. R. Solid shot and common shell			
													Charge 8 lbs.		Charge 6 lbs.	
	Elevation	Time of flight	Fuze s. 1·80	Elevation	Time of flight	Fuze s. 1·85	Elevation	Time of flight	Fuze s. 2·05	Elevation	Time of flight	Fuze s. 2·10	Elevation	Time of flight	Elevation	Time of flight
yds.	° ′	sec.	in.	° ′	sec.	in.	° ′	sec.	in.	° ′	sec.	in.	° ′	″	°	″
100	..	..	..	..	..	..	0 6	..	..	0 5	..	..	0 7	0·2	0 12	0·3
200	0 16	..	..	0 18	0·40	0·22	0 15	0·60	0·31	0 14	0·70	0·31	0 18	0·4	0 27	0·5
300	0 26	1	0·55	0 30	0·90	0·50	0 23	0·85	0·44	0 24	1	0·44	0 30	0·7	0 43	0·8
400	0 37	1·27	0·71	0 42	1·25	0·70	0 35	1·12	0·58	0 36	1·35	0·58	0 42	1	0 58	1·1
500	0 49	1·52	0·84	0 57	1·57	0·88	0 47	1·45	0·75	0 49	1·70	0·75	0 55	1·3	1 14	1·4
600	1 2	1·79	0·99	1 12	1·90	1·06	1 1	1·82	0·94	1 4	2	0·94	1 8	1·6	1 31	1·7
700	1 16	2·08	1·16	1 27	2·25	1·26	1 14	2·14	1·11	1 20	2·3	1·11	1 21	1·9	1 48	2
800	1 30	2·38	1·32	1 42	2·58	1·44	1 27	2·46	1·27	1 37	2·65	1·27	1 35	2·2	2 5	2·3
900	1 45	2·69	1·49	1 58	2·90	1·62	1 41	2·75	1·42	1 54	3	1·42	1 49	2·5	2 23	2·7
1000	2 1	2·90	1·61	2 14	3·26	1·82	1 56	3·06	1·59	2 12	3·3	1·59	2 3	2·8	2 41	3
1100	2 17	3·31	1·84	2 30	3·60	2·01	2 12	3·40	1·76	2 30	3·6	1·76	2 17	3·1	2 59	3·3
1200	2 33	3·62	2·01	2 47	3·96	2·21	2 29	3·75	1·94	2 49	3·95	1·94	2 32	3·4	3 17	3·6
1300	2 50	3·93	2·18	3 6	4·30	2·40	2 46	4·10	2·12	3 8	4·3	2·12	2 47	3·8	3 36	4
1400	3 7	4·24	2·36	3 25	4·63	2·59	3 4	4·43	2·30	3 27	4·6	2·30	3 2	4·1	3 55	4·3
1500	3 24	4·55	2·53	3 44	5·00	2·78	3 22	4·78	2·48	3 47	5	2·48	3 18	4·4	4 15	4·7
1600	3 40	4·86	2·70	4 3	5·35	2·99	3 40	5·15	2·67	4 7	5·35	2·67	3 34	4·7	4 35	5·1
1700	3 57	5·18	2·87	4 22	5·68	3·17	3 59	5·50	2·85	4 27	5·7	2·85	3 51	5·1	4 55	5·4
1800	4 14	5·50	3·06	4 42	6·02	3·36	4 18	5·82	3·01	4 48	6·15	3·01	4 8	5·5	5 15	5·8
1900	4 30	5·83	3·24	5 2	6·38	3·56	4 37	6·18	3·20	5 10	6·50	3·20	4 26	5·8	5 36	6·2
2000	4 46	6·16	3·42	5 22	6·72	3·75	4 56	6·48	3·36	5 32	6·90	3·36	4 44	6·2	5 57	6·6
2100	5 3	6·49	3·61	5 42	7·10	3·97	5 16	6·88	3·56	5 55	7·3	3·56	5 2	6·5	6 19	6·9
2200	5 20	6·82	3·79	6 3	7·50	4·19	5 36	7·27	3·77	6 18	7·7	3·77	5 20	6·9	6 41	7·3
2300	5 38	7·14	3·97	6 25	7·84	4·38	5 57	7·65	3·96	6 42	8·1	3·96	5 40	7·2	7 3	7·7
2400	5 56	7·47	4·15	6 46	8·22	4·59	6 0	8·03	4·16	7 6	8·55	4·16	6 0	7·6	7 25	8·1
2500	6 14	7·79	4·33	7 8	8·58	..	6 43	8·42	4·36	7 32	8·95	4·36	6 20	7·9	7 47	8·5
2600	6 32	8·12	4·51	7 30	8·92	..	7 5	8·81	4·56	7 58	9·4	4·56	6 41	8·3	8 30	8·9
2700	6 50	8·45	4·69	7 52	9·30	..	7 28	9·22	..	8 25	9·85	..	7 2	8·7	8 33	9·3
2800	7 8	8·78	4·88	8 14	9·68	..	7 51	9·64	..	8 52	10·25	..	7 23	9·1	8 56	9·7
2900	7 26	9·12	5·07	8 36	10·05	..	8 14	10·04	..	9 17	10·70	..	7 45	9·4	9 19	10·1
3000	7 45	9·46	5·26	8 58	10·41	..	8 37	10·45	..	9 47	11·20	..	8 7	9·8	9 42	10·6
3100	8 4	9·81	5·45	9 20	10·80	..	9 2	10·87	..	..	..	..	8 29	10·2	10 6	11·1
3200	8 24	10·20	5·67	9 42	11·20	..	9 28	11·28	..	..	..	..	8 51	10·6	10 30	..
3300	8 45	10·63	5·91	10 5	11·55	..	9 55	11·70	..	..	..	..	9 13	10·9	..	..
3400	9 7	11·08	6·16	10 28	11·90	..	..	..	..	..	..	..	9 35	11·3	..	..
3500	9 30	11·54	6·41	10 50	12·35	..	..	..	..	..	..	..	9 57	11·7	..	..
3600	9 52	11·98	6·66	..	..	..	..	..	..	..	..	..	10 19	..	..	..
3700	10 15	12·46	6·92	..	..	..	..	..	..	..	..	..	..	..	..	..
3800	10 38	12·98	7·21	..	..	..	..	..	..	..	..	..	..	..	..	..
3900	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4000	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table XXVII.—*Ranges of Carcasses.*

13, 10, and 8-inch Mortars							5½ and 4⅖-in. Mortars		
Range	Charge for						Range	Charge for	
	13-in.		10-in.		8-in.			5½-in.	4⅖-in.
	lbs.	oz.	lbs.	oz.	lbs.	oz.	yds.	oz.	oz.
1100	...		...		1	5	550	5½	3½
1150	...		2	7½	1	5½	600	6	4
1200	...		2	9	1	6½	650	6½	4½
1250	...		2	10	1	7½	700	7	5
1300	4	13½	2	11½	1	8	...	...	...
1350	5	0	2	12½	1	9½	...	...	...
1400	5	3	2	14	1	10½	...	...	...
1450	5	6	2	15	1	11	...	...	...
1500	5	9	3	0	1	12	...	...	...
1550	5	12	3	1½	1	13	...	...	...
1600	5	15	3	3	1	14	...	...	...
1650	6	2½	3	4	1	15½	...	...	...
1700	6	5½	3	5	2	1	...	...	...
1750	6	9	3	6½	...		...	...	...
1800	6	13	3	7½	...		...	...	...
1850	7	1	3	9	...		...	...	...
1900	7	5	3	10½	...		...	...	...
1950	7	9	3	12	...		...	...	...
2000	7	13½	3	13½	...		...	...	...

Table XXIX.

Ranges, &c., with Curved Fire, from BL. R. Guns.

Distance of object	LS. 12-pr.			LS. 20-pr.			LS. 40-pr.			
	Elevation for			Elevation for			Elevation for			
	Charge 6 oz.	Charge 8 oz.	Charge 10 oz.	Charge 14 oz.	Charge 16 oz.	Charge 18 oz.	Charge 24 oz.	Charge 28 oz.	Charge 32 oz.	Charge 36 oz.
yds.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
550	5 6	...	...	...	...	...	...	...	...	...
600	5 54	...	...	...	...	...	...	...	...	...
700	6 42	4 15	...	6 20	4 50	...	5 30	...	...	...
800	8 0	5 10	...	7 4	5 30	4 50	6 15	5 20	...	...
900	9 30	6 5	4 40	7 46	6 13	5 30	7 8	5 5	5 5	...
1000	...	6 58	5 20	8 30	6 56	6 10	7 55	6 45	5 45	5 0
1100	...	8 6	6 4	9 10	7 40	6 50	8 35	7 30	6 30	5 40
1200	...	9 20	6 46	9 50	8 25	7 40	9 25	8 12	7 10	6 20
1300	...	...	7 40	...	9 10	8 23	...	9 0	8 0	7 0
1400	...	...	8 40	...	10 0	9 10	...	9 46	8 45	7 40
1500	...	...	9 40	...	...	9 55	...	...	9 30	8 25
1600	...	...	...	...	...	...	...	...	...	9 15

The Table is taken from the Report of the O. S. Committee, who in it remark: 'The present practice has fully satisfied the Committee that Armstrong projectiles may be fired with greatly reduced charges, so as to have a high descending angle, and still retain precision of direction and uniformity of range. This adapts them well for silencing guns covered by traverses, or for breaching caponnières and sunken defences.'—*Proceedings of R. A. Institution*, vol. iii. 250.

TABLE XXX.—*Ranges, &c. of ML. Rifled Guns.* (From the Appendix to the 'Text Book of the Construction and Manufacture of Rifled Ordnance.')

Range	12-inch Weight 35 tons Charge 110 lb. P.		12-inch Weight 25 tons Charge 85 lbs. P.		11-inch Weight 25 tons Charge 85 lbs. P.		10-inch Weight 18 tons Charge 70 lbs. P.		9-inch 12 tons 50 lbs. P.		9-inch 12 tons 30 lbs. R.L.G.		7-inch 7 tons 22 lbs. R.L.G.		7-inch 7 tons 14 lbs. R L G.		16-pr. 12 cwt. Charge 3 lb. R.L.G		9 pr. 8 cwt. Charge 1¼ lb. R.L.G.	
	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight	Elevation	Time of Flight
yds.	°	′	° ′	secs	° ′	secs	° ′		° ′	secs.	° ′	secs.	° ′	secs.	° ′	secs.	° ′	secs.	° ′	secs.
100	..	..	7	..	12	..	6	..	6	0·23	11	0·30	5	0·25	11	0·28	..	0 25	..	0·25
400	..	..	31	..	42	..	31	..	20	0·92	47	1 11	25	0 91	43	1·12	19	1·03	26	1·05
700	..	..	58	..	1·12	..	58	..	55	1 63	1 26	1·92	49	1·60	1·16	1·96	57	1·86	1·5	1·95
1000	..	..	1·32	..	1·43	..	1·25	..	1·23	2·36	2 6	2·73	1·16	2·32	1·53	2·80	1·38	2·73	1·44	2·85
1200	..	..	1·57	..	2 5	..	1·47	..	1·44	2·61	2 34	3 27	1·36	2·82	2·20	3·37	2·6	3·32	2·12	3 55
1400	..	..	2·21	..	2·27	..	2·9	..	2·6	3·40	3 2	3·81	1·57	3·34	2·49	3·95	2 36	3·94	2·45	4 15
1600	..	..	2·52	..	2·50	..	2·33	..	2·26	3·95	3·30	4·35	2·19	3·87	3 20	4·53	3·7	4·54	3·20	4 75
1800	..	..	3 20	..	3·14	..	2·57	..	2 52	4 51	4·00	4·91	2·42	4·42	3 52	5·13	3·40	5 23	3 58	5·45
2000	..	..	3·48	..	3·38	..	3 22	..	3·17	5·09	4·30	5·49	3·8	4·99	4·24	5·75	4·15	5 90	4·40	6·15
2500	..	..	4·58	..	4·43	..	4·27	..	4 25	6·59	5·45	6·99	4·16	6·50	5·46	7·32	5 50	7·60	6·34	8·10
3000	..	..	6·8	..	5 52	..	5·36	..	5·38	8·18	7·2	8·58	5·30	8·09	7·14	8 93	7·33	9·60	8 48	10 30
3500	..	..	7·19	..	7·3	..	6·46	..	6·55	9·81	8 25	10·21	6 46	0·69	8·44	..	9·23	11 70	11·27	13·45
4000	..	..	8·31	..	8·19	..	7·56	..	8·17	11·50	9·52	12·01	8·9	..	10·16	..	11 22	13·96	..	..

The above elevations are for Palliser shell for the 12, 11, 10, and 9-inch (with 50 lbs. P.) guns; for common or shrapnel shell for the 9-in. (with 30 lbs. R.L.G.), 7-inch, 16-pr.. and 9-pr. guns.

The following Tables of the penetration of shot and shells are taken from the experiments at Metz, carried on in 1834.

The penetrations in masonry of medium quality are one-fourth greater than those given in the Tables; and in brickwork three-fourths greater. The penetrations into light earth are one-half greater than the tabular quantity; if fresh heaped, nearly double. The penetration into elm is one-third greater, and into pine or birch-wood, three-fourths greater than into oak. From the French experiments at Gavre, in 1836, it was found that a projectile will not lodge in a mass of timber unless it penetrates to a depth nearly equal to its diameter; as the elasticity of the fibres will force the shot or shell out, if the penetration be not deep enough to allow them to close behind the projectile, and so keep it embedded in the wood.

TABLE XXXI.—*Penetration of Mortar Shells.*

(English Measures.)

Angle of elevation	Range	Penetration in Rammed earth			Penetration in Oak			Penetration in Masonry		
		8-in.	10-in.	12-in.	8-in.	10-in.	12-in.	8-in.	10-in.	12-in.
°	yds.	in.	in.	in.	in.	in.	in.	in.	in.	in.
30	704	7·87	17·72	19·68	3·93	7·87	8·66	1·96	3·54	3·93
	1408	13·77	25·59	27·51	6·96	11·19	13·77	3·54	4·72	5·11
45	704	11·19	19·65	21·68	5·90	9·84	10·52	3·14	3·93	4·32
	1408	15·72	27·51	29·52	7·87	13·77	15·72	3·93	5·51	5·90
60	704	17·72	29·52	31·49	8·66	12·99	14·56	4·32	5·90	6·29
	1408	19·65	31·49	33·46	9·84	13·77	15·72	4·72	6·29	6·69

TABLE XXXII.

Penetration of Projectiles from SB. Guns and Howitzers.

(English Measures.)

Calibre		Charge	Distance in yards							
			55	100	219	328	438	656	875	1094
			In good rubble masonry							
pr.	in.		in.	in.	in.	in.	in.	in.	in.	in.
36	6·796	1/3rd	26·4	25·6	23·8	22·2	20·8	17·9	15	12·2
24	6·001	1/3rd	23·8	22·8	21·1	19·5	18·1	15·2	12·2	9·8
		1/4th	22·2	21·5	19·9	18·2	16·7	13·8	11·2	9·1
		1/6th	19·7	18·9	17·3	15·7	14·4	11·8	9·7	7·9
16	5·261	1/3rd	20·7	19·7	17·9	16·3	14·8	11·8	9·3	7·3
		1/4th	19·1	18·2	16·7	15·2	13·8	10·8	8·5	6·7
		1/6th	16·7	16·1	14·6	13	11·6	9·1	7·3	5·9
12	4·775	1/3rd	18·5	17·5	15·9	14·6	13	10	7·7	6·1
		1/4th	17·3	16·5	15	13·4	11·8	8·9	6·9	5·5
8	4·175	1/3rd	15·6	14·8	13·2	11·6	10·2	7·5	5·5	4·1
			In sound oak wood							
36	. .	1/3rd	64·2	62·2	58·3	54·3	50·8	44·1	37·4	31·5
24	. .	1/3rd	57·9	55·9	51·6	47·6	44·1	37·4	30·7	24·8
		1/4th	55·3	52·3	48·4	44·9	41·3	35	28·4	22·8
		1/6th	48·4	46·5	42 9	39·4	36·2	29·5	24	19·3
16	. .	·rd	50	48	43·7	40·2	36·6	29·9	23·8	18·5
		1/4th	46·5	44·5	40·9	37·4	33·9	27·6	21·7	16·1
		1/6th	41·4	39·8	36·2	32·7	29·5	23·2	17·7	14·2
12	. .	1/3rd	44·9	42·9	38·6	35	31·9	25·6	19·7	14·6
		1/4th	42·1	40·2	36·6	33·1	29·9	23·6	18·1	13·4
8	. .	1/3rd	38·2	36·2	32·3	28·7	25·6	19·3	12·8	10·6
		lbs.								
	How. 8-in.	4·4	27·6	26	22·4	19·3	16·5	10	10·6	9·1
		2·2	15·4	14·2	12 6	11·4	10·2	8·7	7·9	7·5
	6 in.	3·3	31·9	30·3	26·8	23·6	20·5	15	11·8	9·8
		2·2	26 8	25·2	21·7	18·5	15·8	11·4	9·1	7·9
24	. .	2·2	26·8	25·2	21·7	18·1	15	10·2	7·9	6·3
			In compact earth, half sand, half clay							
36	. .	1/3rd	106·3	102·4	97·3	93·4	89·4	82·3	75·6	69·7
24	. .	1/3rd	97·7	92 6	85·9	81·1	77·2	70·1	63·8	58·3
		1/4th	90·2	86·7	81·5	77·6	74	67·3	61·8	57·1
16	. .	1/3rd	83·5	79·6	73·6	69·3	65·8	59·9	54·4	49 2
		1/4th	78·3	75·2	69·7	66·5	63·4	57·9	52·4	47·3
12	. .	2/3rd	63·4	59·9	54 7	50·8	48·2	42·9	38·6	35
		1/4th	59·1	55·9	52	48·8	46·1	41·3	37·4	33·9
8	. .	1/3rd	54·7	52	46·9	43 3	40·2	35·4	31·9	28·7
		lbs.								
	How. 8-in.	4·4	47·3	45·3	41·7	38	35·4	30·3	26	23·2
		2·2	41·7	40·2	37	33·9	31·1	27·2	24	21·7
	6-in.	3·3	51·2	48·8	45	41	37·4	30·7	25·2	22·1
		2 2	44·1	42·5	38·6	35	31·9	26·4	22·4	19·7
24	. .	2·2	42·9	41	36 6	32·7	29·1	23·2	18·9	16·1

APPENDIX II.

NOTES ON FOREIGN ORDNANCE.

FRENCH ORDNANCE.

The following table gives the weights, &c., of the French bronze rifled ordnance for garrison, siege, and field service :—[1]

Gun	Weight of Gun	Cal.	Charge	Twist of Grooves	Weight of Shell
	cwt.	in.	lbs.	cals.	lbs.
Canon de 24, long (garrison)	55	6	5·51	1 in 30	52·9 (burster 2·2 lbs.)
,, ,, , short (siege) .	40	,,	,,	,,	,,
,, 12, long (garrison)	30·7	4·7	3·08 (max.)	1 in 24·7	26·45 (burster 1·1 lbs.)
,, ,, , short (siege) .	17·0	,,	2·64 ,,	,,	,,
,, ,, , (heavy field) .	12	,,	,,	,,	,,
,, 8, (heavy field) .	$11\frac{1}{2}$	4·17	1·8	1 in 26	$16\frac{1}{4}$
,, 4, (field) . . .	$6\frac{1}{2}$	3·4	1·19	,,	9
,, 4, (mountain) . .	2	3·4	·62	,,	9

All these guns are muzzle-loading, and rifled on the *système la Hitte*, with six angular grooves, the inclination of the driving side being less than that of the other side, so that when the shell passes through the bore on coming out, the studs rise up the side of the grooves, and the projectile is centred. (See page 36.) Only the short 24-pr. is a new piece, the others being SB. guns rifled. This short 24-pr. has no preponderance when loaded, and is mounted on a wrought-iron bracket carriage, which has no elevating screw, but a clamp at each trunnion-hole, and allows of elevation up to 60° being given to the gun;[2] a BL.R. 7-pr. field-piece was introduced at the end of the last war. Besides the bronze pieces there is a rifled cast-iron canon de 30 for garrison or sea service; it weighs $78\frac{1}{2}$ cwt. and throws a projectile of $55\frac{3}{4}$ lbs. with a

[1] The details have been obtained by comparing those given in the *Handbook for Field Service*, 1867; *Aide-Mémoire Portatif;* Lieut.-Col. Owen's *Report on Artillery exhibited in Paris in* 1867; and Capt. Ellis' translation of *The War in* 1870-71.

[2] In Capt. Ellis' translation of *The War in* 1870–71 it is said (p. 93) that the elevation is preserved merely by the friction of the trunnions, which are therefore made of large diameter; but the carriage I have seen in France had a clamp, as stated above.—C. H. O.

$5\frac{1}{2}$ lbs. charge. The naval gun de 16 *c.m.* (in the next Table) was used in some of the Paris works against the Germans.

The French adopted some six years ago, for naval service, four different natures of heavy breech-loading rifled guns, which were made

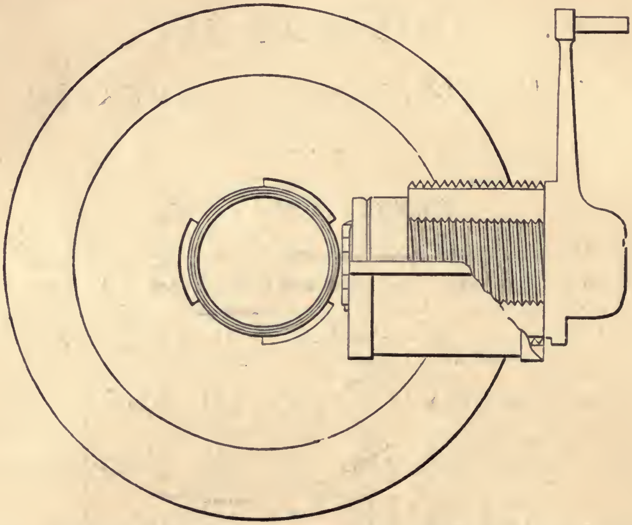


Fig. 1.—Breech open (part of tray removed to show form of breech-plug).

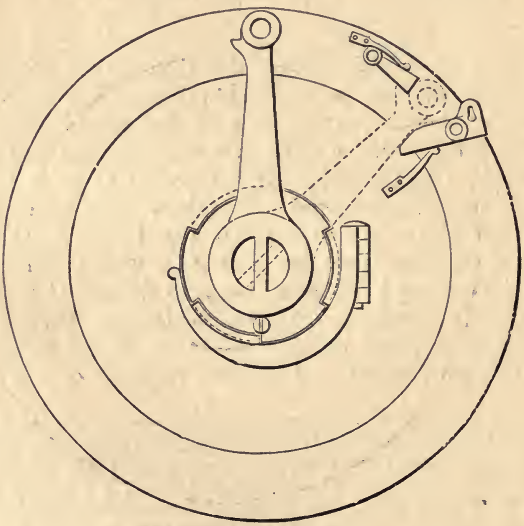


Fig. 2.—Breech closed.

of cast-iron, strengthened behind the trunnions with steel rings shrunk on. The castings were made at the Imperial foundry at Ruelle, near Angoulême, but the steel rings were supplied by MM. Petin and Gaudet. The breech-loading arrangement is similar in principle to that proposed by Eastman, several of whose guns were purchased by the British Government during the Crimean War, but have never been used. The bore is closed by a steel plug, with a thread on its exterior surface, fitting into a screw in the breech of the gun: a brass tray hung on hinges supports the plug when withdrawn from the gun previous to loading (Fig. 1). The thread does not extend round the plug, but it consists of three separate equal portions, which together cover one-half of the surface of the plug; the thread is removed from the three intervening spaces, and this is also the case in the breech. The plug can therefore be easily entered, its screwed portions passing up the plane surfaces in the breech; but when pressed home and turned by a lever handle through one-eighth of a circle, the threads of the plug lock into those in the breech, and the plug is secured in its place. The lever when pressed down passes a spring catch, which secures it, and prevents the plug unscrewing itself (Fig. 2). The lanyard is nipped by the catch until the lever is pressed down, when it is released, so that the gun cannot be fired until the plug is home. Attached to the face of the plug is a circular steel plate with a steel cup screwed on to it to prevent the escape of gas. A thick wad of dried seaweed is put between the cartridge and the base of the projectile. The chief partic lars respecting these ordnance[3] are given in the following Table:—

Gun	Weight	Calibre	Charge		Projectile	
			Battering	Service	Battering	Service
	tons cwt.	in.	lbs.	lbs.	lbs.	lbs.
Canon de 27 c.m.	21 13	10·82	66·2	53	476	310
„ 24 „	13 16	9·45	52·9	35·3	317	220
„ 19 „	7 17·6	7·64	27·5	17·6	165	115
„ 16 „	4 18·5	6·48	16·5	11	99	69 5

The charge is therefore rather more than one-sixth of the projectile. The canon de 16 has three grooves; the others have five. The twist of the grooves is increasing, from 0 to 1 turn in 30 calibres at the muzzle. A large amount of windage, ·2 inch, is given. These guns are mounted on wrought-iron carriages and slides, on the box-girder

[3] The above description of the four naval guns and the breech-loading arrangement is taken, with a few alterations, from Lieut.-Col. Owen's *Report on Artillery exhibited in Paris in* 1867. A monster breech-loading smooth-bored piece of similar construction, but of 42 centimètres (16½ in.) calibre, was exhibited in Paris in 1867. This gun weighed 38 tons, and was intended to fire a solid spherical shot of 660 lbs., with a charge of 110 lbs., and a spherical shell of 462 lbs., holding a bursting charge of 19·8 lbs., with a charge of 72·6 lbs.

construction; the breech of the gun in these carriages is supported by a chain suspended between the brackets.

The compression is given on both sides by a brake of gun-metal embracing the side-piece of the slide, the thickness of which increases from front to rear, so that the compression becomes greater as the piece recoils. The projectiles, which have copper studs, are common shell, and both flat-headed and pointed steel shot, the flat-headed being for close quarters.

The endurance of strengthened rifled ordnance is very doubtful, the results of our own experiments and the failure of the Parrott rifled guns in America proving that little reliance can be placed on cast iron, even when strengthened, for a rifled piece. As, however, there is a certain amount of windage, and a slow-burning powder is used, the strain will probably be less than with ordinary BL. guns. It is also only fair to state, on the authority of a French naval officer, that one of the 24 c.m. guns has stood over 1,000 rounds with battering charges and projectiles.

A heavy gun, lately made in France,[4] has an inner tube of steel surrounded by cast iron and strengthened with external steel hoops; it has a calibre of 12·6 inches, it weighs 34·5 tons, and fires a 760·5 lbs. projectile with a charge of 136·69 lbs. of powder in very large grains.

PRUSSIAN ORDNANCE.

The following are the field and siege rifled BL. guns:—

Gun	Calibre	Charge	Weight of Shell
4-pr.	7·85 c.m.	$\frac{1}{4}$ to 1 lb.	9 lb.
6-pr.	9·15 "	·4 " 1·2 "	15 "
12-pr.	12·03 "	·7 " 2 1 "	31 "
24-pr. (15 c.m.)	14·91 "	1·6 " 4·3 "	61 "

The 4 and 6-prs. are of steel (Krupp's), the 12-pr. is a converted bronze gun, and some of the 24-prs. are converted bronze, others converted cast iron. The BL. system is the double wedge.

The following Table gives details of the heavy guns:—

[4] Report on the French Artillery, by Lieut.-Col. Reilly, C.B., Assistant Director of Artillery. This Report contains details of the ordnance lately tried in France.

German Heavy Guns.[5]

Nature of Gun	Calibre	Weight	Length of Bore	Highest Charge	Weight of Shell	Initial Velocity	Energy foot tons	Remarks
	ins.	cwt.	ins.	lbs.	lbs.	f. s.		
12 c.m. (bronze) .	4·736	17·07	75·32	2·31	31·0	978	206	
15 ,, short . .	5·870	29·53	73·90	3·31	61·1	830	292	
15 ,, long . .	,,	59·05	..	13·67	61·1	1608	1096	New siege gun
17 ,, naval . .	6·796	120·07	144·1	25·35	123·0	1559	2073	
		tons						
21 ,, short . .	8·236	8·86	132·5	37·48	217·2	..	..	
21 ,, long . . .	,,	9·79	163·39	37·48	217·2	1385	2889	
24 ,, short . .	9·268	14·52	157·05	52·91	306·4	..	..	
24 ,, long . . .	,,	15·26	177·64	52·91	306·4	1312	3657	
26 ,, ...	10·236	21·65	194·49	70·55	415·5	1385	5514	
28 ,, ...	11·024	27·07	207·09	88·18	515·9	1394	6953	

These pieces are fired with prismatic powder. The system of rifling has been described on page 33. As before mentioned, the Prussians have a rifled mortar of 21 c.m. calibre, throwing a shell which holds a bursting charge of 15 lbs., exploded by a percussion fuze.[6] A monster 1000-pr. gun of 14-in. calibre was exhibited in Paris in 1867, but like the enormous SB. French gun, it has never been fired.[7]

The heavy guns are built up of steel, on the Krupp method of manufacture, and with the Krupp single cylindrical breech-loading arrangement, which may be thus described:[8]—The 9-in. gun is forged from one ingot, except the trunnion-ring, which is a separate forging. The breech-loading arrangement is a simple cylindro or round-backed wedge, the flat front surface forming the bottom of the bore; it can be quickly moved in or out by means of a screw in the top of the wedge,

[5] From Lieut.-Col. Reilly's *Notes of a Visit to Berlin.*

[6] An interesting and able paper by Capt. (now Major) Majendie, R.A., comparing the English and Prussian guns, called 'English Guns and Foreign Critics,' was given in the *Proceedings of the R.A. Institution*, vol. vii. p. 60.

[7] The 1,000-pr. has a forged inner tube strengthened with three layers of rings over the powder chamber and two layers over the muzzle portion; the rings are forged from ingots without welding. The manufacture of this gun continued during night and day for 16 months, and the cost of the piece is 15,750*l.* The breech-loading arrangement is complicated, and some time would be necessary to go through the different operations in loading. The enormous scale on which M. Krupp's works are conducted will be understood when it is stated that they cover about 450 acres of ground, about one-fourth of which is under cover; that the number of men employed is 8,000, besides 2,000 more in the coal mines at Essen, at the blast furnaces on the Rhine and at the iron pits on the Rhine, and in Nassau; also, that during last year the produce of the works was 61,000 tons, by means of 112 smelting, reverberatory, and cementing furnaces; 195 steam engines, from 2 to 1,000 horse power; 49 steam-hammers, from 1 to 50 tons (the blocks); 110 smith's forges, 318 lathes, 111 planing machines, 61 cutting and shaping machines. The establishment has already delivered 3,500 guns, valued at over 1,050,000*l.*, and it has received orders for the immediate delivery of 2,200 more. Most of the guns made are rifled breech-loaders, from 4 to 300-prs.—Lieut.-Col. Owen's *Report on Artillery at Paris in* 1867.

[8] From Lieut.-Col. Owen's *Report on Artillery at Paris in* 1867.

working half in the latter and half in a nut let into the metal of the gun above. To force the wedge completely home, another screw in the back of the wedge is, however, necessary. The nut in which this second tightening screw works has a certain play right or left, but it can be rendered immovable by the head of a catch pin behind the wedge, and at right angles to it, being screwed forward into a slot cut in the back of the nut. The nut being thus fixed, after the wedge has been brought nearly into its place by the first screw, the point of the tightening screw pushes the wedge home (Figs. 3, 4, and 5). The round-backed wedge has the following advantages over the rectangular wedges: it has no angular surfaces, the strain is more uniformly dis-

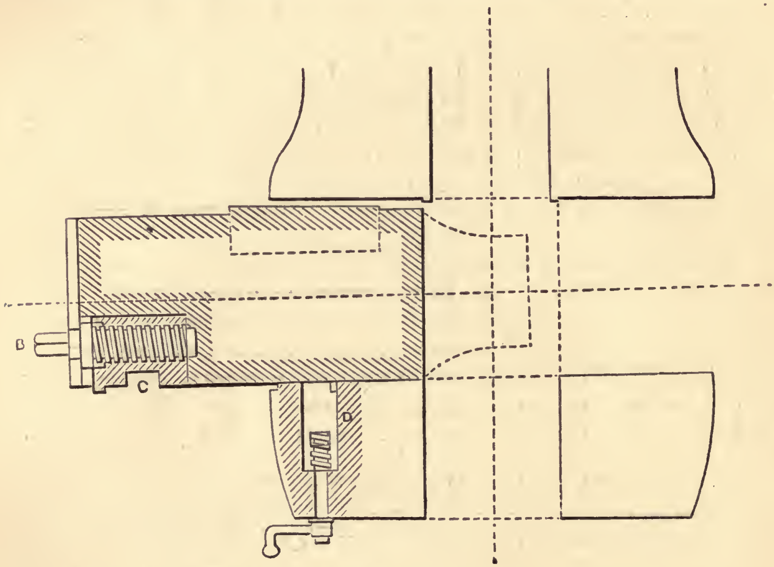


Fig. 3.—Krupp's Cylindrical Wedge (9-in. BL. gun). Horizontal section.

tributed, and the wedge is stronger. The escape of gas is prevented by the use of a copper cup, inserted when loading, or of a steel Broadwell ring, fitting against the face of the wedge and the bottom of the bore. A shot-bearer is attached behind the breech, through which a wooden loading-box, with the projectile in it, is inserted, and the shot thus prevented from catching in the wedge slot. The wedge can be easily and rapidly worked.

A similar semi-cylindrical wedge for closing the breech of a field gun was shown by M. Krupp at Paris in 1867; it has only one screw, working into a thread running across the breech over the wedge, and turned by a lever handle in the left side, a Broadwell ring preventing the escape of gas.[9] Lieut. Col. Reilly, in his *Notes*, gives a description of a single rectangular wedge, which is not so strong as the round-backed wedge, the latter being proposed by M. Krupp as an improvement on the former.

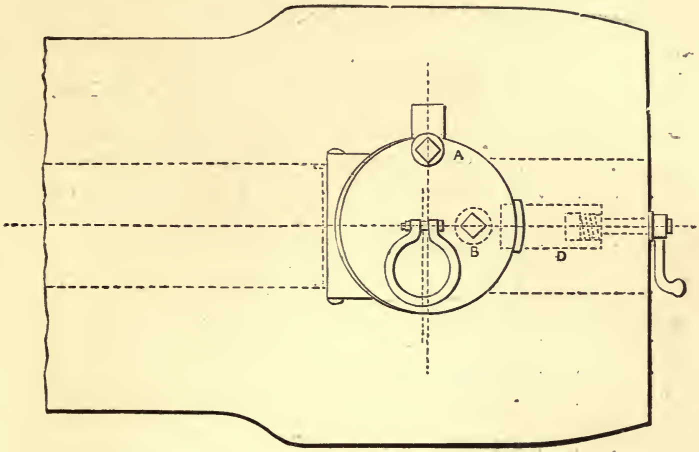


Fig. 4.—Side View.

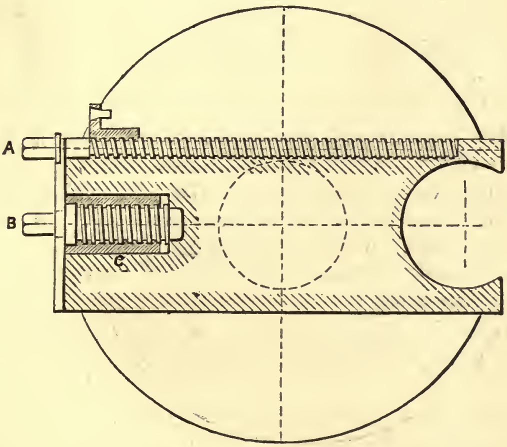


Fig. 5.—Vertical Section.

A. Screw for moving wedge in or out. B. Screw for tightening wedge. C. Nut of tightening screw. D. Catch-pin.

[9] See Lieut.-Col. Owen's *Report on Artillery at Paris in* 1867.

RUSSIAN ORDNANCE.

Russia has obtained considerable numbers of guns from Krupp, but the Government has established steel factories of its own.

Gun	Weight of material	Calibre	Charge	Common shell	Shell	Remarks
	cwt.	in.	lbs. oz.	lbs. oz.	lbs. oz.	
Mountain:						
3-pr.	2 (bronze)	3	0 13	9 12	11 3 (shrapnel)	
Field:						
4-pr.	6¾ (bronze) 6 (steel)	3·42	0 7 0 10 1 8	14 0	16 2 ,,	
9-pr.	12 (bronze) (steel)	4·2	0 11 1 1 3 0	27 0		
Siege and Garrison:						
12-pr.	18½ ,,	4·8	3 8	36 0		
24-pr.	43¾ ,,	6	7 0	71 4		
8-in. (light) . . .	101¾ (steel)	8	19 0	195 0	192 0 (chilled)	Prismatic powder
Coast:						
6·03-inch . . .	75½ ,,	..	16 0 19 0	93 0	96 0 (steel)	
8-in. (unstrengthened)	148¾ ,,	..	25 0	195 0 (hardened iron)	195 0 ,,	
,, (strengthened with hoops) . .	176¾ ,,	..	31½ 0	,, ,,	,, ,,	
8½-in. (unstrengthened).	143¼ ,,	..	25 0	196 2 ,,	200 13 (hardened iron)	
9-in. (strengthened with hoops) . .	292½ ,,	..	52 0	300 0	300 0 (steel)	
11-in.	511	..	91½ 0	431 0	550 0 ,,	

Besides the above are cast-iron BL. R. 12 and 24-pr. garrison guns, and BL. R. mortars of 6 and 8 inches calibre, weighing 30 and 77 cwt., and capable of firing 90 and 195 lbs. shells, with charges of 8 lbs. of cannon and 19 lbs. of prismatic powder respectively. All the guns are breech-loading, some having one and others two wedges.[1]

The Russians also possess 50 batteries of mitrailleuses, each of 8 pieces, the system being the Gatling 10-barrel, with an arrangement to give lateral spread. Each mitrailleuse is supplied with 6,290 rounds, in 262 cases, conveyed in an ammunition cart.[2]

[1] For the above list of Russian ordnance see Capt. (now Major) C. Brackenbury's *Foreign Armies and Home Reserves*, p. 86.

[2] See a lecture on 'The Russian Army,' by Lieut. C. E. H. Vincent, 23rd R.W. Fusileers, at the R. U. S. Institution, May 17, 1872.

AMERICAN ORDNANCE.

The following Table gives the weights, &c., of the large SB. cast-iron ordnance used in the service of the United States of America :—

SB. Cast-iron American Ordnance.

Gun	Weight of gun	Charge		Weight of shot	Weight of shell	Bursting charge of shell
		Service	Maximum			
–	tons	lbs.	lbs.	lbs.	lbs.	lbs.
20-in. LS.	51·42	100	...	1000		
do. SS.	44·64	100	...	1000		
15-in. LS.	21·91	50	...	440	330	17
do. SS.	18·75	35	60	400		
13-in. LS.	14·61	30	...	300	224	7
do. SS.	16·07	40	...	280	224	
11-in. SS.	7·14	15	20	170	130	
10-in. LS.	6·72	{15 shell, 18 shot}	...	127½	100	3
do. SS.	5·35	12½	16	125	100	
do. SS. (or 125-pr.)	7·36	40	...	125	100	

All cast hollow, except the 10-in. of 5·35 tons.

All shell guns except 10-in. 125-pr.

20-in. gun, only a few made.

Solid shots are only to be fired from the 15-in. SS. gun at iron-clad vessels, and then with 50 lbs.; 20 rounds may, however, be fired with 60 lbs.

A great many different rifled guns were tried by both sides during the late American war, but those most approved of by the Federals were the Parrott guns, which are hooped cast-iron pieces; six of these pieces burst in the Federal fleet while bombarding Fort Fisher, and 44 men were killed, after which they were naturally condemned as unsafe by the admiral.

Rifled Ordnance of the United States Service.

Gun	Weight	Proportional charge	Shot	Common shell	
				Weight	Burster
	cwt.		lbs.	lbs.	lbs.
10-in. . .	...	$\frac{1}{10}$	250		
8-in. . .	...	$\frac{1}{11}$	175		
100-pr. . .	86½	$\frac{1}{7}$ to $\frac{1}{10}$	{100, 70}	100	8
30-pr. . .	37½	$\frac{1}{10}$	30	25	1
			Shrapnel		
20-pr. . .	15½	$\frac{1}{10}$	19½	18¾	
3-in. . .	7½	$\frac{1}{10}$	10	10	

Some 12-in. R. guns are said to have been made, but it is difficult to ascertain any trustworthy particulars concerning them.[3]

[3] For a description of the guns employed in America see Holley's *Treatise on Ordnance and Armour*, Major-Gen. Gillmore's *Engineer and Artillery Operations against Charleston*, and Brig.-Gen. Abbott's paper on *Siege Artillery*.

APPENDIX III.

MITRAILLEUSES.

Mitrailleuses, or machine guns, have attracted much attention of late, and many different constructions—the Requa, Gatling, French service, Montigny, &c.—have been tried experimentally, or in actual war. As stated on page 496, the Federals used the *Requa* at Charleston, and the French have largely employed their mitrailleuses, latterly in batteries of ten pieces, during the late war, and with most destructive effects. The French weapon is much the same in principle as the Montigny. The object of this class of guns is to throw *mitraille* or case shot to longer ranges than can be obtained with effect from ordnance; case shot ranges being about 300 yards, those of mitrailleuses are 1,000, or, in some cases, 1,400 yards. As before pointed out,[1] it must be remembered, in comparing them with ordnance, that these weapons cannot fire shells; they are not effective on material; nor are they of use against troops posted behind cover either natural or artificial.

The Montigny consists of thirty-seven rifled steel barrels hexagonally formed exteriorly, and fitted and soldered into a wrought-iron tube somewhat in the form of an ordinary piece of artillery; this has a movable breech piece worked by means of a lever, and containing a spring and striker corresponding with each barrel. The whole of the barrels can be charged simultaneously by the introduction of a steel plate containing the thirty-seven cartridges; they can be fired independently and at any intervals of time, or the whole may be fired in one second; reloading takes five seconds, and a continuous fire at the rate of ten discharges per minute can be maintained.

The gun is provided with both vertical and horizontal adjustments, and may be made to sweep horizontally along a line by adjustment between each discharge, or during the discharge itself.

As there is no recoil, the gun once laid will continue to throw 28 lbs. weight of projectiles per minute on the same spot, or on various points

[1] In note to page 406.

of any line requiring the same elevation, without any further labour than that involved in the working of the lateral adjustment.[2]

Weight 400 lbs., No. of barrels 37,
Calibre, ·534 in.,
Rifling, Metford,
Hardened bullet, weight 600 grains,
Charge of powder, 115 grains,
Rapidity of fire, ten rounds=370 shots per minute,
Mean absolute deviation at 500 yds., 31 in.,
Angle of elevation at 500 yds., 1° 24′,
Mean absolute deviation, 800 yds., 51 in.,
Angle of elevation at 800 yds., 2° 5′,
Angle of elevation at 1,000 yds., 2° 35′.

The following is a brief description[3] of the construction of the *Gatling Battery* (Fig. 6):—

'The gun consists of a series of barrels in combination with a grooved carrier and lock-cylinder. All these several parts are rigidly secured upon a main shaft. There are as many grooves in the carrier and as many holes in the lock-cylinder as there are barrels. Each barrel is furnished with one lock, so that a gun with ten barrels has ten locks. The locks work in the holes formed in the lock-cylinder on a line with the axis of the barrels. The lock-cylinder, which contains the locks, is surrounded by a casing which is fastened to a frame, to which trunnions are attached. There is a partition in the casing, through which there is an opening, and into which the main shaft, which carries the lock-cylinder, carrier, and barrels, is journaled. The main shaft is also at its front end journaled in the front part of the frame.

'In front of the partition in the casing is placed a cam, provided with spiral surfaces or inclined planes. This cam is rigidly fastened to the casing, and is used to impart a reciprocating motion to the locks when the gun is rotated. There is also in the front part of the casing a cocking-ring, which surrounds the lock-cylinder, is attached to the casing, and has on its rear surface an inclined plane, with an abrupt shoulder. This ring and its projection are used for cocking and firing the gun. This ring, the spiral cam, and the locks, make up the loading and firing mechanism.

'On the rear end of the main shaft, in the rear of the partition in the casing, is located a gear wheel, which works to a pinion on the crank-shaft. The rear of the casing is closed by the cascable plate. There is hinged to the frame in front of the breech-casing a curved plate covering partially the grooved carrier, into which is formed a hopper or opening, through which the cartridges are fed to the gun, from feed

[2] From a description in *Short Notes on Professional Subjects.*
[3] Given by Dr. R. J. Gatling, *Journal of R. U. S. Institution*, vol. xiv. p. 511.

cases. The frame which supports the gun is mounted upon the carriage used for the transportation of the gun.

'The operation of the gun is very simple. One man places a *feed-case* filled with cartridges into the *hopper;* another man turns the *crank*, which, by the agency of the gearing, revolves the main shaft, carrying with it the *lock-cylinder*, *carrier*, *barrels*, and *locks*. As the gun is rotated, the cartridges, one by one, drop into the grooves of the carrier from the feed case, and instantly the lock, by its impingement on the spiral cam surfaces, moves forward to load the cartridge, and when the butt end of the lock gets on the highest projection of the cam, the charge is fired, through the agency of the cocking device, which at this

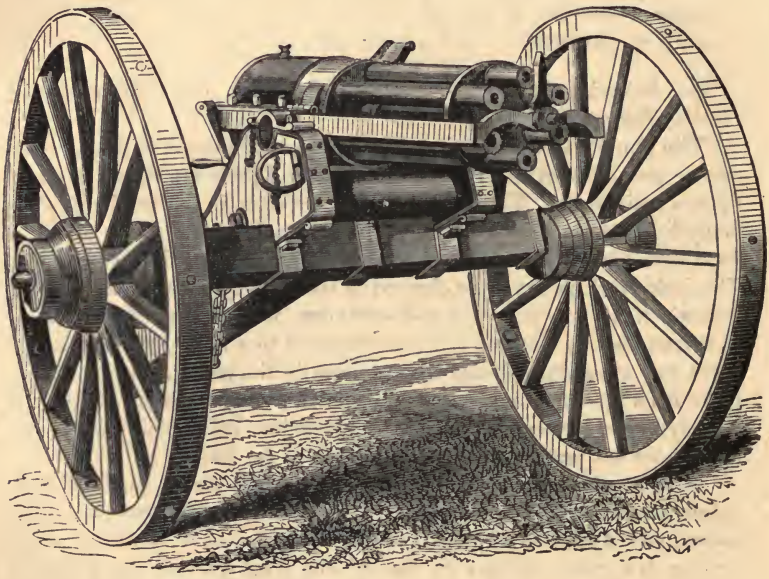


Fig. 6.—Gatling Battery Gun.

point liberates the lock, spring, and hammer, and explodes the cartridge. As soon as the charge is fired, the lock, as the gun is revolved, is drawn back by the agency of the spiral surface in the cam acting on a lug of the lock, bringing with it the shell of the cartridge after it has been fired, which is dropped on the ground. Thus it will be seen, when the gun is rotated, the locks in rapid succession move forward to load and fire, and return to extract the cartridge shells. In other words, the whole operation of loading, closing the breech, discharging, and expelling the empty cartridge shells is conducted while the barrels are kept in continuous revolving movement. It must be borne in mind that while the locks revolve with the barrels, they have also, in their line of travel, a spiral reciprocating movement; that is, each lock revolves once and moves forward and back, at each revolution of the gun.

'By a mechanical arrangement under the breech a lateral motion, right and left, can be given to the gun when discharged, so that a perfect sheet of balls can be made to sweep the sector of a circle within its range.'

Three sizes are made:—

(1) The largest having six barrels with 1-in. calibre, and throwing lead bullets of $\frac{1}{2}$ lb. weight.

(2) Ten barrels, calibre ·75 in., and lead bullets $4\frac{1}{2}$ oz.

(3) Ten barrels, with calibre to suit the musket cartridges of different governments.

The Gatling gun has been adopted for our service, the calibre being ·45 in., like that of the Henry-Martini rifle, but the cartridges are of special construction; each drum or feeding case contains 240 rounds of cartridges (16 columns of 15 in each), which could be discharged in one minute. The number of rounds to be carried with the carriage and in reserve has not yet been decided. The carriage is of iron and weighs about $5\frac{3}{4}$ cwt., and the limber weighs about $6\frac{3}{4}$ cwt. Traversing motion is given to the barrels, and therefore lateral spread to the bullets, by means of a worm fitted with a crutch.

APPENDIX IV.

INSTRUMENTS FOR DETERMINING THE VELOCITIES OF PROJECTILES.

As stated at page 194, the instruments used for determining experimentally the velocities of projectiles may be divided into two classes.

1st. Those depending upon mere mechanical arrangement.

2nd. Those in which electricity is employed to obtain the requisite action.

First Class.

One of the first machines for ascertaining velocities was contrived by Mattei, an Italian mathematical instrument maker, about 1767, and consisted of a vertical paper cylinder attached to a wooden frame; the cylinder being made to rotate by means of a cord having a weight at the end which descended into a well. An equable motion being given to the cylinder, and its velocity being known, the bullet was fired through the cylinder, the holes showing the arc through which the cylinder had turned while the bullet passed across it. Careful experiments appear to have been made with this machine, and the initial velocities of bullets from muskets, wall pieces, and rifled muskets determined. An account of them, as well as a description of the machine, may be found in General D'Antoni's 'Treatise on Gunpowder and Fire-arms.'

About 1804 a modification of Mattei's machine was introduced by Colonel Grobert, a French officer. It consisted of *two discs of card-board connected by a shaft*, to which a rapid rotatory motion could be given. The discs were each divided by radii into 360°.

When put in motion, and a ball fired through them, an *angle was shown* by the hole on the second disc not being in the same radius as that on the first disc, or between the same radii on both discs.

After Grobert's machine came an *improvement on it by Gregory* in 1818. By a system of cogwheels he got a more rapid rotation.

The objection to all these machines is that the time taken by the shot in passing over the requisite space cannot be measured with sufficient minuteness. They cannot measure probably less than $\frac{1}{30}$ second, although Gregory professed to measure $\frac{1}{150}$ second.

Another contrivance was proposed in 1818 by Colonel Dobooz of the French Artillery. It depends on the action of gravity. At fifty yards from the gun is a fixed screen, and just in the front of the latter hangs a movable screen, suspended by a cord passing over a pulley above it. The cord stretches from the pulley to a second pulley just over the muzzle of the gun, before which the cord hangs, being kept down by a weight attached to the end. When the gun is fired the cord is cut, the movable screen descends, and both it and the fixed screen are pierced about the same time. The distance between the holes shows the time taken by the ball in passing fifty yards.

We now come to Robins' pendulum, consisting of a plate of iron, to which was bolted a thin block of wood, 9 in. square. This was suspended by a wooden shaft and axis to a tripod, and the recoil of the block was measured by a ribbon attached to it, and passing through a band on a brace connecting the two front poles of the tripod. The length of ribbon pulled out showed the arc of vibration.

The principle upon which the value of the ballistic pendulum depends is this: By the third law of motion *action and reaction being equal*, if a body impinge on another, the momentum lost by one is gained by the other, and the sum of the momenta is unchanged. So that if a ball be fired at a block into which it penetrates, and where it remains, the momentum of the block and ball together is equal to the momentum of the ball before the impact; and therefore, knowing the weights of the ball and block, if the velocity of the block can be found its momentum is known, and this momentum being equal to that of the ball, the velocity of the ball can be easily found. Thus—

$$\begin{aligned} \text{If } w &= \text{weight of ball,} \\ W &= \text{that of block,} \\ v &= \text{velocity of ball,} \\ V &= \text{velocity of block,} \\ w\,v &= (W+w)\,V, \\ v &= \frac{(W+w)\,V.}{w} \end{aligned}$$

The block, when struck by the ball, recoils upwards, describing an arc, from the magnitude of which the velocity can be calculated. Besides the weight of the block it is necessary to know the distance of *its centre of gravity* from the axis of suspension, and also that of the *centre of oscillation* from the same axis.

In experiments with the ballistic pendulum the velocity found is that with which the shot strikes the block, and not the initial velocity; for the block being at some little distance from the gun, the projectile will have been retarded by the resistance of the air while passing between the gun and block. Besides the ballistic pendulum, the initial velocity of projectiles may be found by means of the gun pendulum, which consists merely of a gun suspended like the block of the ballistic pendulum in a frame so that it can vibrate freely when a force is applied to it. The broad principle of the gun-pendulum is—'that the gas from the explosion of the charge acting equally in all directions, the force exerted to project the ball is equal to that which, acting upon the bottom of the bore of the gun, causes the recoil of the piece, and therefore that the momentum of the gun is equal to that of the ball.'

The velocity of the gun can be found from the *observed arc of vibration*, as with the block of the ballistic pendulum. The gun-pendulum, however, gives too high velocities.[1]

Dr. Hutton made many improvements in the construction of the different parts of these machines. Robins' pendulum was only adapted to bullets, Hutton's to 1-pr. balls. Dr. Gregory carried on experiments in 1814 with a pendulum capable of receiving the balls of 24-pr. guns.

From 1842 to 1846 the French made experiments with a ballistic pendulum suited to balls of over 26 lbs. weight. At about the same time (1842-45) Major Mordecai (U.S. Service) found the velocities of 24 and 32-pr. balls by experiment with the ballistic pendulum. About 1858 a ballistic and a gun-pendulum, of large size and improved construction, were made for the British Government. They were put up first at Shoeburyness, but were removed in 1863 to the Royal Arsenal, Woolwich.

Second Class.

The idea of determining the velocities of projectiles by means of electricity was first suggested many years ago by Professor Wheatstone, who invented in 1840 an instrument called the electro-magnetic-chronoscope for this purpose. Many other instruments have since been contrived—those of Breguet, Vignotti, Navez, Benton, Schultz, &c., but those which have afforded the most valuable results are the—

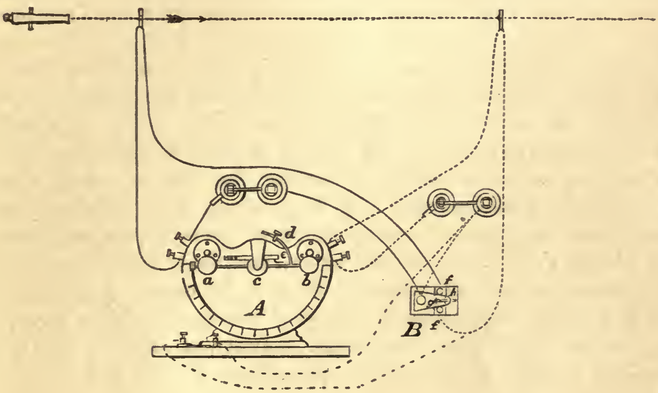
Navez-Leurs chronoscope,
Bashforth chronograph,
Noble chronoscope,
Le Boulengé chronograph.

The *Navez-Leurs Chronoscope* is a modification of the Navez electro-ballistic apparatus; in the former the conjunctor and horse-shoe magnet are suppressed, and an additional pendulum, with a mechanical arrangement to clamp the index needle, is substituted for them. The chronoscope may be said to consist of two separate instruments, the *pendulum* and the *disjunctor*. The pendulum may be thus described.

[1] Boxer's *Treatise*, p. 35.

An upright plate of vulcanite with a graduated arc (Fig. 7 *A*), mounted on a stand, supports two pendulums, two electro-magnets, a pair of springs, and the pivot upon which the escapement system works. One of the pendulums (*a*) is termed the *chronometer pendulum*, and the other (*b*) the *register pendulum*; and the magnets are so adjusted, one behind each pendulum, that when magnetised by a current of electricity they will just sustain the bobs of their respective pendulums, into both of which a piece of soft iron is inserted. An index needle, having a vernier at the end to slide along the graduated arc, is riveted to a steel disc (*c*) working on the same axis as the chronometer pendulum, with which it oscillates, simply by friction, until clamped

Fig. 7.



———————— Circuit from the Battery which magnetises the Chronometer Electro-Magnet.

.... Circuit from the Battery which magnetises the Register Electro-Magnet.

– – – – – – – – Arrangement of the Second Circuit to determine the value of the Coefficient x.

by the action of the escapement. The springs are attached to the vertical plate, and pass one on each side of the steel disc (*c*); near the end of the spring are two cleats, one on each spring, between which a wedge lever (*e*) can be adjusted to keep the springs apart; two other cleats close on the disc of the index needle, which is between the springs, when the wedge lever (*e*) is displaced by the fall of the stirrup (*d*).

The rod of the *register pendulum* is provided with an arc carrying a stirrup (*d*), which, in its descent when the pendulum is released, knocks away the wedge lever (*e*) from between the springs, and so closes them upon the disc (*c*) of the index needle, thus clamping it.

The *disjunctor* (*B*) consists of a small stand, on which are two pieces of brass (ff) each provided with a pressure screw, a brass spring (g) fastened by another pressure screw, and a cam (h) to work the spring; the brass pieces have platinum points, separated from each other by a very short interval, and the spring has also a platinum point below it, which when pressed down by the action of the cam, connects the two other points, thus completing when requisite the circuits through the apparatus.

The electric currents are obtained by means of Bunsen's voltaic batteries, there being two circuits for an ordinary experiment, one (Fig. 7) passing through the magnet of the chronometer pendulum and the first screen, the other through the magnet of the register pendulum and the second screen; as both pass through the disjunctor the simultaneous disjunction of both circuits can be effected by turning the cam, releasing the spring, and so disconnecting the platinum points.

The apparatus is placed in a small hut at a distance of about 130 yds. from the gun, so that it may not be affected by the firing, and the arrangement of the gun and targets is as follows:—The first target (Fig. 7) is placed at a distance of 10 yds. in front of the muzzle of the piece, and the second target 40 yds. beyond the former; both targets are of the same construction and dimensions, each consisting of a wooden frame, having copper wires stretched across in parallel rows by means of pins in the sides of the frame, and these wires are broken by the passage of the shot through them. In order to protect the wires of the first target from the action of the gas a wooden screen is placed about 40 in. from this target, between it and the gun; the screen has a circular hole (about $1\frac{1}{2}$ calibres in diameter) through which the projectile passes.

The operation of the instrument is as follows:—The gun is fired, the projectile passes through the first target, breaks the first circuit, and demagnetises the magnet of the chronometer pendulum; the bob begins to fall, carrying with it the index needle. When the projectile cuts the wire of the second target, the second circuit is broken, and the magnet of the register pendulum is demagnetised, the bob falls, carrying with it the arc and stirrup, which in its descent knocks away the wedge lever, and clamps the index needle.

The time due to this arc of vibration can by the theory of the pendulum be readily ascertained, but it would be greater than the time taken by the projectile to pass from one target to the other; for, a certain small interval of time elapses between the rupture of the second circuit and the clamping of the index needle. This small portion of time is found by means of the disjunctor, before the gun is fired, by breaking both circuits at once, and the small arc so found must be deducted from the arc determined by firing the gun.

The distance between the targets divided by the time thus found will give the velocity of the projectile at the point of the trajectory equidistant from the targets; but as the projectile will, in passing from the gun to this point, have lost a certain amount of velocity, a formula, somewhat similar to Dr. Hutton's, given in Boxer's 'Treatise' (page 33), is generally used to obtain the initial velocity.

The following is a description [2] of the *Bashforth Chronograph*, with its various useful appendages:—Fig. 8 gives a general view of the chronograph. A is a fly-wheel capable of revolving about a vertical axis, and carrying with it the cylinder K, which is covered with prepared paper for the reception of the clock and screen records. The length of the cylinder is 12 or 14 in., and the diameter 4 in. B is a toothed wheel which gears with the wheelwork M so as to allow the string C D to be slowly unwrapped from its drum. The other end of C D, being attached to the platform S, allows it to descend slowly along the slide L, about $\frac{1}{4}$ in. for each revolution of the cylinder. E, E′ are electro-magnets; *d*, *d′* are frames supporting the keepers; and *f f′* are the ends of the springs which act against the attraction of the electro-magnets. When the current is interrupted in one circuit, as E, the magnetism of the electro-magnet is destroyed, the spring *f* carries back the keeper, which by means of the arm *a* gives a blow to the lever *b*. Thus the marker *m* is made to depart from the uniform spiral it was describing. When the current is restored the keeper is attracted, and thus the marker *m* is brought back, which continues to trace its spiral as if nothing had happened. E′ is connected with the clock, and its marker *m′* records the seconds. E is connected with the screen, and records the passage of the shot through the screens. By comparing the marks made by *m*, *m′* the exact velocity of the shot can be calculated at all points of its course. The slide L is fixed parallel to F, and the cylinder K by the brackets G, H. Y is a screw for drawing back the wheelwork M, and J a stop to regulate the distance between M and B. The depression of the lever *h* raises the two springs *s*, which act as levers, and bring the diamond points *m*, *m′* down upon the paper. When an experiment is to be made, care is taken to see that the two currents are complete. The fly-wheel A is set in motion by hand, so as to make about three revolutions in two seconds. The markers *m*, *m′* are brought down upon the paper, and after four or five beats of the clock the signal to fire is given, so that in about ten seconds the experiment is completed, and the instrument is ready for another.

The pendulum of a half-seconds clock strikes once each double-beat a very light spring, and so interrupts the galvanic current in E′ once a second.

Fig. 9 gives the details of the screens. It represents a piece of board 1 in. thick and 6 or 7 in. wide, and rather longer than the width of the

[2] From a pamphlet published by Professor Bashforth (Bell and Daldy), and printed in the *Proceedings of the R. A. Institution.*

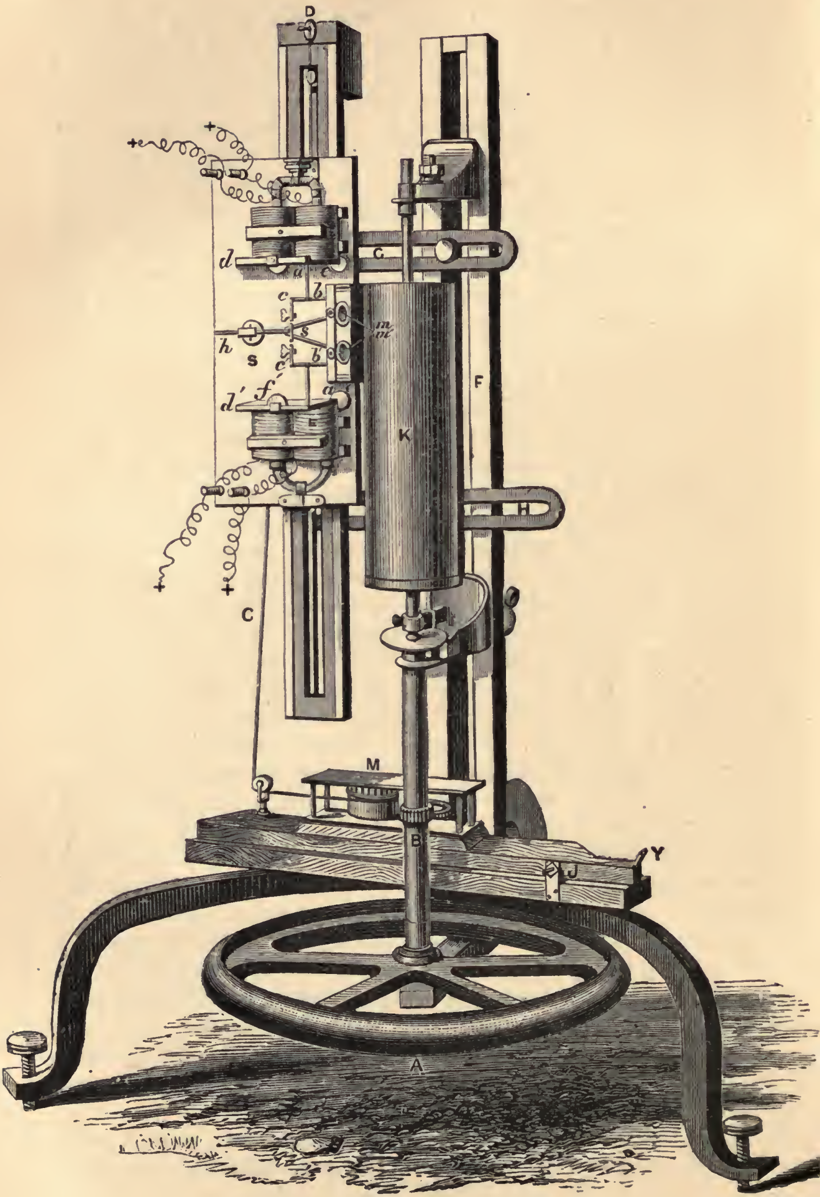


Fig. 8.—Chronograph.

screen to be formed. Transverse grooves are cut at equal distances, something less than the diameter of the shot, as shown in the diagram. Staples of hard brass spring-wire (No. 14 or 15) are fixed with their prongs in the continuation of the grooves. Pieces of sheet copper A

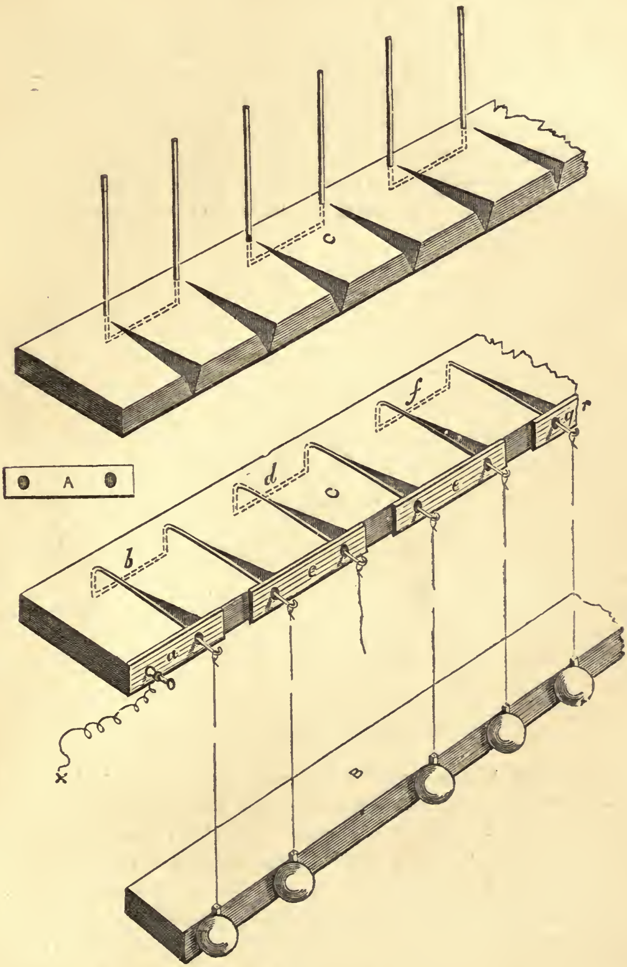


Fig. 9.—Screens.

are provided, having two elliptical holes, the distance of whose centres equals the distance of the grooves. The pieces of copper A are used to connect each wire staple, as C, with its neighbour on each side. Thus, Fig. 9, *a*, *c*, *e*, *g*, &c., represent these copper connexions put in their places and holding down the wire springs, which, when free, are in contact with the tops of the holes; but when properly weighted, they rest on the lower edge of the holes. Thus the copper *c* forms a connexion between the staples *b* and *d*; the copper *e* joins *d* and *f*, and so on. A galvanic stream will therefore take the following course, whether the springs be weighted or unweighted: copper *a*, brass *b*, copper *c*, brass *d*, copper *e*, brass *f*, copper *g*, &c. The current will only be interrupted when one or more threads have been cut and the corresponding spring is flying from the bottom to the top of its hole. About one-fiftieth of a second is required for the complete registration of such an interruption, the spring traversing about half an inch. The shelf B is placed for the weights to rest against, partly to prevent them from being carried forward by the shot, but chiefly to prevent the untwisting

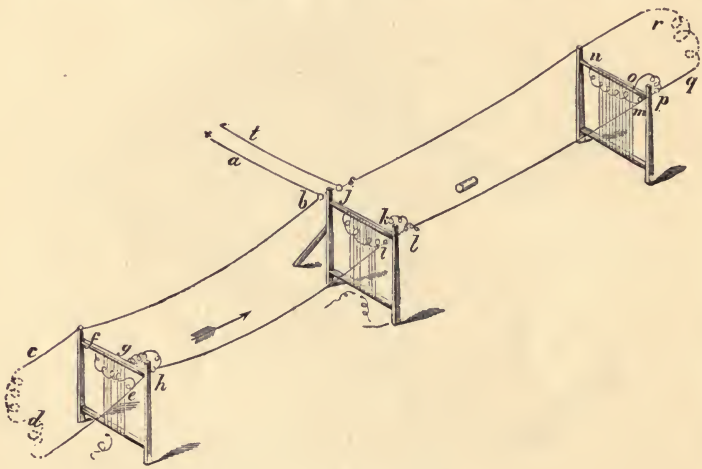


Fig. 10.—Arrangements of Screens.

of the threads which support the weights. The weights used were about 2 lbs. each, and the strength of the sewing cotton for supporting them was equal to a stress of about 3 lbs., which was sufficient to withstand a tolerably strong wind. As the weights were equal the threads were kept equally stretched.

The arrangement of the screens for an experiment is shown in Fig. 10. The wires for conveying the galvanic current are like the common telegraph wire, carried on posts. *abc* is a continuous piece of wire; but there are interruptions between *e* and *h*, between *i* and *l*, between *m* and *p*, &c., in order to make the galvanic current circulate through the screens. The course of the galvanic current is + *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*, *s*, *t*. The ends *a*, *t*, are connected with the instrument and battery. The shot, being fired through the screens, in passing cuts one or more threads at each screen, so that corresponding to the instant at which the shot passes each screen there is an interruption of the galvanic current, and a simultaneous record on the paper.

The *Noble Chronoscope*, contrived by Capt. A. Noble, F.R.S. (late R.A.), has been thus described:—'The principle of action of this instrument consists in registering, by means of electric currents upon a recording surface, travelling at a uniform and very high speed, the precise instant at which a shot passes certain defined points in the bore. It consists of two portions, firstly, the *mechanical arrangement* for obtaining the necessary speed and keeping that speed uniform; secondly, the *electrical recording arrangement*. The first part of the instrument consists of a series of thin metal discs each 36 inches in circumference, fixed at intervals upon a horizontal shaft, which is driven at a high speed by a heavy descending weight arranged according to a plan originally proposed by Hughens, through a train of gearing multiplying 625 times. The driving weight is, during the experiment, continually wound up by means of the handle. If the requisite speed of rotation were got up by the action of the falling weight alone, a considerable waste of time would ensue; to obviate this inconvenience the required velocity can be obtained with great rapidity by means of the handle. The precise rate of the disc is obtained by means of the stop-clock, which can at pleasure be connected or disconnected with the revolving shaft, and the time of making any number of revolutions of this shaft can be recorded with accuracy to the one-tenth part of a second. The speed usually attained in working this instrument is about 1,000 in. per second linear velocity at the circumference of the revolving discs, so that each inch travelled at that speed represents the one-thousandth part of a second; and, as the inch is subdivided by the vernier into a thousand parts, a linear representation at the circumference is thus obtained of intervals of time as minute as the one-millionth part of a second. As a small variation in speed would affect the relation between the several records obtained, the uniformity of rotation is ascertained on each occasion of experiment by three observations; one immediately before, one during, and one immediately after the experiment, the mean of the three observations being taken for the average speed. With a little practice there is no difficulty in arranging the instrument so that the discs may rotate either uniformly or at a rate very slowly increasing or decreasing.

'The arrangements for obtaining the *electrical records* are as follow: the revolving discs are covered on the edge with a strip of white paper, and are connected with one of the secondary wires of an induction coil. The other secondary wire, carefully insulated, is brought to a discharger opposite the edge of its corresponding disc, and is fixed so as to be just clear of the latter. When a spark passes from the discharger to the disc a minute hole is perforated in the paper covering upon that part of the disc which was opposite to the discharge at the instant of the passage of the spark; but, as the situation of this hole in the paper would be very difficult to find, on account of its extreme minuteness, the paper is previously coated with lamp-black, and the position of the hole is thus readily seen; a distinct white spot is left on the blackened paper, the lamp-black at that point having been burnt away by the spark, so that the white paper is shown beneath. A hollow plug is screwed into the gun, carrying at the end next the bore a cutter, which projects slightly into the bore. The cutter is held in this position by the primary wire, which passes in at one side of the plug, then through a hole in the cutter, and out again at the other side of the plug. The two ends of this wire are connected with the main wires leading to the instrument when the plug has been fixed in the gun. When the shot is fired it presses the cutter into the second position, thereby severing the primary wire, and causing the induced spark instantaneously to pass from the discharger to the disc, its passage being marked by the spot left upon the edge, as already described. To prevent a possibility of the cutter being forced down by any gas that may escape past the projectile, a safety-pin secures the cutter firmly in its place. This safety-pin is cut simultaneously with the primary wire.'[3]

Capt. A. Noble has lately written a pamphlet in the *Philosophical Magazine* for March 1873, in which he has investigated mathematically the question of relative strains upon the studs of projectiles, due to accelerating and uniform twist of grooves in rifled guns. He points out that as the strain with a uniform twist is very great at starting, and very slight near the muzzle, the late O. S. Committee 'selected as the simplest form of an increasing spiral the curve which, when developed on a plane surface, should have the increments of the angle of rifling uniform,' so as to thus obtain a nearly uniform pressure on the studs throughout the bore. Capt. Noble also says:—'The argument commonly advanced against an accelerating twist is based upon the fact of the shot moving slowest at first, it being supposed that while moving slowest the shot will require less force to make it rotate; but there is a fallacy in this argument, which lies in confounding velocity with rate of acceleration. The shot undoubtedly moves slowest at first, but it acquires velocity most rapidly at first, and it is the *gain* of velocity that determines the strain upon the stud.' The following conclusions are arrived at:—

That in the 10-in. gun (and other guns similarly rifled) the pressure on the studs due to rifling is but a small fraction (about $2\frac{1}{4}$ per cent.) of the pressure required to give translation to the shot.

[3] *Preliminary Report of the Committee on Explosives*, p. 4.

That the substitution of the parabolic for the uniform rifling has reduced by about one half the maximum pressure on the studs.

That the increment of the gaseous pressure, or pressure tending to burst the gun, due to rifling, is exceedingly small, both in the case of the uniform and parabolic rifling.

That, small as the increment in gaseous pressure due to rifling is, it is still less in the parabolic than in the uniform system of rifling.

The *Le Boulengé Chronograph*, which is of simpler construction than the Navez-Leurs, is now used for the proof of gunpowder. As with the latter, the projectile, in passing through two screens, breaks successively two currents, and demagnetises two electro-magnets in connexion with the first and second screen respectively, which had before supported two rods, one called the *chronometer*, and the other the *registrar;* the chronometer is partially covered with two zinc tubes to receive the indents made by a knife, which is held back or carried forward by means of a trigger. When the first screen is cut by the shot the chronometer falls, and on the breaking of the second screen the registrar falls upon the trigger and releases the spring, the knife moves forward and makes an indent upon one of the zinc tubes on the chronometer, which is received by a trough padded with leather to prevent rebound or injury. There is no pendulum; the time is measured by the distance through which the chronometer falls as indicated by the indents made on the zinc tubes, the zero point being found by releasing the trigger when the chronometer is at rest. A disjunctor is used to cut the currents simultaneously, to obtain a small interval of time, which must be deducted from the time found when the gun is fired, and allows for the time taken in demagnetising the magnets, in the fall of the registrar, in the disengagement of the trigger, and by the knife in reaching the chronometer.[4]

[4] For a full description of the instrument see a translation of Capt. P. Le Boulengé's pamphlet, by Lieut. C. Jones, R.A.

APPENDIX V.

DEVIATION OF FLAT-HEADED SHOT.

The attention of the writer having been drawn to a paragraph in the *Pall Mall Gazette*, of the 16th April, 1873, which appeared to call for some notice from him, he sent a letter to the editor, requesting that it might be inserted in that paper. No notice having been taken of this communication, another letter was sent to the *Broad Arrow*, in which it appeared on the 17th May. Independently of any personal question, the point raised is of some importance, as bearing upon the cause of the deviation of projectiles from rifled guns, and the following remarks are inserted to supplement the explanations given in Part II. Chap. V.

The paragraph ran thus:—'But Colonel Owen, in "Modern Artillery," states that flat-headed shot, under similar conditions, deviate in the opposite direction—that is, to the left. Though this theory has apparently been proved to be mathematically correct by Professor Bashforth, in his treatise "On the Motion of Projectiles," still it has not been generally accepted by artillerists; and to test it, some flat-headed projectiles have been fired from the ten-inch howitzer. This piece was chosen on account of the very rapid twist of its rifling, and consequently great deviation of its projectiles; and it is found that all shot, whether flat or round headed, deviate in the direction of their rotation.'

Why Professor Bashforth should be thus dragged in, considering he has made no special study of the subject, and merely makes a few remarks on what others have done, is not very apparent; it looks like an attempt to discredit the scientific investigation of gunnery questions, but it is to be hoped it was mere blundering, for the correspondent of the *Pall Mall Gazette* was evidently but imperfectly acquainted with the subject. Professor Magnus, of Berlin, about fifteen years ago, propounded the theory of flat-headed shot deflecting to the left, and it was to ascertain the point practically that the writer proposed experiments which were carried on in 1864 by himself and Major

Alderson, R.A.; Captain W. H. Noble, R.A., being also present. The results of those experiments may be found in the *Proceedings of the Royal Artillery Institution*, in a paper of his on 'The Derivation of Elongated Projectiles,' and from the paper it may be seen that forty-five flat-headed shots were fired at elevations varying from one to ten degrees. These showed pretty conclusively that the deviation of flat-headed shot fired with *high velocities* and at *low angles* was to the *left* with *right-handed* rotation. About half-a-dozen out of the forty-five went to the right, and, on the other hand, some of the service projectiles (which everybody admits deflect to the right generally) went to the left; but for these exceptional cases reasons were given in the paper. Before this, however, the writer had tried experiments with wood and paper shot, then with bullets, assisted by Captain (now Lieutenant-Colonel) Fraser, R.A , in the Arsenal, and he gave, in a work published in 1862 ('The Motion of Projectiles'), the results of practice at Shoeburyness, in November 1858, with Whitworth flat-headed shot (not his present tapered form, which appears well adapted to decrease deviation), showing, thatfive shot, fired at five degrees of elevation, all had left deflections varying from forty-five to seventy-two feet. The shots were fired from a 32-pr. gun, rifled on the Whitworth system, and giving right-handed rotatory motion to the shot; the charge was 6 lbs., the ranges and deflections as below:—

Round	Range yds.	Deflection feet
1	2240	66 left
2	2090	54 „
3	2230	72 „
4	2180	60 „
5	2225	45 „

Against these forty or fifty rounds fired with great care, so as to obtain trustworthy results, the correspondent's 'all shot, whether flat or round-headed,' only include three flat-headed shot, and these were fired with a very small charge (about one-fortieth), and therefore experienced a comparatively low resistance; and at an angle of forty degrees of elevation, giving very long time of flight, and probably causing the resultant of the air's resistance to act on the body, below the head, which would thus give a reflection to the right. At page 211 of the first edition may be found this remark (page 242 of this second edition):— 'But if R acts between *b* and *c*, the head will be raised, as with the cylindro-conoidal shot in Fig. 61,' and the writer was surely justified in supposing that a reader could, without further explanation, understand that in such a case the effect, as regards deviation, would be similar to that of the pointed shot.

The velocity of rotation is another point to be considered, for although the twist of the grooves of the 10-in. howitzer is very sharp, the charge was very small. The 40-pr. flat-headed shot fired in 1864 made about 82 revolutions per second on leaving the muzzle, but the 10-in. flat-headed shot fired lately with such a very small charge could only have made about 50 revolutions in a second.

The correspondent of the *Pall Mall Gazette* (evidently not the correspondent who usually writes on artillery questions, and who would doubtless have displayed more care and less conceit) talked modestly of his three rounds having 'definitely set at rest' the question, but those who are capable of examining it thoroughly will not probably be so easily satisfied with his solution. This confidence in the exhaustion of a question on such small data, and in face of a much larger number of facts showing a different result, could hardly be felt by a mind capable of appreciating scientific investigation.

To lay down one rule for all cases of velocities, angles of elevation, different positions of centre of gravity, varying direction and strength of wind, with either flat-headed or pointed projectiles, is evidently impossible, and the writer has not attempted to do so. The question is complicated, and not to be examined in a careless or off-hand manner; but the writer would be the last man to discourage further enquiry, and not to accept another conclusion if supported by better evidence than he has given, for a theory in physical science merely holds good as long as it accounts for the greatest number of known facts; only let such enquiry be undertaken with a full knowledge of what has been done, and with close attention to requisite conditions and reasonable deductions.

In the mean time, the writer is satisfied by what has already been done, that if a flat-headed projectile be fired with a high initial velocity, with its axis steady on leaving the bore, with a velocity of rotation sufficiently high to keep the axis steady, and at such an angle that the resultant of the resistance of the air will act upon the flat surface, the deflection with a right-handed rotation will be to the *left*, according to the theory of Magnus, not Bashforth.

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