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A N D A

TREATISE on the SERVICE of ARTILLERY
in TIME of WAR :

TRANSLATED FROM THE ITALIAN OF

ALESSANDRO VITTORIO PAPACINO D'ANTONI,

Major General in the Sardinian Army, and Chief Director
of the Royal Military Academies of Artillery
and Fortification at Turin.

By CAPTAIN THOMSON, of
The Royal Regiment of Artillery.

L O N D O N :

SOLD BY T. AND J. EGERTON, AT THE MILITARY
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M D C C L X X X I X .

TO HIS GRACE,
CHARLES,
DUKE *of* RICHMOND,
LENNOX, *and* AUBIGNY,
&c. &c. &c.
MASTER GENERAL
OF THE
ORDNANCE.

MY LORD DUKE,

THIS translation has more than a common claim to your Grace's patronage; for, to whom could a work, compiled expressly for

the instruction of young men destined to serve in the artillery, be with such peculiar propriety inscribed, as to your Grace? under whose auspices the Royal Military Academy has attained a pitch of excellence, that promises to the Sovereign and nation, whose bounty supports it, an ample compensation in the knowledge and talents of the students.

The era of your Grace's command of the ordnance has been distinguished by many salutary reforms and useful regulations ;

regulations; and by an attention to every thing that can tend to the advancement of the public service, or the promotion of science: I have, therefore, presumed to dedicate this translation, the employment of my leisure hours, to your Grace; in the hope, that it may serve more generally to diffuse the superior military knowledge of M. D'Antoni.

I beg leave to seize this opportunity of expressing my wish, that the Royal Regiment of Artillery may long

flourish under your Grace's protection, and of subscribing myself,

MY LORD DUKE,

Your GRACE's most obedient

and devoted humble Servant,

The Translator.

T H E
T R A N S L A T O R ' S
P R E F A C E .

LITTLE apology is necessary for giving to the public in an English dress, the three following treatises, written originally in Italian by M. D'Antoni; who, from his extensive knowledge and voluminous publications, ranks high among the military writers of the present age.

The object immediately proposed by the author in these and his other works, is the instruction of the young officers of artillery and engineers; and the students in the military academies, over which he presides. From this circumstance and from the particular subject of these treatises, it may at first sight be conceived, that their scope is too confined to merit general attention; but this objection will instantly vanish
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on the reflection, that from the various combinations and calculations, which inevitably enter into the military systems of modern days, a course of study is requisite to form an officer: and where can this so properly commence, as with gun-powder? on the effects of which victory or defeat essentially depend. The evolutions of squadrons and the manœuvres of battalions are in themselves necessary parts of a military education; they stand in the predicament of many other qualities, which it is reproachful to want and not very meritorious to possess: “*Multa sunt, quæ quamvis cognita non magnam merentur laudem, eadem tandem ignorata non leve possent dedecus imprimere.*” But an officer who looks forward to distinction will go farther; not content with superficial knowledge, he will trace the military science in its progress from the most simple to the most complicated details; examine the properties and force of each particular agent; and thence form those combinations, which adapted to circumstances and situations display, what is justly termed, a knowledge of the art of war.

Considered in this point of view, there can be little doubt but that the productions of M. D'Antoni may be eminently useful: for though many of the observations may have occurred

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to some writer or other before him; yet the copiousness, and, in general, the originality of the matter, together with the clearness of the arrangement, will, it is conceived, render it more satisfactory and fit for general use, than any preceding work of the kind.

It must indeed be confessed, that in this country, the inducement for an officer to make a study of his profession is not very great; weight of interest and length of purse supersede all necessity for knowledge or application: few will submit to the drudgery, requisite for attaining a mastery of the profession, since such attainment avails nothing, opens no avenue to rank or emolument, no prospect of advancement: in the law, in the church, in other lines of life, learning and application have some effect; in the former particularly, there are daily instances of abilities forcing their way through the gloom of friendless poverty and starting into the broad sunshine of rank and riches: in the military line, few such instances occur.

This picture, however true, ought not to be displeasing; on the contrary, it will, on reflection prove what every true-born Briton insists on with exultation, that the military is a very secondary order in the class of society. Every thing

thing in the course of time finds its level : had the situation of this country rendered its existence inseparably connected with a numerous army ; or had an extensive frontier, exposed to the invasion of powerful neighbours, made a chain of fortresses requisite for its protection ; the necessity of cultivating the military science would have been felt : consequence would have attended the officer, considered both in his political capacity with respect to the state, and in his individual capacity as to his superior endowment, and he would naturally have risen to the highest level in society. But the peculiar felicity of our insular situation, having in a great measure superseded the necessity of maintaining these armies and fortresses, we are fallen by a gradation natural to human nature, into the opposite extreme : an extensive line of sea-coast left totally to the protection of the navy ; invaluable deposits of naval stores either wholly uncovered, or exposed to be destroyed by a few hundreds of the enemy ; and not a single fortress, where the young men designed for the army, may see the operations of attack and defence, and exemplify the lessons they may have received at their several academies or schools.

It may be urged that officers cannot be formed in time of peace, that all the theory in the
world

world is incompetent to this end : the fallacy of this argument, however specious it may at first sight appear, is easily exposed. During the gloom of the middle ages, when the sun of science underwent a total eclipse, and the arts, by which the Grecians and Romans had conquered the world, sunk with all other species of knowledge into one common grave; while armies, in the ignorant spirit of the feudal system, were composed of peasantry drawn together on the emergency, badly armed, and worse disciplined ; there seemed little more requisite to direct their endeavours for the sudden and short-lived occasion, than bravery in the officers. But the necessity of science was soon felt : before mathematics were applied to the purposes of war, before systems of tactics were formed ; there was a certain combination of circumstances founded on calculation and previous arrangement, which every officer commanding a body of troops found essentially necessary to ensure success.

Since the invention of gun-powder and the introduction of fire-arms, what was formerly the effect of muscular strength, is now the result of solid principles, deduced from theory and confirmed by experiment. Hence, war as a science, is grounded on certain immutable
axioms ;

axioms; a knowledge of which, joined to habits of reflection and an acquaintance with the best military writers, will go far towards forming an excellent officer.

Not that experience is to be undervalued, or the merit of those depreciated, who by dint of observation have in time acquired a very large share of practical knowledge, to their own honour and the advantage of the service; and it must be confessed, that practice unaided by theory will in many cases effect more, than theory without practice can do: yet while we admit that experience is our surest guide, it must be granted at the same time, that to make judicious observations and accurate experiments; to draw just inferences; not to confound the effects of one cause with those of another, and to apply our observation and experience to the best purposes; is not a very simple or common thing.

Happily for mankind, wars are neither so frequent or of sufficient duration for an officer to be formed by practice alone: the commentator on Polybius, whose voluminous work is fraught with excellent maxims and just remarks, asserts that "the Coup d'Oil" that talent by which a general seizes at once all the advantages presented by a country and improves them to the utmost, may be acquired in time of peace by continually

tinually observing the varieties of ground offered to the view, and for this purpose particularly recommends the “chase.” Now if this branch of the military art, which perhaps more than any other is the test of genius, can be obtained during peace, how much more must the subordinate parts be within our reach?

It would exceed the bounds of a preface to pursue this idea and point out the plan of education best adopted to our natural and political circumstances: the discussion of the question, why this island so fertile in men of genius in all other branches of science, has produced so very few men of first rate talents in the military line; and why we have had few or no writers of real, original merit on the same subject, would be naturally involved in the enquiry? let it therefore be dismissed for the present, with a hope that the preceding remarks will not be deemed altogether impertinent in the preface to a didactic work.

The selection of the three following treatises has been made from the rest of M. D’Antoni’s works, in the desire of diffusing the knowledge contained in them among military men in general; but more particularly among the officers of artillery: for it must be the wish of every man, that a corps so eminently useful as the royal
artillery;

artillery; that has obtained the seal of their good conduct in the approbation bestowed on their services, by the men that Britain has chosen to command her armies for several wars past, should still retain their right to the applause of the discerning part of their profession and to the gratitude of their country. The sentiments of an artillery-officer, grounded as he should be in the several parts of military science, are in every service held in high estimation; a flattering distinction, the right to which can only be preserved by superiority of knowledge. In this respect, the very high state of improvement that the royal academy at Woolwich has attained, and the numberless good regulations that have been made within these few years past, present a most pleasing prospect.

After the recent publications on artillery by Doctor Hutton, wherein he has by a series of the most accurate experiments, established certain principles and deductions, as absolute data in gunnery; a translation of the treatise on gun-powder might by many be deemed superfluous; particularly, as it militates against some of the conclusions drawn by the learned professor at Woolwich: but whoever reflects for a moment, on the various opinions that have for a long time prevailed among practitioners,

oners,

wners, on the theory of powder and its action on projectiles, will be pleased to find the opinions of celebrated men brought forward to public view; that the points on which they agree may be laid down as fixed axioms, and those wherein they differ more fully discussed. Dr. Hutton, for instance, asserts that no stress whatever is to be laid on the wadding of guns, with respect to increasing the force of the charge: D'Antoni affirms the contrary, and in this he is supported by Colonel Thompson; who has favoured the world with several ingenious papers on gunnery. Truth can only be attained by experiment; and to reason from effects to causes is the only mode for beings acquainted with nothing but effects: without this, causes can only be conjectured at; and the different ideas that have at various times prevailed on the subject of artillery, is a convincing proof of the gross error to which conjecture is liable.

Without entering into the history of the science, it will suffice to observe, that before Robins, who was in gunnery what the immortal Newton was in philosophy, the founder of a new system deduced from experiment and nature, the service of artillery was mere matter of chance, founded on no principles, or at

best, but erroneous ones. All the nations of Europe have joined in commendation of Mr. Robins, and adopted his axioms: yet much remained to be done; and it was left for the abilities and profound scientific knowledge of Dr. Hutton, by prosecuting his discoveries on a larger scale, to confirm his conclusions.

The military reader will not be displeased with an account of the productions of M. D'Antoni and a short sketch of their contents: being composed in a language that is not in general technically understood in this country, they are less known than their merit entitles them to be.

M. D'Antoni's works consist of thirteen volumes in 8vo. the first in point of publication was the treatise or examination of powder: the author, considering fire as the basis of all experiments upon gun-powder, gives in the first part of this treatise a definition of it; and then investigates its effects on bodies, pointing out the several modifications it is liable to: he afterwards proceeds to analyze sulphur, charcoal and saltpetre; the properties of which he considers individually and then collectively, as in the manufacture of gun-powder, of which he describes the various sorts. He then lays down a theory of the inflammation of powder,
and

and deduces a number of inferences practically useful and in general coinciding with the results of experiments made in this country. In the second part, after expatiating upon the difficulty of measuring the force of fired gun-powder, even when the utmost care and precaution are taken to guard against error and irregularity; and thence inferring the impracticability of doing it to an absolute certainty in military operations, where a thousand circumstances concur to baffle the attempt: he asserts the absurdity of laying down any rule as regular and constant; since the utmost that can be obtained is an approximation, sufficient with a tolerable share of intelligence and accuracy for all common purposes. To this end, he first considers the force of powder in its most simple, and afterwards in its most complex state: then having dwelt on its modifications when fired in guns, he passes to an investigation of the initial velocity of projectiles, of the law of their impulsion, and terminates the treatise with experiments on the resistance of the air.

Having in the former treatise, examined the nature and composition of gun-powder, and analyzed it's properties, the author in the second work, entitled a Treatise on Fire-arms, applies these principles to practice: but in order to

carry method and perspicuity into every part of his subject, he takes up the matter *ab initio*; and in the first place treats of the resistance of fire-arms: in the course of which, he examines the hardness and tenacity of the metals employed in their construction, giving at the same time the method of refining and fusing them, with remarks on the several proportions in which they are to be mixed together. Then, having made some observations on the windage, figure, length, and casting of brass guns and mortars, he points out the inconveniences arising from what is called "the running at the vent," and concludes with the several methods of proving and examining new guns. The second part of this work is entitled "On Projectiles;" he explains the duty of an artillery-officer, both on battery and in the field, as far as regards the initial velocity of shot, the path of the shot's flight, and its effects upon works; and calculates the number of men, that may be killed or wounded in action, both by round or case-shot fired from guns of different calibres at various positions of the enemy. He draws a comparison between the effects of the howitzers and field pieces, and finishes with a chapter on shells projected from mortars.

The various properties of powder being thus
ascertained,

ascertained, and its application to fire-arms fully considered; the author as a necessary consequence, treats in the third work, "Of the Service of Artillery in the Time of War," beginning with the attack of places; in the course of which he develops, the first dispositions for laying siege to a fortified town, wherein are comprehended the proportion of guns and stores for the attack of fortresses; the precautions necessary to be taken for ensuring the safety of the convoys; the situation of the park; the construction of the first, second and third batteries; the attack of the countermines and the surrender of the place: distinguishing the several kinds of sieges, and giving directions for dismantling and blowing up the works of a reduced fortress. The second part includes the whole science of defence; the author is particularly diffuse on the subject of mining, and lays down rules for the defence of a place constructed on a system of demolition. The third part treats of the field service of artillery: to convey to artillery officers an adequate idea of this essential branch of their profession, he enters into the formation of an army, and the system of tactics, and lays down dispositions for the march and encampments of armies, and for parking the artillery: in the next place, he gives the

method of disposing the artillery in the day of action; and its use in the defence and attack of field-works, together with the principles of their construction; whether for covering a country or intrenching an army: and concludes with the duties to be performed in cantonments and winter quarters. Although these three treatises did not immediately follow each other in point of time, yet as they are in a manner connected together and form the subject of the following work, it was deemed expedient to class them together.

The first book of military architecture is prefaced with a general idea of fortification and of the art of war, with a succinct account of the writers on those subjects. The situations proper for regular fortifications are pointed out, with rules and directions for the construction of the body of the place, and out-works of every denomination.

This first book containing as it were, the elements of fortification, which is considered under three heads, viz. the ancient, the primitive modern, and the present system, is followed in natural order by the second volume, comprehending the attack and defence of regular fortifications.

The third comprehends the maxims and
principles

principles of fortification; with remarks on the various systems that have been hitherto published, and directions for disposing the mines in a regular fortress.

The fourth includes the whole system of irregular fortification.

The fifth treats of the materials used in the construction of works, with directions for ascertaining their several qualities; and concludes with a chapter on hydraulics, and on works that are to be occasionally made in water.

The sixth comprizes irregular attack and defence, and the systems of field fortification.

In the two volumes on natural philosophy and mechanics, stiled "Physico-mechanical Institutions," the author treats of the various branches of those sciences which he esteems indispensably necessary for an artillery officer to be acquainted with, and enlarges on chemistry and metallurgy, which are brought into practice in the analysis of powder and the treatise on fire-arms.

The practice of artillery in time of peace, contains rules for examining and proving guns, shot, shells and powder; with the dimensions of pieces of ordnance, and of the carriages used in the service of artillery; the construction of the furnaces and moulds for casting cannon, and

the duties of the laboratory and arsenal are explained.

In the essay "On the Management of Guns, &c." are comprehended directions for using the several machines, as the gin, capstan, &c. and dispositions for posting the men numerically to the several duties.

This is a slight sketch of the contents of these volumes, which altogether form a complete system of artillery and engineering; and perhaps, in a future day, some individual whose leisure permits may favour the public with a translation of them: well would the editor of this work deem his labours requited, should his example excite others of the corps to pursue the same route; a route, not strewed, 'tis true, with many flowers, nor leading either to the temple of fortune or of fame, yet abounding with objects sufficient to afford matter of observation and reflection to a contemplative mind.

It will be a source of satisfaction to professional men to observe, that the same ideas and modes of practice prevail among men of genius in different countries. M. D'Antoni, for instance, makes frequent applications to chemistry, and recommends it in common with other branches of natural philosophy; a course of chemical lectures is established at Woolwich by the
master-

master-general of the ordnance: Who after this concurring testimony can doubt, that chemistry enters into the education of the complete officer? A former master-general laid a foundation for theoretical and practical knowledge by founding the royal military repository; where the inventions of ingenious men of all nations in the military art may be collected together and displayed both in models and books: M. D'Antoni refers his reader frequently to the models in the royal schools; as to a place, whence he may draw from actual observation the most accurate knowledge with respect to the construction and mechanism of military machines.

The repository in both countries has been equally productive of a further good: in Turin, it has led to the compilation of a kind of manual of artillery in the two books entitled "the Practice of Artillery and the Essay on the Management of Guns, &c.": with us, we are indebted to the exertions and abilities of Major Congreve for the establishment of a plan of exercise, and a system of practical knowledge.

It would be tedious to dwell on all the points wherein these two systems agree; the artilleryist who has made himself master of the principles established at Woolwich, will on a perusal of M. D'Antoni's works find them fully confirmed at
Turin.

Turin. Similar institutions at the same time and at different places prove their own propriety and utility: one man or set of men may err; men of liberal minds and comprehension of intellect in different countries thinking alike, can hardly think wrong.

It would be a pleasing theme to a man, who regards with any enthusiasm the future prospects of the corps of artillery, in respect to knowledge and emancipation from prejudice, to dwell on the several useful and salutary regulations that have within these few years past been adopted: but, the enumeration which would gratify zeal, would be irksome to indifference. One institution, indeed, from its general good to the country merits particular attention. If Britain ranks high in the scale of nations, she is indebted for that pre-eminence to her maritime force; the second point in that force, is her naval ordnance: the establishment, therefore, of the office of inspector of artillery became a very important consideration; the number of guns defective in essential principles was become a matter of serious alarm; the artifices of contractors and the ignorance of founders made it necessary, that officers of knowledge and respectability should be appointed to the superintendance of that department: the institution took place
under

under the direction of Major Bloomfield, and the good effects resulting from it are too recent to need recapitulation.

There are some points in which M. D'Antoni differs widely from the commonly received opinions: in his proportion of ordnance and stores for the attack and defence of places, he omits howitzers and includes a large proportion of mortars. It is doubtless an object, highly worthy the attention of professional men to investigate, how far mortars can in most cases supply the place of howitzers. The absurd idea of fixing them in their beds at a certain elevation is at length, to the credit of the present day, in a fair way of being exploded: the adoption of Captain Lawson's mode of elevation, which seems at once to unite strength and simplicity, the two leading features in military mechanics, will go far toward the completion of this object. The field-howitzer, notwithstanding the apparent fairness of M. D'Antoni's comparison, will still maintain its ground: it is true as he asserts, that the moral effects of howitzer-shells cannot be calculated; yet, such is the constitution of human nature, that though we cannot ascertain to mathematical precision the force of terror, we are nevertheless certain that it works wonderful effects

effects on the most stupid as well as on the most enlightened minds. His general condemnation of light, short guns is deduced from the fairest of all principles: the only true criterion to judge of the efficacy of field artillery, is their relative effects when compared with musquets; whenever the fire of artillery can only produce an effect a little greater than a few files of musqueteers can, no man who considers impartially the advantages and disadvantages attending the use of each fire-arm will hesitate to declare, that the artillery should be disused. In saying this, there is no reason to dread that artillery will lose any of its credit; professional men will ever know how to estimate its consequence; it is only by bringing forward guns, that cannot produce the effect expected from them, that the service of artillery can be brought into disrepute. The infantry form the soul of an army; it is to support and strengthen their disposition, that guns are brought into the field. Each arm has its particular attribute: to the infantry, belong solidity and firmness; to the cavalry, velocity and weight of charge; and to the artillery, length of range and irresistible force. As well would a squadron of cavalry, whose utmost velocity could not exceed the quick march of infantry, answer
the

the purpose of cavalry ; as a gun, whose range with certainty would not much exceed the range of a musquet, answer the purpose of artillery. The reveries of speculatists, or the crude, ill-digested productions of mere practitioners are equally to be rejected. The perfection of artillery is to unite solidity with lightness, simplicity with strength, and to add length of range to certainty of execution : whoever does the most toward attaining these objects, is best intitled to the gratitude of his country.

There are a few terms used in the course of this translation that may require a short explanation. A *system of demolition* implies a system of fortification, where the works are connected together by arches thrown over ditches, or in any similar manner ; and where the exterior work may be demolished or taken possession of by the enemy, and the communication destroyed, without the interior work being in the least degree exposed or weakened. In short, it is an improved mode of making intrenchments in the bastion and ravelin and behind the curtain : its invention is attributed to *Busca* of Milan, who wrote in the beginning of the last century.

In treating of mines, the word *provisional* has been

been adopted; since those works which the author terms branches of precaution, are not only intended as *listeners*, but to be also occasionally converted into galleries and chambers: they differ from the permanent works in not being made before the siege, whereas the permanent ones are constructed previous to it. All foreign words have been as much as possible rejected: why our language so rich in other respects should be so poor in military terms, it is difficult to account for; unless it be from the absurd vanity of shewing a knowledge of foreign languages. Surely there is sufficient strength and copiousness in the English language to express our ideas; nor have we shewn any backwardness in adopting new terms when necessary; yet we ought to be careful of “naturalizing useless foreigners to the injury of the natives;” and rather form a word from our own stock than admit needless circumlocution or foreign idiom. Dr. Johnson left much to be done with respect to technical terms; but it is to be hoped that the Oxford Lexicographer will amply supply this deficiency; and not leave the military language a prey to every petty innovator. A standard of terms should be settled: this can only be done under the authority of some judicious compiler, who may
stamp

stamp a lawful currency on sterling words, and proscribe those that are unnecessary or improper.

It cannot escape the intelligent reader, that M. D'Antoni has adapted his directions for the conduct of officers, to the meridian of his own country: Turin has the Alps on one hand and the plains of Lombardy on the other; the greater part of the wars in which the Piedmontese have been engaged, have been in the Alps, the frontier towards France and Savoy; and some of their strongest fortresses are expressly for the defence of the passes of the mountains: this will account for the frequent introduction of remarks on mountainous situations.

A comparison between the English and Sardinian artillery will prove that there are many points wherein our service is better arranged, and many instances where we have the advantage of them in respect to mechanism and the making up of stores: but this will detract nothing from the goodness of the general principles, nor invalidate in the smallest degree the justness of the author's observations. The difference of the two services in one respect is particularly striking: with us, the engineers are accustomed to construct the batteries, the artillery officer having little more to do than prepare

prepare the stores and fight the guns: in the Sardinian, and indeed, in most other services on the continent, the artillery officer plans the batteries in conjunction with the engineer, and constructs them himself: how far this method may be advantageous, it would be foreign to the present purpose to discuss. Should it appear that M. D'Antoni brings the artillery officer too much to the fore ground of the picture, it ought to be recollected, that he professes to regard artillery only, as one of the principal conditions in the constitution of an army; and perhaps some little allowance may be made for predilection to a favorite service.

The translator had at one time an intention of subjoining by way of note, remarks on the several conclusions drawn by the author in the course of this work; and comparing them with the received opinions of the English and French artillerists, and with the discoveries and improvements made in the several branches of science on which he treats: but beside, that an ample discussion of these several points would have swelled into a voluminous commentary, it might have involved him in controversies in which neither his time nor his inclination permitted him to engage.

A second plan was merely to give such remarks

marks as necessarily grew out of the subject: but this was abandoned, as imperfect; and the reader is left entirely to the suggestions of his own mind, with respect to the merits or demerits of the work. The translator has only taken advantage of the different genius of the language, to condense as much as possible, what he conceived to be, the meaning of the original; and has left the mathematical and algebraical parts exactly as they stood, with the simple alteration of the weights and measures. To have shewn by notes, as was intended, the construction of the theorems would have been an operation of great length; the mathematical reader is therefore referred to the *Physico Mechanical Institutions*. All the weights and measures are reduced to the English standard: this, though a work of much labour, was deemed necessary; and indeed without it, a translation would be very defective. The same denomination is left to the guns to distinguish their several natures, as in the original; it being found that they corresponded to natures unused among us and to fractional parts: it was therefore apprehended that the most simple mode was to leave them as they were; the reader having only to recollect that the 32 pr. corresponds to the 27 pr. English; the 16 pr.

to $13\frac{1}{2}$; the 8 pr. to $6\frac{1}{2}$; and the 4 pr. to $3\frac{3}{4}$. One alteration indeed was judged necessary in speaking of guns: they are divided by M. D'Antoni into two kinds; viz. heavy and light: but the term light when applied to guns of that length and weight appeared so inapplicable to our idea of light guns, that the translator has taken the liberty of using the term *medium* guns, being an expression familiar to an English artilleryist: reserving the term light for those short, light guns which M. D'Antoni proposes for fallies, &c.

Some difficulty occurred in fixing the precise proportion between the Piedmontese and English weights and measures. The Piedmontese artilleryists use the Lyprand foot: now the length of the second-pendulum at Turin being $\frac{31}{8}$ of this foot, and at London $39\frac{3}{8}$ English inches; the foot Lyprand of 12 inches, making a very small allowance for the difference of latitude, is equal to 20.23457 English inches. The accuracy of this proportion is confirmed by the ratio between the diameters of the Piedmontese and French shot, as laid down by M. D'Antoni. The French 24 pr. shot is equal, he says, in diameter to the Piedmontese 32 pr. and the French 24 pr. being known to be equal to the English 27 pr. the former proportion

answers

answers very exactly for the diameters of the shot. Having thus established the relative diameters of the shot, it was easy to determine their weight; and thence, the proportion between the Piedmontese and English pounds; which is as 1.00 : .82, or the Piedmontese pound is 13oz. 2 dr. English. It is true, that this differs from the common ratio established in the tables of the weights of the several nations of Europe, but agrees with Ferguson's table inserted in his tracts; wherefore we may conclude that in Piedmont, as in most other countries, there are two weights. The relative numbers in the tables in the second treatise are unaltered, as they would still have borne the same proportion to each other; but the ranges and lines of descent are expressed in English measure.

In fine, the translator trusts that this work will prove an useful addition to the soldiers library: with regard to the merit of the original, he can only say in support of his own judgment, that it has been deemed worthy of translation into the French language by officers of high rank. The Treatise on Powder was translated by M. le Viscomte de Flavigny: the Treatise on Fire-arms, by M. le Marquis de St. Auban, lieutenant general in

the French service; who thought the evening of a life, during which he had made 17 campaigns, had been present at 38 battles or sieges, and had served 46 years, well and usefully employed in giving to the officers of artillery, in which corps he had acquired great reputation, a work that he deemed excellent: the third treatise was translated by M. le Chevalier de Mont-Rozard, lieutenant colonel of artillery, an officer of great merit and experience. These concurring testimonies, joined to the opinions of some officers in our service of great professional knowledge, induced the translator to offer the following work to the public. He was well aware, that in the performance, two duties would necessarily be exacted from him; the one he owed to the author, the second to the public: by the former, he was bound to give the sense of the original with fidelity and accuracy; by the latter with perspicuity and conciseness. How far these objects may have been fulfilled, is left to the public to decide: to that tribunal he submits in the confidence, that if his abilities have by any means been equal to his zeal, the verdict must be in his favour.

T A B L E

O F

C O N T E N T S.

Treatise on Gun-Powder.

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T R E A T I S E
O N
G U N - P O W D E R .

F I R S T P A R T .

OF THE PROPERTIES OF GUN-POWDER.

The properties and effects of Gun-powder can only be ascertained by the means of Fire: let us, therefore, in the first place, examine the nature of Fire itself; according to the doctrine of those philosophers, who, by the closest investigation of its effects, have endeavoured to explore its principles and causes.

C H A P. I.

OF FIRE.

THE celebrated HERMAN BOERHAAVE, whose opinions have been adopted by the most eminent chemists, could only, after a long series of experiments, discover a few of the properties from which fire has derived its several denominations; according to the various modifications under which it presents itself to our senses.

1. Pure fire is called *fire, solar matter, light and heat*: under this idea it is conceived to be a substance essentially fluid, composed of particles very subtle, and continually agitated,

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tated, though not always in the same degree. The learned BECCARI has proved that it exists in all places, and in almost all bodies, without being able to decide whether it be a constituent and essential principle. A gentle friction of a globe of glass in the electric machine, shews that every thing partakes of it; and two hard bodies rubbed violently together gradually grow warm, and at length emit sparks and flame according to their several qualities.

2. Fire, which seems to pass from a fluid to a solid state, and become a part of the body, as the inflammation of some bodies evidently shews, is called *combustible matter, sulphur, the food of fire, and phlogiston*.

3. One of the distinct characters of fire, considered as solar matter, light, &c. (1.) is to easily penetrate bodies, by insinuating itself into them equally, and expanding them so as to cause a disjunction of the component parts when introduced in quantity. But the facility with which fire effects this is different, according to the qualities of the bodies it enters: there are even some which, far from being dilated by the action of fire, are contracted; as wood, animal bodies, &c.

4. Another character of fire is, to render substances luminous, either by means of the flame which breaks from them, or by their becoming red.

5. Fire, considered as combustible matter, sulphur, phlogiston, &c. (2.) causes no change in the body in which it resides, nor does it communicate to it either light or heat, unless it pass from a quiescent state to ignited motion, or inflammation.

6. The different effects of the first species of fire may be considered under three heads.

1. In a determined space.

2. As actually existing in a body.

3. With regard to the manner and law in which it enters and expands bodies of different natures.

7. Considering fire in a determined space, we find that, as its quantity and velocity may vary, so also in the same proportion will its activity and efficacy be different; as may be observed in burning glasses, reflecting telescopes, &c. The activity and efficacy of fire can only be ascertained by the expansion of bodies, and the disjunction of their parts; but hitherto the method of measuring exactly not only the quantity

quantity and velocity of fire separately, but even its absolute effects on bodies, are unknown. The point to which a body entirely deprived of fire can be condensed is equally undetermined with the first instant of its expansion. The condensation of mercury, produced by a certain quantity of sal ammoniac and snow mixed together, is, in the construction of thermometers, the lowest point that we know; while that, from experiments made in more northern climates, it is clear that mercury can be much more condensed. In the construction of pyrometers, the point of the greatest condensation depends on the variable temperature of the atmosphere. Thus these two instruments serve only to shew, by their graduation, the difference of expansion, according to the degree of fire that they contain or are penetrated with.

8. The activity of fire considered as actually existing in a body, (6. N^o 2.) depends not only on the quantity and velocity of the ignited matter, but also on the mass of the body in which it exists. On attempting to reduce two fluids of unequal density to the same temperature, the most dense requires the greatest degree of heat: thus, when the activity and degree of fire which the two bodies contain are proportional to their respective masses, they are equally hot. On touching two bodies of unequal density, reduced to the same temperature, the most dense appears the hottest; because the hand being in contact with a greater number of particles in the denser body, the sensation excited is proportionally stronger.

9. The manner and law (6. N^o 3.) under which fire penetrates bodies, is modified by the degree of its activity; the time of application, and the superficies, quality, and mass, of the surrounding bodies; for should any one of these circumstances vary, a different modification will result. Put into the same fire two pieces of iron of the same quality, but of different sizes, the smaller piece will become hot much sooner than the larger one; and if the surface of the larger piece be increased by flattening it with a hammer, it will become hot in less time. This diversity of effects may be equally remarked on comparing a piece of iron with a stone, or any other body, put into the same fire.

These observations on the facility with which fire insinuates itself into bodies, are equally applicable to the facility

with which it quits them, and diverges from its focus: for when the quantity of fire in any body is greater than in the atmosphere or other surrounding bodies, it quits that body, and removes from it, spreading itself equally on all sides; its activity diminishes in proportion to its distance from the body which it quitted, and its extension depends on its excess over the external fire, on the time of application, the superficies, quality, and mass, of the surrounding bodies.

10. Having thus examined the various circumstances that tend to modify the effects of fire, let us now consider these modifications with respect to the ignition and destruction of combustible bodies. Whether the ignited motion excited in a combustible body appears under the form of flame, or burning coal, it is always produced in two manners; *either by applying to the combustible body a quantity of external fire, or by increasing the motion of the fire that exists in it.*

11. From the facility with which combustible bodies take fire, they may be ranged in two classes. In the first may be placed spirits of wine rectified, sulphur, &c. in which, by applying fire to any one part, it is communicated to the whole mass, so as to produce a total destruction. In the second class may be ranked coal, the greater part of vegetables, &c. in which fire can be propagated only by a continued application; by increasing the motion in the ignited parts; or by placing the bodies in such a manner, that the fire, in escaping from the burning particles, may meet almost instantaneously those not yet ignited.

12. The degree of ignition varies according to the different qualities of the bodies themselves; for a greater degree of fire is requisite in proportion to the rarefaction of the surrounding air, or to the difficulty of removing from the ignited body smoke or other substances which do not serve as food to fire. In both these cases, it is necessary either continually to apply fresh fire, or to increase the motion of that which already exists in the body.

13. From these premises, it may be inferred, that fire admits of infinite diversity in its effects, arising not only from the time of application, the superficies, quality, and mass, of the bodies to which it is applied, and which surround it, but even from the modifications that ensue from the quantity and velocity of the ignited matter.

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14. Wherefore, the force of gun-powder fired in muskets, cannon, mortars, mines, &c. being in proportion to its inflammation, its effects must inevitably be modified by the quantity and the proportion of the ingredients, the temperature of the atmosphere, and other circumstances that will be hereafter pointed out. And since it is not in our power to determine every point that affects its inflammation and total consumption, we cannot be always certain of producing the same effects with the same quantity of powder fired from the same piece of ordnance.

C H A P. II.

OF SULPHUR, SALTPETRE, AND CHARCOAL.

15. **S**ULPHUR is a substance composed of *vitriolic acid and a combustible matter*. It is ranked in the class of minerals, because it is extracted from the bowels of the earth. When exposed to a moderate degree of heat, it liquefies, and sublimes in little tufts called *flowers of sulphur*: thus it is purified from heterogeneous substances by sublimation.

16. The property of sulphur is to take fire, inflame, and be entirely consumed, when exposed in the open air to a stronger fire than that which will liquefy it. It is made use of in the composition of gun-powder, because the ignited motion is easily propagated in it.

17. The facility with which sulphur takes fire and burns depends on the rarefaction of the surrounding air. To burn it in an exhausted receiver, it requires a continued application of a much greater degree of heat than would inflame it in the open air: the receiver should also be of a size proportioned to the quantity of sulphur, lest the condensation of the smoke prevent its total consumption. (12.) The only method of decomposing sulphur is by burning; which destroys the combustible matter, and the vitriolic acid exhales in vapour.

18. Charcoal, used in the composition of gun-powder, is defined to be a body composed of *a combustible matter, and*

of the dense earthy particles contained in vegetables. In making charcoal, the vegetables are burned in such a manner, that they do not inflame; and then the combustible matter unites itself intimately with the most dense earthy particles. Charcoal can only be decomposed by fire; which, at the beginning of the ignition, separates the combustible matter from the earthy particles; which are then termed *cinders*.

19. When charcoal is exposed in the open air to a sufficient degree of fire, its property is to burn and be consumed. It sometimes emits a little blue flame; but more frequently sparkles, and becomes red, without emitting any flame. If, in this state, it be agitated by the wind, it appears of a more lively and brilliant red in proportion to the force of the wind, and is sooner reduced to cinders. From this property it enters into the composition of gunpowder.

20. Generally speaking, charcoal appears red only when a greater degree of fire is applied to it than will burn sulphur: the propagation of the ignited motion, and its total consumption, are effected more slowly than in sulphur. These effects differ according to the quality of the charcoal: that which is the lightest, or which contains least of the dense earthy particles, takes fire and is consumed the quickest.

21. The more the air is rarefied, (12.) the more difficultly charcoal burns, and the greater degree of fire is requisite to keep it red-hot.

22. Saltpetre is formed from a combination of *the nitrous acid with a fixed alkali*. It is extracted principally from animal and vegetable substances, found in a putrescent state, mixed with stones, earths, and plaisters; and is separated from them by boiling them in a water impregnated with a fixed alkali. The salt chrysalizes in long filaments, lying the one upon the other. This is the only method of purifying it; and must be repeated two or three times, according to the quantity of the heterogeneous matters. When, by this process, the saltpetre has been well purified, it has always the same properties, from whatsoever substances it may have been extracted.

23. Its properties are, to dissolve in water, more fully in boiling than in cold water; and to liquefy, by a greater degree of heat than is required to liquefy sulphur. If the heat be increased while the saltpetre is in fusion, it sublimes
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in visible particles; which, collecting together on the upper part of the vessel, are called *flowers of nitre*. To separate the acid from the alkali, without putting the saltpetre in contact with a combustible body, it is necessary to expose it a long time to a very strong fire; and even then the decomposition is brought about very slowly.

24. If a combustible body, containing a sufficient degree of heat, touch saltpetre, a very fierce flame is excited at the point of contact, accompanied with detonation and a wind, which increases the activity of the fire. In this operation the acid is separated from the alkali, and dissipated. The combustible body is instantly consumed, and the alkaline residuum is termed decomposed or fixed nitre.

25. This decomposition of saltpetre takes place equally in the open air and in vacuo; provided that, in vacuo, the action of the fire be sufficient to keep the combustible body (12.) in a state of ignition.

26. Saltpetre may be decomposed by fire in two ways.

1. By coming in contact with an ignited combustible body when in a solid state.

2. Or by communicating, when in fusion, the ignited motion to a combustible body in contact with it.

27. In the first case, by applying burning charcoal, the decomposition begins and continues till the saltpetre or the charcoal be entirely consumed. To effect the destruction of both at the same time, the quantity of charcoal must be proportioned to the quantity of saltpetre. The better the substances are mixed together, the more immediate will be the contact between the several parts, and the sooner will both be consumed.

28. Burning sulphur not being able of itself to decompose saltpetre, charcoal is added to it. Now charcoal of every kind burns when exposed a sufficient time to the action of burning sulphur; yet this takes place sooner or later in proportion to the density of the charcoal, or to the quantity of dense earthy particles; wherefore, that the fire produced from the sulphur may be sufficient to burn all the charcoal, the quantity of each must be exactly proportioned, and attention paid, at the same time, to the quality of the charcoal.

When this proportion is determined, a quantity of saltpetre added, and the three substances well ground together, in order to render the inflammation more instantaneous, even then the effects vary; for if the saltpetre be

in too great a quantity, the combustible particles being too far separated, the fire applied to one part will not be able to spread to the others; or the combustible particles, being in too small a quantity, will be consumed long before the saltpetre. If, on the contrary, the saltpetre be in too small a quantity, it will be consumed before the other two ingredients: wherefore, that the destruction of the three may begin and end at the same time, they must be mixed in a just proportion. As soon as the saltpetre begins to be decomposed, the wind (24.) generated from it, renders the heat of the charcoal more intense, increases the activity of the fire, and accelerates the total destruction of the whole. (7.)

29. This decomposition of saltpetre, by the application of charcoal and sulphur, is similar to the process that takes place when powder is burned in the open air, or in fire-arms.

30. It requires a greater degree of heat to decompose saltpetre in the second manner (26. N^o 2.) than in the first.

FIG. I. To the plate A B of the pneumatic machine, fix a thin thimble C, of beaten brass, with the convexity downward; put into it a mixture of saltpetre, sulphur, and charcoal; and apply a red-hot iron concave in D, so that it may exactly admit the convexity of the thimble: in a short time the mixture will explode, and be entirely consumed. Put again into the thimble an equal quantity of the same mixture, and place above the plate a glass receiver, from which pump out some of the air, then the red-hot iron being applied as before, the explosion will not so soon take place. If the air be entirely exhausted, the decomposition of the saltpetre will not begin till both it and the sulphur are liquefied, and fall into ebullition.

31. To burn powder in *vacuo*, the second method must be used; for it will not explode before it be reduced to a state of liquefaction, and an ebullition ensues.

32. On decomposing saltpetre in either of these methods, if the vessel be suffered to cool, and a small aperture be opened, an air will be instantly perceived to rush out, with a force proportioned to the quantity of saltpetre used in the experiment.

experiment. This air proceeds from an elastic fluid generated at the decomposition of the nitre, and is essentially different from the smoke which, after a little time, fixes upon the inside of the vessel, and produces no effect. On the contrary, the elastic fluid proves its force and effects after a considerable interval of time; whence may be inferred, that it is a *permanent fluid*, and in it consists almost the whole force of gunpowder. It may be further observed, that this force is always increased by heat.

33. When the experiment is made in the first method, (26. N^o 1.) in a close vessel, with a quantity of sulphur and charcoal sufficient to decompose the nitre, if the vessel be too small, or a considerable time be requisite to effect the decomposition, on account of the want of sufficient proximity in the nitrous and combustible particles, the redundancy of the smoke inclosed in the vessel will retard the operation, the combustible body will lose its heat, and recourse must be had to the second method of continually applying fresh fire.

34. The following experiment proves that the *permanent elastic fluid* proceeds from the saltpetre alone. Let a quantity of sulphur and charcoal be burned in a close vessel, the vessel be suffered to cool, and a hole be opened, no wind will be perceived to issue: from this and other experiments, it is clear that no permanent fluid is produced by burning together these two combustible bodies. The smoke, nevertheless, is elastic when hot; but so soon as it is deprived of heat, it not only entirely loses its elasticity, but even absorbs a portion of the common air, and a part of the permanent elastic fluid generated from the nitre, whenever this fluid mixes with the smoke; as will be shewn hereafter.

35. From these experiments, and others that might be made on the same subject, the following properties may be deduced—

1. A certain degree of heat is requisite to set fire to the combustible bodies, and decompose the nitre.

2. The degree of heat must be increased in proportion to the rarefaction of the surrounding air, or to the density of the smoke.

3. The decomposition of the nitre being always progressive, the more intimate the mixture, and the juster the proportion of the combustible ingredients, the sooner will it be effected.

4. In

4. In the decomposition of saltpetre, an elastic fluid is generated, which is permanent for a considerable space of time.

C H A P. III.

OF GUN-POWDER.

36. **GUN-POWDER** is composed of very light charcoal, sulphur, and well-refined saltpetre. These materials are put into a wooden trough, where they are ground together, to render the contact of the nitrous and combustible particles intimate and equal throughout the whole mass. The mixture is occasionally sprinkled with water, to form an amalgam, which is afterwards granulated, and prevent the finer particles of the sulphur and charcoal from flying off, which would necessarily alter the proportion of the composition. The powder-makers employ more or less time in the operation of grinding, in proportion to the quantity of saltpetre. When they conceive that the ingredients are properly mixed together, they form from the paste those little grains which, being dried, obtain the name of gunpowder.

37. There seems to be nothing in the fabric of gunpowder that can alter any of the properties of the constituent parts, taken either individually or collectively. (35.) The necessity of having a combustible body capable of producing the total and instantaneous decomposition of the nitre, makes sulphur and charcoal requisite ingredients: sulphur, because it easily takes fire, and propagates the inflammation, though the heat it produces is not sufficient to decompose the nitre: charcoal, because its inflammation, as well as the propagation of fire into all its parts, being slower, it acquires, when it becomes red-hot, a stronger degree of heat than the sulphur, and is therefore more capable of producing the entire decomposition of the nitre. Therefore, from their combination with a proper proportion of nitre, the most instantaneous explosion may be expected; but if the quantity of nitre be too great, the fire communicating to the combustible particles with so much the more difficulty as the excess is the greater, may produce no effects.

If to a composition of 14 parts of saltpetre, 1 of sulphur, and 1 of charcoal, a burning coal be applied, those parts
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only of the mixture in contact with the coal will burn, the flame not being able to communicate itself to the other parts. If, on the contrary, the nitre be in too small a quantity, on applying fire to one part, the flame which breaks out at its decomposition is too weak to spread itself to the others, owing to the great distance of the nitrous particles: the destruction of the whole, therefore, requires a much longer time; and the quantity of permanent elastic fluid, on which depends the greatest force of the powder, is less; as may be proved by burning a mixture of equal parts of sulphur, charcoal, and saltpetre.

38. That proportion which will most readily produce the destruction of all the composition, and yield the greatest possible quantity of the permanent elastic fluid in a given time, ought to be found out, and will constitute powder of the best quality: it evidently appears, from the above experiments, to lie between the quantities there made use of.

39. In the first years that succeeded to the discovery of gun-powder in EUROPE, the proportion of the constituent parts, and the size of the grains, varied very much; which gave rise to the several denominations it has obtained. At the beginning of this century, these proportions and sizes were almost every where reduced to three; and at present, throughout all Europe, only one kind is used for military purposes.

As it will be shewn in this treatise that the properties of powder are modified by the qualities of the ingredients and the size of the grains, to save repeated descriptions of the different kinds of powder that may come under our investigation, we will subjoin a general account of them, according to the various denominations that they are commonly known by; with this observation, that whatever may be advanced concerning the modifications of one kind of powder is applicable to all others.

40. Powder composed of 5 parts of saltpetre, 1 of charcoal, and 1 of sulphur, and granulated so as to enter with ease into the vents of new musquets, is called *musquet powder*; when the grains are three or four times larger, it is called *cannon powder*. Powder composed of 6 parts of saltpetre, 1 of charcoal, and 1 of sulphur, the grains of which are of the same size as musquet powder, is called *common war powder*; and obtains the name of *fine war powder* when the grains are about half that size. Powder made with the same proportion,

proportion, and with grains of the same size, as the fine war powder, but with a less dense charcoal, is used by sportsmen in shooting game. When composed of 7 parts of saltpetre, 1 of charcoal, and 1 of sulphur, and granulated as the fine war powder, it is called *fire-work*, or *rejoicing powder*.

41. We will now proceed to prove, that fired powder preserves constantly the properties remarked in the combination of its ingredients; (35.) modified, nevertheless, by the exactness of the mixture, the size of the grains, and other circumstances that will be pointed out.

42. All degrees of heat are not sufficient to fire powder for if it be only sufficient to inflame sulphur, the effects before mentioned (28, 35. N° 1.) will result, as may be proved by throwing several grains of powder near hot coals. The burning of the grains contiguous to the coals will be so instantaneous, as not to be distinguishable from the inflammation of the sulphur; but the grains at a little distance from the coals will emit, after some time, a small, blue, lambent flame, which at length becomes brighter; the intenseness of the fire increases, and the gradual destruction of the saltpetre is clearly discernible; some of the grains are consumed, while in others the blue flame disappears without producing their destruction: at length the more distant grains become warm, without emitting any flame, or being consumed. This may be exemplified by putting some large grains of powder on an iron plate, which may be put near to, or drawn back from the fire, in order to give it different degrees of heat; or by directing upon them the solar rays, united by means of a convex glass; as different degrees of heat may be produced by augmenting or diminishing the circle formed by the re-union of the rays.

43. These experiments prove that powder, like other combustible bodies, may become hot or inflamed, without being in the same instant consumed. It is necessary, therefore, to distinguish between the inflammation and the final destruction of each grain: for fire, when applied to two grains of different sizes, does not always cause any sensible difference in their destruction; yet there is a great difference in the force of two equal quantities of powder, made with the same proportion of ingredients, of the same quality, but differently granulated, as is seen on comparing cannon and musquet powder.

44. The following experiment will prove that the degree of heat to fire powder should be greater in proportion to the rarefaction of the surrounding air, or to the density of the smoke. (35. N^o 2.)

PLATE I. FIG. II. To the plate A B of the pneumatic machine, let a thin thimble C of beaten brass, be joined, with the convexity upwards. Let the iron M exactly fill the concavity D; and a moveable ring, F G, be fitted round the thimble, so that on covering the convexity C with powder, part may fall on it. Then if M, made red-hot, be introduced into D, when F C G is covered with powder, in the open air, the powder will instantly explode; but if a glass receiver be placed upon the plate A B, and in part exhausted, and the hot iron be applied, the explosion of the powder on C will not be so sudden as before, and part of that on F G will remain unaffected by the heat, in proportion to the quantity of air left in the receiver. When the air is quite exhausted, the powder upon the convexity C will liquefy before it takes fire, after having emitted several ebullitions; then explode at once, and cover with its flame the powder upon F G: this will, nevertheless, not liquefy; and a part of it will remain upon the ring and plate, where it has been pushed by the blast.

45. This proves that the powder upon the ring, being in a very rarefied medium, does not burn, though surrounded by the flame of the fired powder. In this case, the fired powder spreading itself on all sides in the receiver, which is much larger than the space occupied by the powder, the grains that remain unfired are only surrounded by a part of the flame. If the receiver were filled with powder, the fire inclosed in a smaller space would be more intense, but the quantity of fired powder would be proportioned to the rarefaction of the atmospheric air contained between the grains. (FIG. III.) A B C is a funnel of bronze or iron, of which the part C C is made to screw on to V V of a receiver of beaten copper V X Z, containing about 70 cubic inches. The part D F of the funnel, which is to contain the powder for the experiment, may be diminished at pleasure, by means of the rings G, of exact calibre, and of different lengths, to be applied to the part F of the space D F. A H I is a canal conical from A to H, and cylindrical from H to

H to I; shorter than the funnel A B C by half a diameter D D. The part K L of the iron rod K L M, fits the conical part A H so exactly, that no air can pass: the cylindrical part is a little longer than H I. The capital N N O of brass, of which the aperture O O is less than D D, can be fastened by the spirals N N to B B.

Let the space D F be so diminished by the ring G, that the remaining part D P be entirely filled with the powder used in the experiment; and let the powder be retained by a hog's bladder tied fast to the thread of the screw B B. The funnel, thus charged, is screwed into V V of the receiver, placed upon the base X Z, which keeps the funnel perpendicular. Then if the iron rod be made red-hot, and pressed forcibly into the funnel, the point M coming below the bottom of the funnel I, without touching the bladder, will nevertheless set fire to the powder, and the bladder will burst. If this experiment be made with 24 grains of cannon powder, when the receiver is placed so that the lower aperture X Z fits a large tub or other vessel, no unfired grains of powder will be found; but if the receiver be placed upon the plate of the pneumatic machine, and the air be half exhausted, $\frac{7}{8}$ or $\frac{5}{8}$ of the grains will be found unfired upon the plate after the explosion; and if the receiver be exhausted, $\frac{2}{3}$ or $\frac{5}{8}$ of the grains will be found untouched by the fire.

In these three modifications of the air in the receiver, the funnel is always charged in the same manner, and with the same quantity of powder; and the bladder tied fast in B B entirely prevents any communication between the receiver and the part D P of the funnel; so that when the receiver is exhausted, no change takes place in the part of the funnel that communicates with the external air by means of the little canal A H I; and consequently, when the rod is introduced into the canal, the powder inclosed in the funnel, and the air contained between the grains, remain in the same state, whatever alteration be made in the air of the receiver; wherefore, the bladder bursting at the beginning of the inflammation of the powder, the air which is between the grains in D P, spreads itself into the receiver; and in proportion as it becomes more rarefied, less powder is fired. In each of these three different states of the air in the receiver, it may be observed, that the insides D P of the funnel

pel are bronzed by the flame of the powder. As the powder first takes fire in R, that which is placed above in P cannot fall upon the plate without passing across the flame of the burning powder in R; so that, in this experiment, the fire being inclosed in a smaller space, is more active than in the former one; (44.) yet all the powder is not fired, because the air, on the bladder's bursting, is too rarefied.

46. But to destroy all doubt of this property of gun-powder, let the funnel be charged as before, the capital N O screwed on to B B, and a wad put at the aperture O to retain the powder: then, if the bladder be tied fast in q q, and the receiver be exhausted, the quantity of fired powder will always be greater in proportion as the hole O is narrower; and if it be nearly of the same size as the hole I of the little canal A H I, all the powder in D P will be consumed. In the preceding experiment, (45.) it was found, that when the air had been entirely exhausted from the receiver, only $\frac{1}{3}$ or $\frac{1}{2}$ of the powder took fire, and that a great part of the flame spread itself into the receiver when the bladder burst; while that the remaining part expanded itself in D P, which it bronzed. On the contrary, in this experiment, where the aperture O O is narrower than D D, as neither the air contained between the grains, nor the flame, is able to pass with the same facility into the receiver, they remain in much greater quantity in D P; the fire is therefore more intense, and consequently a greater quantity of powder is consumed; indeed all the powder will be fired when O O is reduced to the size of I. The same effects take place with all kinds of powder, (40.) the only difference being in the quantity that remains unfired.

47. It is then ascertained (44, 45, 46.) that, in order to fire powder, the heat should be in proportion to the rarefaction of the surrounding air, and that it is increased by preventing the expansion of the flame. It remains now to be proved, that the degree of heat must be likewise greater in proportion to the density of the smoke.

It has fallen within the observation of every artillerist, that when shells sink into stiff earth with the fuses downward, the smoke finding no passage, the fire is extinguished, and the shell does not burst; but if they fall into water, the smoke mixing with the water, the fire continues till the powder in the shell explodes. Fuses are generally filled with a
mixture

mixture of mealed powder, sulphur, and saltpetre. Let two or three fuses, of the same size, be filled with composition of different degrees of strength; after being set on fire, let them be buried in earth equally stiff, or covered in any other manner, so as to prevent the escape of the smoke; it will be found, on taking them out after some minutes, that the quantity of composition which is consumed is in proportion to its strength; since the density of the smoke was the same, as the ground was equally solid. Hence, it is evident, that the greater the force of the fire, the greater is the consumption of the composition. Care should be taken not to make it so strong as to burst the fuses.

48. Having ascertained those two properties, it remains to demonstrate, that when fire is applied to grains of powder, the inflammation of the contiguous grains, and the destruction of each individual grain, takes place progressively; (35. N° 3.) and that the velocity with which fire spreads itself on all sides to inflame the contiguous grains, is greater than that with which it penetrates into the substance of each grain. It is too obvious to need insisting on, that all motion, however rapid or short it may be, takes up a certain time; though to us, from the shortness of its duration, it appears instantaneous: consequently, the inflammation and entire destruction of powder produced by the action of fire, communicating itself to every thing around, like rays from a centre, must necessarily take place in a determined space of time; which varies according to the strength of the fire, the proportion of the ingredients, the nicety of the mixture, and the size of the grains.

When a sufficient degree of fire is applied to one grain of powder, it first acts upon the surface, and then penetrates towards the centre. (43.) As the surface burns, a flame is excited which catches the nearest grains; if the degree of heat be sufficient, and the surrounding air not too much rarefied. In the mean time, the fire which attacked the first grain, continues its action towards the centre till it be totally consumed. There are then two distinct actions in the inflammation and the total consumption of powder: the first is the expansion of the inflamed fluid; which, spreading itself from the surface of the burning grains, surrounds the contiguous ones: the second is the penetration of the fire from the surface of each grain towards its centre. But the flame always spreads with more rapidity between the intervals of the other

other grains, than it penetrates towards the centre of each grain.

49. The following observation will prove that a determined time is requisite for the consumption of each grain. Make, of the common mixture, some grains of powder as large as pistol bullets; dry, and set fire to them: it will then be seen that the fire penetrates from the surface to the centre, in a longer or a shorter space of time according to the size of the grains; so that if there be no difference between these large grains and common ones than in size, it may be inferred, from analogy, that the smallest must require a certain space of time, however short. It is likewise clear, that the flame, in spreading itself from the burning grains to the contiguous ones, takes up a certain space of time; as may be exemplified by setting fire to a train of powder.

50. An experiment will prove, that the action of fire is also progressive when applied to powder confined in a vessel; where the burning fluid being more dense, is also more active than when powder is burned in the open air. (FIG. III.) To the funnel charged as before, (45.) let the capital N O be fastened, with the aperture O of such a size, that the receiver being exhausted, only $\frac{1}{4}$ or $\frac{1}{5}$ of the powder contained in the funnel may take fire. Introduce the red-hot rod, and leave it to cool; then admit by degrees the air into the receiver, and loosen carefully the capital from the funnel. If proper attention has been paid in this process, it will be seen—

1. That nothing touches the point M of the rod; as the powder being burnt all around, leaves a cavity nearly spherical.

2. That each of the grains which form the sides of the cavity are burnt a little towards the concave side; as may be distinguished by the fixed nitre, and the smooth surface of each grain.

3. That the grains which are between the interior surface of the funnel and those which form the sides of the cavity, are whitened by the flame of the sulphur, and that the sides of the funnel are bronzed.

It is then proved, that the fire both spreads itself between the intervals of the other grains, and penetrates from the surface to the centre of each grain progressively.

51. But it is not sufficient to have proved that the burning of each grain, and the inflammation of the contiguous ones, are progressive; it is necessary further to shew, that the

activity with which fire spreads itself between the interstices of the grains, is greater than that with which it penetrates from the surface toward the centre of each grain. If we consider that the inflamed fluid, in passing between the grains, meets no other resistance than the common air, which is easily penetrated, by reason of its rarefaction; and that the fire, in insinuating itself from the surface toward the centre of the grain, must pass through a substance much more dense; it is evident, that the resistance in the second case being greater than in the first, the fire must consequently be slower in its progress.

The following experiment will serve in proof of this assertion. Let a pistol barrel, with the vent closed up, be filled with powder to the muzzle: on applying fire to it, the barrel will instantly empty itself, with an explosion. Let it be again filled with powder well compressed, so that the interstices between the grains may be as small as possible, and form, as it were, a solid body; the time that the barrel will take to empty itself will be sensibly longer than before.

The great velocity with which the inflamed fluid passes from the muzzle to the breech of the pistol barrel, between the interstices of the grains, is observable in the first experiment; and, in the second, it is seen how much this velocity, from the necessity of penetrating the powder itself, is retarded.

52. From the three preceding paragraphs, the following principles are deducible.

1. That in burning two equal quantities of powder, made of the same composition, but differently granulated, as cannon and musquet powder, the latter will be consumed in less time than the former; because the grains being smaller, (40.) present to the fire a greater superficies, and produce, at the first instant, the inflammation of a greater quantity of matter; which is consumed so much the sooner, as the fire has less space to pass through from the surface to the centre of each grain.

2. That this depends not only upon the size of the grains, but also upon the facility with which the fire passes between them. On the other hand, the grains should not be too small; for then the interstices will be so diminished, as to admit the flame to pass with difficulty; and they will be so compact, as to form, as it were, a solid body.

53. The

53. The grains of powder are generally of a very irregular form and uneven surface; whence arise many varieties in the quickness of its inflammation and explosion. To remedy these inconveniencies, some manufacturers put the powder into a barrel suspended by ~~two~~ pivots; and having turned it for some time, separate, by means of a screen, the dust from the grains; which are, by this operation, sufficiently smoothed and rounded. On comparing powder made in this manner with powder of an irregular form and uneven surface, the latter is found to take fire more quickly, though the proportion of ingredients be precisely the same in both. Nevertheless, as the interstices between the round grains are larger than between grains of an irregular figure, and as upon them the quickness of the inflammation greatly depends, the round grains may be so small, that the interstices being equal in both, the fire may be able to spread itself equally, and consume the powder with the same rapidity; and as powder of an irregular grain takes fire more easily than smooth-grained powder, a proportional size might be fixed on which would cause the latter to inflame with greater, or at least equal promptitude.

54. As these properties are common to all kinds of powder (40.) that are well made, of proper materials, and equally dried, varieties in their effects can only result from the different proportion of the ingredients, the size of the grains, their figure, and smooth or uneven surface. If the ingredients, however good in quality, are not well mixed together, the powder will not so readily burn, and the difference of the effects will be very sensible.

55. The following experiment will prove, that from fired powder a permanent elastic fluid (35. N^o 4.) is produced in great quantity, upon which depends its principal force. (FIG. IV.) A B C Z is a hollow cylinder of bronze, with a screw at B C to receive D E F. G G is a key to open or shut the communication between the parts of the funnel H H. To the spiral F F, fix the air-gun M M, to receive the elastic fluid generated in the cavity B P; and screw D E into B C. Put the powder into the cavity; and screw I K L, made of bronze, into A P. L m is the vent; *n o* a small moveable plate of iron, to which is fastened a fuse *o p*, and joined to the pin K, &c. *q r* is a smooth bar of iron, made to slide in a groove by the spring V y, which keeps it in the position *t s*, when not forcibly held back; and closing the vent, totally prevents the passage of the air; so that, when

the several parts are properly adjusted, and the bar of iron qr is in the position ts , the elastic fluid inclosed in the cavity BP , though very much condensed, cannot escape. QQ are pivots, or trunnions, to support the machine.

In this experiment the machine must be placed vertically, that the powder contained in the space BP may rest on BX ; the little funnel Hb having been previously filled with hog's lard, that the powder, when fired, may not act immediately on the key GG , and prevent it from being drawn out. By means of a thread of silk, fastened with two little nails at the hole m , the iron qr is held back, the fuse is charged with powder, and the vent Lm primed. Then IK is screwed into AP , and fire applied at L ; which, communicating by m , sets fire to the fuse in o ; and burning, at the same time, the thread of silk, sets at liberty the iron qr ; which, pressed by the spring Vy , slides into st , and closes the hole m . The fuse burns from o to p , and sets fire to the powder in BX : the vent being closed in m ; and, for greater certainty, a little screw introduced into L .

(FIG. V.) When it is judged that the powder in BX is fired, which can only be known by the heat of the cylinder $ABCZ$, as no motion can be perceived, let a bullet be put into the air-gun, and the machine be pointed against a plank, by means of the semicircle of iron BB , which can be stopped by C in any direction; then giving a half turn to the key GG , that the cavity BP may communicate with the bore of the air-gun, on touching the trigger A the bullet is discharged with velocity, and impinges on the plank with the same force as would have been produced by a very great condensation of air.

The cavity BP will contain ten ounces of powder, but with one ounce only, sixteen or eighteen bullets may be discharged successively, and at the distance of forty paces, each bullet will pass through a fir plank half of an inch thick. After these discharges, if the key GG be turned as it was at first, the air-gun be unscrewed, a large bladder fastened in its place, and the key again turned, the bladder will be filled with an invisible fluid; which, being close tied up for several days, will not sensibly diminish in bulk. In the coldest weather it is equally elastic; so that, considered relatively to its elasticity, it may be compared to the atmospheric air. Unscrewing KI , the inside BPX will be found covered with saline particles; which, collected and examined, form a fixed alkali

alkali that easily attracts moisture, and falls in *deliquium* when exposed to an air abounding in vapour.

56. Since the fluid generated at the burning of powder preserves its elasticity for a long time, it follows, that at the instant of explosion its elastic force must be the greatest. In proof of this, let a barometer be fixed to the pneumatic machine; and, having exhausted the receiver, apply fire to the thimble. (FIG. I.) At the instant of explosion, the mercurial gage descends rapidly, then rises; and, after some undulations, seems to fix, for a time, below the point where it was before the explosion. This apparent fixation shows that the elastic fluid is reduced to the temperature of the air; and the sinking of the mercury, in the beginning of the experiment, proves that the force of this fluid is much greater at the instant of the explosion than afterwards. If, instead of burning the powder in vacuo, it be fired in the open air, the elasticity of the fluid will be greater during the application of fire than when its effects totally cease.

57. From these premises (32, 34.) it may be inferred, that the quantity of the permanent fluid is always in proportion to the quantity of nitre contained in the powder, since it alone produces the fluid; as sulphur and charcoal, when burned, produce none. Other experiments might be made to confirm this, by burning different quantities of powder, of the same or different qualities, under the receiver of the pneumatic machine; exhausting the air to the same degree in each experiment, and observing the apparent fixed point of the mercurial gage: it would then be seen that it sensibly falls or rises in proportion to the saltpetre contained in the different quantities of powder.

58. Though the penetration of the bullet into the plank, and the apparent fixed point of the mercurial gage, (55, 56, 57.) be the effects of the permanent fluid generated from the saltpetre, yet they ought not to be attributed solely to that; as the smoke and the common air contained in and between the grains of powder, are also rarefied by the action of the fire.

59. From all experiments hitherto made upon smoke, it is found to be elastic while hot; wherefore it is reasonable to conclude, that the smoke produced at the explosion is one of the causes that concur to give it force: but when cold, it not only ceases to be elastic, but even absorbs a portion of the permanent fluid. It is impossible, at the explosion, by separating

rating the smoke from the elastic fluid, to determine the absolute force of each; yet it may be safely inferred, that the greater part of it depends upon the permanent fluid.

60. The common air that is within and between the grains contributes likewise, by its expansion, to the force of the powder when fired. Its absolute force might be easily determined; but is very small, in comparison of the elasticity of the permanent fluid generated from powder.

61. Thus, the diminution of the ranges of fire-arms, when heated by frequent discharges, or when the air of the atmosphere is more rarefied, ought not to be attributed to less elasticity in the air, but rather to the second property of powder; where, being fired in a rarer medium, less takes fire though the same quantity be used; and hence the range is shortened, as will hereafter be more clearly proved.

62. For the same reason, the increase of force obtained by triturating powder for a long time, and the force which damaged powder resumes after having undergone a fresh process, proceed not, as some think, from the greater quantity of air compressed into the substance of the powder, but simply from a more exact mixture of the ingredients, whence they more easily and generally take fire.

63. In illustration of this remark, it is sufficient to observe, that the best manufactured powder is liable to be damaged by excessive heat or moisture. The powder-makers, in drying powder, take care to stir it frequently, and suffer it to cool before they put it into the barrels; as they pretend that it ferments when very hot: and in fact, if, when much heated, it be closed up in a barrel for some hours, and afterwards poured gently upon a cloth, a great part of the grains, especially those towards the middle of the barrel, will be caked together; on examining them carefully, it will be found to be owing to the great heat, which having liquefied the sulphur, it glues the grains together when cold: but this never happens if the powder be allowed to cool before it is put into the barrel. A partial or total liquefaction of the sulphur is always prejudicial to the inflammation and quick destruction of the powder, (27, 28.) as it destroys the exact mixture of the ingredients, which can be only recovered by subjecting it to a fresh process. If the heat be not sufficient to liquefy the sulphur, a large quantity of dust, consisting principally of sulphur and charcoal, will be found in barrels of powder that have been long manufactured and exposed to damp. The powder from which this dust is detached will
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be altered in quality; and while the interior of the grains, from which the sulphur and charcoal are fallen off, continue in the same state they were in when made, the exterior will have lost the greater part of the substances necessary to facilitate the inflammation. Thus, on applying fire to these grains, the surface burns slowly till the fire penetrates the interior, and meets a sufficient quantity of sulphur and charcoal; the powder must therefore have become weaker. Now, if the powder, thus reduced in strength, be manufactured again, the grains will become homogeneous both internally and externally; but, owing to the diminution of the quantity of sulphur and charcoal, they will be altered in quality, since the saltpetre will be in greater proportion than either of the other two ingredients; so that if, before the powder became damp, it was not very strong, it will now have become much stronger; but, on the contrary, if it was as strong as possible before, and the ingredients (38.) well-proportioned and intimately mixed together, it will in this new operation have lost part of its strength. Hence it may be inferred, that grinding serves only to mix the ingredients together; and that when there is a perfect contact between the nitrous and combustible particles, it is useless any longer to continue the operation.

64. Powder, however well dried and fabricated it may have been, loses its strength when allowed to become damp. If daily observations on powder, put into damp magazines, and carefully preserved in barrels, are not sufficient to establish this fact, the following experiment will render it incontrovertible.

Let a quantity of well-dried powder be nicely weighed, and put into a close room, where the air is temperate, and seemingly dry, and be left for three or four hours; on weighing it again, its weight will be increased. This same powder, exposed to an air loaded with vapour, acquires much additional weight in a short time. Now the increase of the weight being proportional to the quantity of vapour contained in the atmosphere, and to the length of time that the powder is exposed to it; it follows, that powder easily attracts moisture.

65. Wherefore, if a degree of heat, sufficient only to fire dry powder be applied to powder that is damp; the moisture will oppose the action of the fire, and the grains either will not take fire at all, or their inflammation will be slower: thus, as the fire will spread more slowly, fewer grains will

burn; and the penetration of the fire from the surface to the centre of each grain, and consequently their consumption, will require more time. Whence it may be concluded, that all degrees of moisture diminish the force of powder. Saltpetre, not sufficiently refined, attracts moisture very readily; and as the substances that render it impure lessen the quantity of fluid, and prevent its detonation, it should be refined as much as possible before it is employed in the fabrication of gun-powder.

66. In drying damp powder, the degree of heat should be moderate. (63.) When any of the saltpetre has been dissolved, it should be ground afresh, to establish a just mixture of the several ingredients; and if part of it be absolutely lost, which may be known by passing a certain quantity of the powder, well dried and weighed, through a sieve, it will be necessary, before it is ground, to add the quantity of saltpetre that is deficient.

67. Having thus shewn that the force of powder is owing to an elastic fluid generated at the explosion, the suddenness of which depends upon the proportion of the ingredients, the contact between the nitrous and combustible particles, and the size of the grains, &c. it may be concluded, that when several powders, equally well dried, and fired under the same state of the atmosphere, are compared together, that which produces the greatest quantity of the elastic fluid, in a given space of time, is the strongest.

C H A P. IV.

THE PROPERTIES OF POWDER ARE THE SAME IN FIRE-ARMS OF ALL CALIBRES.

68. **H**AVING proved that every degree of heat is not capable of firing powder, and that its force depends on the elastic fluid generated at the explosion, it is needless to adduce any more arguments in support of this fact; but with regard to the second and third properties (44, 48, 49.) of powder, which are undoubtedly of greater consequence, and have often, for want of due investigation, occasioned a difference of opinion among artillerists, in treating of the proper charge and length of guns, it is necessary to be more particular.

particular. These two properties, as well as the first and fourth, hold good in all fire-arms, and in every other cavity where powder is burned; they are also modified by the same causes, (41.) and by others that will be hereafter mentioned.

69. The second property is observable in all fire-arms, when, on applying fire to different quantities of the same powder, either the whole or a part only of the grains take fire, in proportion to the strength of the fire, and the density of the medium. For example, if a quantity of cannon powder be all burned in a gun of large calibre, the same quantity, in a piece of smaller calibre, will not be all burned. In the same piece, charged with different quantities of powder, the smaller charge will entirely explode, while a part only of the larger will be consumed. If, in the largest charge, the resistance to the explosion be increased by a high wad, shot, &c. a greater quantity of powder will burn than when the piece is fired with a common wad, and without shot. These varieties constitute the second property of powder. (44, 45, 46, 47.)

70. The third property of powder is equally observable in all fire-arms. The inflammation of each grain, and of the contiguous ones, being progressive in all kinds of powder, the varieties that occur arise not only from the size of the grains, and the proportion of the ingredients, but also from the size of the vessel in which the powder is fired. For example: if in two vessels, of unequal sizes, two equal quantities of powder be burned, the fire in the smallest vessel, being most intense, accelerates the destruction of each grain, and all the powder is consumed in less time than in the larger vessel. The same circumstance occurs, when two equal quantities of powder are burned in vessels of equal size; one of which resists the action of the powder, and the other bursts at the beginning of the explosion: the heat being more intense in the vessel that resists than in the other, the destruction of each grain is accelerated.

71. To prove that the inflammation of powder in fire-arms of all calibres depends on the density of the air contained between the grains, and the degree of fire that surrounds them, (69.) let a musquet or pistol barrel be filled with powder to four or five diameters; let a small wad, made of a substance not easily combustible, be lightly compressed upon the powder; and let the piece be fired into a vessel made

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on purpose to receive the discharge: a certain number of grains will be found unfired; let these be collected and weighed. If this experiment be repeated several times, with the same piece, and with the same quantity of powder of the same quality, and the piece be suffered to cool after each discharge, the number of unfired grains will be always nearly the same. Instead of repeating the experiments with the same piece, let two or three, of the same calibre, but the lengths of which are in the ratio of 1, 2, 4, be charged with the same quantity and quality of powder, and fired as above, the same number of unfired grains will be found in the vessel; which proves that the additional length does not contribute to the inflammation of a greater number of grains, provided that the experiments be made with dry powder, and in a very dry day. These effects equally take place in musquets or cannon: for if a thirty-two-pounder be charged with 8lb. 5oz. of powder, carefully collected together in the chamber, and lightly compressed with a wad, and the gun be fired horizontally upon hard snow or ice, a great quantity of dirt will be found before the muzzle of the gun, but hardly any unfired grains of powder; but if the gun be fired with 25lb. of the same powder, a number of unfired grains will be found: again, with 50lb. of powder, the number of unfired grains scattered upon the snow will be greater. It evidently results, from these experiments, that in all fire-arms the quantity of powder that burns is limited. It now only remains to be proved, that this proceeds from the intensity of the fire, and the density of the air contained between the grains; and that when these causes vary, the quantity of powder that is burned in the same piece varies also, though the charges be equal.

72. When one of the barrels is charged with the same quantity of powder, of the same quality, if a very high wad be rammed on it, or the resistance to the explosion considerably increased by any other method, after the discharge, fewer unfired grains will be collected. This not only corresponds with the result of former experiments, (46.) since the degree of fire is increased by the resistance, but serves to confirm the progressive inflammation of the grains. But it should be remarked, that the increase in the quantity of powder that takes fire is not always proportional to the increase of the resistance; for, under some circumstances, a slight resistance

resistance causes a more intense fire than a much greater one does in others.

The experiments made with the machine described in the third figure, prove that a difference in the density of the air between the grains produces varieties in the quantity of powder that takes fire; the following simple experiment will further confirm it. Let a musquet be charged with a full quantity of powder, with a single wad, and fired into a large vessel, when the air of the atmosphere is very dense and dry; let it be again charged precisely in the same manner, and fired when the air is rarefied, as it is sometimes in summer, at two or three o'clock in the afternoon; and, to render the effects more striking, let the barrel be heated by exposure to the sun. If the powder, after each discharge, be collected and weighed, a much greater number of unfired grains will be found after the second than after the first: now the only difference between them being in the density of the air contained between the grains, it is evident that this must be the sole cause of the varieties that take place. The decrease in ranges, observed in very hot weather, or when the guns are much heated by preceding discharges, ought not to be attributed to the less elasticity of the air, since its action, compared to that of the elastic fluid generated from powder, is hardly sensible; the true cause is the rarefaction of the air, whence less powder takes fire.

73. The size and position of the vent render this property of powder subject to other varieties. On firing two pistols, of the same calibre, but the vent of the one larger than that of the other, fewer unfired grains will be found in the vessel from the former than from the latter. The same circumstance occurs when the vent of the one is situated at a greater distance from the bottom of the bore than the vent of the other, though they be equal in size.

74. The charges that at each elevation produce the longest ranges, depend also upon this property of powder. It is necessary to vary the charges according as the density of the air contained between the grains differs, as the elevation is altered, or as the atmosphere is more or less loaded with vapour. Thus it constantly happens, that on firing at the same time two pieces of the same calibre, but of unequal lengths, the vents of which are of the same size and in the same position; the charge which in the longest piece gives the longest range, gives it equally in the shortest piece; provided

vided that the two longest ranges of the two pieces, when compared together, be unequal.

75. In seeking the charge that gives the longest range, it will be found that by using small charges at first, and increasing the quantity of powder by degrees, the ranges will increase to a certain point; after which, if the charge be augmented, they will progressively diminish; though the recoil will still continue in the ratio of the increase of the charge. This is a consequence deducible from the foregoing experiments, and agreeable to the principles of mechanics; since the recoil and the range ought to be in the reciprocal ratio of the gun and the shot, making allowance for the resistance which these bodies meet with. Thus, when all the powder explodes, the recoil and the range ought to be in the above ratio; but when a part only takes fire, the burning powder must not only impel the wad and the shot, but also the unfired grains. Now the substances impelled towards the muzzle of the gun being in greater quantity, the weight approaches nearer to the weight of the gun, which always remains the same, and the range is consequently diminished.

76. The following experiments will prove the third property of powder in fire-arms of all calibres. (7c.) Let a gun of any nature be taken, and, to simplify the experiment, be charged with such a quantity of powder as will all explode: on examining the ranges from two equal charges of powder, of the same quality, but of differently sized grains, as cannon and musquet powder, it will be constantly found, *ceteris paribus*, that the range produced from the musquet powder is much longer than that from the cannon powder. Now as the action of fired powder depends on the elastic fluid, the shot, in the longest range, must necessarily have been impelled by a greater quantity of this fluid: but it has been demonstrated, (57.) that from equal charges of cannon and musquet powder, equal quantities of the elastic fluid are generated when they are totally consumed; wherefore, in this case, all the fluid is not generated in the time that the shot is moving along the bore of the gun, and consequently we may conclude that its generation is progressive. A comparative trial of all other kinds of powder that have the same proportion in their ingredients, and differ only in the size of the grains, gives a similar result: whence it is clear, that each grain is consumed progressively in pieces of all calibres; and

and that the only variation consists in the length of time from the first instant of its inflammation till its final consumption.

77. Some artificers, from the intense heat excited in a piece of ordnance at the instant of explosion, particularly with large charges, conceived that all the powder must be consumed before the shot begins to be in motion; but it having been already proved (71, 72.) that the quantity of powder that burns is limited, it will suffice to shew, by a conclusive experiment, that the inflammation and destruction of each grain is progressive. It is well known that fine war powder is much stronger than musquet powder; and that, on firing equal quantities of these powders from the same piece, the former will give the longest range: but if of the same paste from which the former powder be made, grains four or five times larger than those of the musquet powder be formed, and the difference of the ranges between this large grained powder and musquet powder, fired in equal quantities from the same gun, be remarked, the ranges from the latter will be found much longer than from the former; consequently the shot must have been impelled by a greater quantity of the elastic fluid. But the large grained powder, if totally consumed, should produce the same quantity of fluid as the fine war powder, which was found to produce more of it than an equal quantity of musquet powder. In this experiment, therefore, all the fluid is not disengaged from the large grained powder, and the destruction of each grain is progressive, as the charge is so proportioned, that the whole should take fire in the gun.

78. This progressive destruction of each grain is never totally effected within the bore of the gun, in the charges at present in use; for, independent of the above observations, fire is always seen to issue in great abundance from the muzzle of the gun, which could never happen if all the powder were consumed before the shot began to move.

79. Upon this third property of powder in some measure depends the difference of ranges in two guns of unequal length, but of the same calibre, charged with equal quantities of powder of the same quality. The reason why the shot from the longest piece ranges farthest, is not only because it is impelled for a longer time by the fluid, but also because a greater quantity is generated during that time. But shot from long pieces only range farther when at quitting

ting the gun they are still impelled by the elastic fluid; or, in other words, when arrived at the mouth of the piece, their velocity is less than that of the fluid itself.

80. The action of the elastic fluid on the shot in moving along the bore of the gun is so powerful at the beginning of the movement, that the range from a small charge sometimes equals, and even exceeds, that from a larger charge, though they both take fire before the shot begins to move. This is owing to the small charge occupying a less space of the bore; whence the shot is longer impelled by the fluid, as it has a longer space to move through in the gun. To elucidate this, let an experiment be made with a gun a diameter and half of its shot in length; the ranges, or the penetrations of the shot into soft earth, will be greater when the charge occupies half, than when it occupies a whole diameter. Thus the decrease of range in a piece of ordnance that is over-charged arises not only from the greater weight of matter to be impelled by the fired powder, but also from the less space that the shot has to pass through in the piece, and the less impulsion of the elastic fluid.

81. From these premises, it will be easy to explain, why, in fire-arms loaded in the common manner, only a certain quantity of powder can take fire.

There are two actions to be distinguished in the fluid generated at the burning of powder; of fire, and elasticity. As the fluid separates, and disengages itself from the burning grains, it carries off with it different inflamed combustible particles; the degree of fire is then weakened, as much from its expansion, as from the extinction of the flame, owing to the destruction of these combustible particles: wherefore the fluid, at a certain distance from the burning grains, does not contain heat sufficient to inflame other grains; but its elasticity, though weakened by the decrease of heat, does not cease to act against the sides of the containing vessel. Now as the inflammation of powder in fire-arms commences at the vent situated at the bottom of the bore, there is generated from the first grains an elastic fluid, which insinuates itself into the interstices of the other grains; but the more this fluid expands, and the combustible particles mixed with it are destroyed, the heat becomes less intense, and unable to fire the grains more distant from the vent: but a fresh fluid is successively generating, and inflaming those which the first produced fluid had not power to inflame; the quantity of the fluid,

fluid, and the intensity of the heat, increase by degrees, till the wad and shot begin to move. From this instant of movement the space containing the fire, the fluid, and the unfired grains, enlarges; and though fresh fluid is continually generating, yet, as the fire does not increase in proportion as the space which contains it is enlarged by the removal of the wad and shot towards the mouth of the gun, the unfired grains will not be inflamed; as, from the rarefaction of the air, the fire is not sufficiently intense. Hence we may conceive why, in moderate charges, properly wadded, the fluid has sufficient elasticity to force out the wad and shot, and, at the same time, heat enough to fire all the grains; and why, in charges that are too large, and wadded in the same manner, the heat is not intense enough to inflame the grains that are distant from the vent, while that its elasticity is sufficient to overcome the resistance of the shot and wad, and put them both in motion.

82. It may be concluded from the preceding observations, that the form of the vessel in which powder is burned has no influence on the force of the elastic fluid. Indeed, as the powder may be more compact in one form of chamber than in another, the fire, in spreading itself from the vent with more rapidity, may inflame more grains; thus a greater quantity of the fluid may be produced in equal times, but the absolute force of an equal portion of it will not be increased. Mortars with spherical chambers give the longest ranges; because, of all the different forms, of equal contents, in which chambers can be made, the spherical has least superficies, as may be demonstrated geometrically; all the powder, therefore, is nearer to the vent in this chamber than in any other.

83. As the properties of fired powder are the same in fire-arms of all calibres, in proportion to the compactness of the charge around the vent, the resistance opposed to its explosion, and the variation in the density or moisture of the atmosphere; it is evident that, in firing equal quantities of powder of the same quality, at different times and places, different effects will result. If the state of the air be altered, both with respect to density and moisture, the ranges will be sensibly shorter, as the successive inflammation of the grains will be slower: this frequently occurs when cannon are fired over the sea, lakes, or marshy grounds, from which there is a strong exhalation.

It will be shewn, in the second part of this treatise, that the initial velocity of a musquet bullet, in a very moist day, is to its velocity, with an equal charge, in a dry day, as six to seven.

84. It might be supposed, that experiments made at different times and places, with mortars constructed with the same proportions, and from the same model, might be conclusive in proving the comparative goodness and force of different powders; but the contrary is the case: for, independent of the varieties ensuing from alterations in the state of the atmosphere, there will inevitably be a difference in the construction of the mortars, in spite of the utmost precaution of the founder. These differences, or inequalities, though scarcely discernible, will nevertheless greatly affect the range; even if the mortars are fired from the same spot, in the same position, and with all other circumstances as nearly corresponding as possible.

85. To ascertain the goodness and force of powder, by proving it with a mortar—

1. Fire some rounds with a particular powder, made with the greatest exactness, called *proof powder*; then fire the same number of rounds, from the same mortar, charged with an equal quantity of the powder to be proved, which should be of the same kind as the *proof powder*: if the ranges be equal, the force and goodness of the powder is ascertained. It signifies little whether the *proof powder*, provided that it be in good preservation, has at other times given longer or shorter ranges; since this comparative trial proves that the two powders are of equal force.

2. Before the proof, the two powders should be exposed to the sun for some time; (63, 66.) and the proof made on a day when the air is clear and serene.

3. To lessen the varieties that any alteration in the rarefaction of the air might occasion in the inflammation of the powder, or the resistance of the shot, the two powders should be fired as nearly at the same time as possible, and in small quantities, that the whole charge may take fire: wherefore, if the chamber be cylindrical, as it commonly is in *proof mortars*, and the vent situated at the bottom, the charge ought not to exceed one diameter of the chamber; though a larger quantity might take fire, if the powder be of sufficient strength.

4. The

4. The mortar should be firmly fixed in a heavy bed, that the machine may not be deranged by the explosion, and laid at 45° ; the shot should be of equal weights and diameters, with the centre of the figure corresponding with the centre of gravity: without these precautions, the result of the experiments cannot be depended upon.

In this manner the goodness and force of powder may be with more accuracy ascertained, than by any other method yet invented: for complicated machinery is subject to numerous accidents; many of which are avoided by fixing the mortars so solidly and firmly in their beds, as to form as it were but one simple machine.

C H A P. V.

OF THE CHARGES THAT GIVE THE LONGEST RANGES.

86. **T**O ascertain the charges that give the longest ranges, has ever been one of the chief objects of research among artificers; it is to be deduced from the second property of powder, and can only be known by experiments made in particular cases. Having proved, in the preceding chapter, that the second property of powder has effect in all fire-arms (47, 71), and that the quantity which takes fire is in proportion to the resistance to the explosion, the density of the air contained between the grains (72, 74), the size and position of the vent, the form of the chamber, and the state of the atmosphere (82), it is impossible to fix invariably the charges for giving the longest ranges; the utmost that can be done, is to establish rules adapted to certain determined circumstances: and, in order to render them useful and conclusive, they should be deduced from experiments made with guns of the same calibre with those of which the proper charge is sought, and the common mode of firing should be observed.

87. In these experiments two objects are principally to be had in view:

1. To find the charge which, of all others under similar circumstances, will with powder of the same quality produce the longest range.

C

2. To

2. To ascertain the greatest quantity of the same powder that takes fire in the piece, fired precisely in the same circumstances. This distinction must be carefully observed.

It has been demonstrated, in speaking of short guns (80), that when the greatest number of grains take fire, the range is not always the longest: Now it is easy to extend this demonstration to pieces of all lengths. To suppose that the charge is entirely converted into elastic fluid before the shot begins sensibly to move from its place, and that the fluid preserves constantly the same degree of heat, is to consider it as liable to no other modification than expansion as it passes along the bore of the gun, which is proved to be false in the experiments related in the Philosophical Institutions. It is there shewn, that the longest range is obtained from a charge that occupies about $\frac{1}{3}$ of the length of the bore, and that all other charges give shorter or longer ranges according to their deviation from this proportion. Thus the experiments made with the powders described (40), far from invalidating the former conclusion, on the contrary confirm it; by proving, that in fire-arms overcharged with powder, and the shots and wads rammed as usual, all the grains do not take fire, and that all the elastic fluid is not generated before the shot issues from the mouth of the piece. Whence on comparing two unequal charges of cannon powder, the smallest of which is entirely consumed in the piece, while the larger is only consumed in part; it will be seen, that though the longest range might be expected from the largest charge, as more of it may take fire; yet conclusions entirely opposite may be drawn from practice: whether it is, that the unfired powder increases the weight of the substances to be impelled; or whether from the quantity of the charge, the space through which the shot should pass is too much diminished. Since, then, in spite of the inflammation of a greater number of grains, these large charges do not always give the longest ranges, and they uselessly increase the consumption of powder, and shatter the carriages; our principal object should be to determine precisely the charge which, of all others under similar circumstances, will give the longest range in pieces of all calibres.

88. There are three methods of determining experimentally the charge that impels the shot with the greatest force, and of course gives the longest range.

1. By

1. By finding the initial velocity of the shot near the mouth of the piece.
2. By firing against a butt penetrable and homogeneous, in which may be measured the penetrations of the shot.
3. By measuring the length of the ranges.

The last method is the most complex, and gives approximations least exact; as several circumstances may concur to impede the motion of the shot, and alter its direction; but, as it is most common in practice, we will first examine it. The investigation of the others will lead us to the solution of several very important problems.

To find the charge that gives the longest range—

1. Fire several rounds from the same piece, under circumstances as nearly similar as possible, with shot of the same kind, and with wads rammed with the same force as is generally employed; in a word, with no other difference than in the quantity of powder.
2. Continue firing till a charge be found, any increase or decrease of which gives shorter, or at least equal ranges,
3. Alter the elevation of the guns, and fire several rounds in each position, till the proper charge be found.

Impressed with a necessity of adhering to these principles, and anxious, at the same time, to avoid a prolixity that could add nothing to the exactness of the conclusions, the officers of artillery at TURIN, in making the following experiments, laid the gun, at first, horizontally, and afterwards, at the highest elevation the carriages would admit of.

89. The experiments began the 7th of February, and terminated the 30th of March, 1746. They were generally carried on in moderate weather, and in the afternoon. Several rounds were fired from each piece, with equal charges. The guns were mounted on a part of the fortifications of the city, where the axis of the piece was thirty feet higher than the level of the country where the shot fell. In the direction of the range a line was traced, and pickets fixed in the ground at every hundred feet; and, to prevent all possibility of mistake, each picket was numbered. To the right and left of the ranges, men were posted to mark exactly the spot where the shot first grazed; while the officers made the necessary observations upon the guns, which moved freely upon a solid horizontal platform, twenty feet in length, and ten in breadth. The guns were four, eight, sixteen, and thirty-two-pounders; and those

which had the bore cylindrical, and the vent situated at the bottom, were constructed according to the proportions laid down in the First Book of Artillery.

Nature of Guns.	Length of Bore.			Weight.		
	Pounders.	Calibres.		Cwt.	q.	lb.
4	—	27	—	9	1	9
8	—	27	—	18	2	10
16	—	23	—	31	3	26
32	—	20	—	57	2	17

They were fired on their carriages, and loaded with the ladle: the powder was the common-grained cannon powder; four strokes of the rammer were given to the wad over the powder, and three to that over the shot, by the same gunner, and as nearly as possible with the same force. The wads were of twisted hay, properly gauged; the shot were weighed, to see that they were exactly equal in weight; and the windage was in the ratio of twenty to twenty-one.

The guns being loaded, and pointed along the range, were fired with the axis always horizontal; which was ascertained by the pendulum and water-level. After each discharge, the length of the recoil was measured; the wheels were placed in the same position, between lines, to prevent the slightest difference. The coins placed under the breech were marked before the discharge; and if moved by the shock, the experiment was not considered as exact.

These precautions being taken, the smallest charges were used at first, and increased gradually till the ranges began to diminish; three rounds, at least, were fired with each charge. The charge that gave the longest range having been ascertained by repeated firings, the principal object was, during the last five days, to remark what alteration might arise from any change in the state of the atmosphere; with this view, the same gun was fired each afternoon, with the charges marked in the following table. For example, from the four-pounder three rounds were fired, with each of the charges of 1 lb. 4 oz. 1 lb. 10 oz. 2 lb. 1 oz. of powder: the following day, from the eight-pounder three rounds were fired, with the charges of 2 lb. 7 oz. 3 lb. 5 oz. and 4 lb. 2 oz. of powder. In like manner the sixteen-pounder was fired on the third, and the thirty-two-pounder on the fourth day. At length, to form a comparison of the ranges of the different guns, on the fifth day the four and eight-pounders were fired, with charges equal

equal to half the weight of their shot : the charges of the sixteen and thirty-two pounders were equal to $\frac{1}{3}$ of the weight of their shot. The following table will shew the result of the experiments during the five days.

Nature of Guns. Pounders.	Weight of Powder. lb. oz.	Length of Range. Yards.	Recoil. Inches.
4	1 4	478	43
	1 10	489	62
	2 1	472	72
8	2 7	512	45
	3 5	532	64
	4 2	532	82
16	3 5	505	42
	4 6	526	55
	4 15	522	78
32	6 9	485	54
	8 12	492	71
	9 13	489	82

90. These experiments having been made with the greatest accuracy, we may conclude, that in cannon fired under similar circumstances, the charge of powder which will give the longest range, is equal to half of the weight of the shot in four and eight pounders, and to $\frac{1}{3}$ of its weight in sixteen and thirty-two pounders ; and moreover draw the following inferences with respect to two important effects which constantly appear.

1. The recoil always increases in proportion to the augmentation of the charge, that the length of the range increases to a certain point, and afterwards decreases in a much less ratio than the recoil increases.

2. That the charge which gives the longest range in pieces of small calibre, is proportionally larger than in pieces of large calibre.

91. The following experiment will explain the cause of the first effect (90, No. 1.) : Charge any piece of ordnance with the greatest quantity of powder that will all take fire without a wad ; after the discharge mark the recoil : use again the same quantity of powder, with a wad strongly rammed on it ; the length of the recoil will be greater than at the first discharge : fire a third round with the same charge

well wadded, with the addition of a shot and wad over it, the length of the recoil will be again increased. At length, with similar charges and wads, and, instead of one, putting two or three shot into the gun, the recoil will increase in proportion to the number of shot, and the range will diminish.

Q21. We may easily apply this fact to the experiments of 1746.

It has been proved (71 75), that only a limited quantity of cannon powder takes fire: thus, till the charge be so proportioned as to be all fired in the piece, a greater quantity of elastic fluid is generated in proportion to the largeness of the charge. Now considering the gun and its carriage taken together as a constant quantity termed C, and the substances impelled towards the mouth of the gun, viz. the two wads and the shot, as P; the length of the range ought to be to the length of the recoil as C : P, without making allowance for friction and the resistance of the air to the motion of the shot. But as the space that the shot should move through in the piece is diminished in proportion as the charge is increased, and the *vis matrix* consequently acts upon it for a shorter time; the decrease of impulsion must be deducted from the action of the elastic fluid generated in greater quantity as the charge is larger: Hence it results, that the ranges are proportionally shorter than the recoil, though they both increase as the charge is augmented.

But if the charge be so augmented; that a part I arrives at the mouth of the piece without taking fire, then the substances to be impelled being in greater quantity, the same circumstance that occurs when several shot are put into the piece will in part occur here. As no more grains will be fired, than if the charge were smaller and all ignited, the shot will acquire its velocity; but the reaction against C increasing at the same time, the recoil will be greater than before. The substances P + I forced towards the mouth of the piece, presenting to the explosion of the elastic fluid a greater resistance than P alone, and the number of ignited grains and the quantity of fluid generated during the time that the shot is moving along the bore being more considerable, the absolute increase of fire acting against the gun and carriage must also augment the recoil; while the range may be shorter, equal, or longer, than that produced by a charge that is entirely consumed in the gun, in the ratio that the increase of fluid bears to the substances P + I, and to the space that the shot has

has to move through in the piece. This shews clearly, that *the ranges or the initial velocities of shot impelled from guns are proportionally less than the recoils*, and that if the charge be augmented to a certain point, the ranges will diminish, while the recoils will increase.

93. Thus, very large charges should never be used in the service of artillery, as the ranges from them are shorter, or at most but equal; and beside the useless expenditure of powder, the carriages are soon rendered unserviceable, and the greater part of the shot are of no effect.

94. The causes of the recoil merit a more particular examination. There are two motions in the breech of a gun, at the instant of discharge; one up and down, by which it sinks into the coils, and sometimes throws them upon the ground, if too obtuse or improperly placed: this reflected movement of the breech takes place when the center of gravity of the gun is too near to the axis of the trunnions, or when the coils are made of too elastic a substance. The other is an attempt to retire with all the machine in a direction opposite to that of the movement of the shot, which is termed the recoil.

95. The better to understand the cause of this double motion; let a resisting vessel, in which powder takes fire, be supposed to have the vent stopped at the beginning of the inflammation, no motion will in this case be perceived, because the elastic fluid, pressing equally upon the sides of the containing vessel, and all the parts having a mutual attraction, its powers are in equilibrio: the balloon inflated with air is a very simple demonstration of this.

96. But if the elastic fluid can escape through an aperture made on purpose, or through a cleft caused by its action on the sides of the vessel, it will be impelled in a direction opposite to the aperture, with a force proportionate to the density and velocity of the fluid. For the elastic fluid in escaping meets resistance from the external air, and impels it and the vessel in opposite directions; and if the vessel itself be not equal in weight to the action of the fluid, it will be put in motion: since the column of air which resists this motion, and tends to preserve the vessel in a state of rest, will not be able to prevent it; (its resistance being proportional to the velocity of bodies moving in it:) the greater the velocity with which the fluid rushes out, the greater will be the resistance, and the longer the recoil: a number of experiments

might be adduced in support of this, but the common sky-rocket fully exemplifies it.

97. When fire is introduced into the vent of a gun, the action of the breech against the coins is in proportion to the density of the elastic fluid in the charging cylinder: now as the wad and shot cannot move before there be a sufficient quantity of the fluid generated to overcome their resistance, and force out the column of air from the bore of the gun; if the wad be too strongly rammed, or a part only of the powder take fire, or more than one shot be put into the gun, or it be more elevated at one discharge than another, the resistance to the fluid being increased by one or more of these causes, a greater quantity must be generated before the shot and wad will be moved. Before this motion commences, there can be no recoil (95), for the shot and wad form; as it were, a part of the gun itself: wherefore, if so large a quantity of substances be put into a gun, as totally to prevent, by their resistance, the escape of the elastic fluid, there will be no other movement in the piece than that of the breech up and down against the coins; which might, if necessary, be more fully demonstrated. Moreover, since a part of the elastic fluid escapes through the vent during the time of its generation in the charging cylinder, it is clear, that the action of the breech against the coins in the opposite direction, must commence as soon as the powder takes fire, but the recoil will begin sooner or later according to the resistance opposed to the explosion.

98. Hence, if the movement of the breech up and down has not totally ceased before the shot quits the gun, it may be thrown above or below the point aimed at. When the wheels are of unequal diameters, or not placed in the intervals of the corresponding lines and nails, or the platform on which the gun moves while the shot is passing along the bore, is not even and solid; in all these cases, the gun will not recoil in the proper direction, and the shot will be thrown wide of the mark.

99. The length of the recoil during the time that the shot is passing along the bore varies according to circumstances. If the charge, for instance, be rammed in the common method, and the gun placed on an even horizontal platform, the elastic fluid must exert more force to move the charge than to move the gun; as is the case in using the wad-hook to draw out the charge, the gun being drawn forward before

before the wad is displaced. If, on the contrary, part of the platform be raised, the same force that will draw out the wad will not be sufficient to draw the gun up the inclined plane. Similar varieties occur in the recoil, when the elevation of the gun is altered, or the wheels turn more freely on the axle-tree.

To give to this question a practical solution, with respect to charges that all take fire in the gun; let the gun and carriage be considered as one body = C, the wads and shot = P, the length of the bore from the shot to the muzzle = D, the

recoil will be = $\frac{PD}{C}$. Let one round be fired with a wad

over the powder, and the recoil = A. Let a second be fired with the addition of a shot, the recoil = B will be greater

than A; and $A : B :: \frac{PD}{C} : \frac{BPD}{AC}$ = the length of the recoil

in the time that the shot is passing along the gun. This experiment having been made with a thirty-two pounder, charged with common powder, and fired horizontally on a

horizontal platform $\frac{BPD}{AC} = \frac{1}{2}$ an inch. So that if the plat-

form be very solid and even for $\frac{1}{2}$ an inch, at the spot on which the wheels and trail of the carriage rest, the remainder of the platform is only useful in facilitating the operations

of the artillery-men: indeed, as the value $\frac{BPD}{AC}$ may from

circumstances vary a little, allowance should be made for it. 100. Let the second effect (90. N^o 2.), viz. that *the charge which gives the longest range in pieces of small calibre, is proportionally greater than the charge which gives the longest ranges in pieces of large calibre*, be now considered. This effect, which constantly appeared in the foregoing experiments, could only proceed from the size of the vent being equal in the four guns, and from the wads being rammed with the same force. From the former circumstance, a relatively greater degree of fire is produced in the small guns; and from the force with which the wads are rammed, the powder is more compact, and the charge adhering closer to the

the sides of the gun, the resistance is increased, and more grains are fired.

101. In the spring of 1750, the officers of artillery being directed to investigate some professional points under the orders of the Chevalier FERRERO DI PONSIGLIONE, made several experiments to find the charge that gives the longest range, when the piece is fired at the highest elevation the carriage will admit of. The guns were of the same calibre and proportions as in 1746, only the shot being rather larger, the windage was less. They were loaded with the ladle with different charges of common grained cannon powder: three rounds were fired from each gun with the same charge; the same artillery-men gave five strokes of the rammer to the wad over the powder, and three to that over the shot; the guns on their carriages, moving freely upon a horizontal platform were always laid at the same elevation, and every precaution was taken to load them equally; and measure exactly the length of the ranges, upon a flat piece of ground nearly on the same level with the battery.

Result of Experiments made in the Spring of 1750.

Nature of Guns.		Weight of Powder.	Length of Range.	Recoil.
Pouuders.	Elevation.	lb. oz.	Yards.	Inches.
4	14°	2 1	2375	52
		2 8	2219	60
		2 14	2422	70
		3 5	2526	76
		3 5	2321	46
8	11°	4 2	2463	65
		4 15	2486	85
		5 12	2375	102
		6 9	2675	119
16	12°	5 12	2659	71
		6 9	2860	76
		7 3	2663	90
		8 3	2810	97
		9 0	2764	108
		9 13	2892	113
32	11½°	11 8	3172	117
		13 2	3032	120
		14 6	2995	124
		16 6	3220	146
		18 0	3084	168

102. It results from these experiments, that the charges that give the longest ranges when cannon are fired at the highest elevation their carriages will admit of, are greater than those which produce the same effect when fired horizontally (89). But the ranges do not increase in the regular progression that might be expected. For instance, in the sixteen pounder, the charges of 5 lb. 12 oz. and 7 lb. 3 oz. gave ranges nearly equal, while 6 lb. 9 oz. gave one much longer. These irregularities proceed from the different charges not having been fired on the same day; the 5 lb. 12 oz. were fired the 23d of March, the 6 lb. 9 oz. the day following, and the 7 lb. 3 oz. on the 1st of April; if they had been fired on the same morning, the modifications in the explosion of the powder, and the air's resistance to the shot, resulting from the alterations in the state of the atmosphere, would have been avoided: in the 4th and 5th chapters of the second part, this matter will be more fully discussed.

On repeating these experiments with such precautions as to avoid the modifications arising from changes in the state of the atmosphere, the charges (101) that give the longest ranges will be found to be almost double of those used in 1746; but the increase of range is of little importance compared to the increase of the recoil, and the greater shock sustained by the carriage; these large charges should never be used for common service.

103. In experiments of this kind, a remarkable inequality between two ranges from equal charges of powder will occasionally occur, though every precaution be taken to fire them under circumstances as nearly similar as possible. These inequalities were neither so frequent nor considerable in 1746 as in 1750; but it is impossible totally to avoid them, for supposing the direction of the guns to remain unaltered at the explosion, yet there are two causes which separately or conjointly may render the ranges from equal charges of powder unequal.

1. The shot in passing through the plane of the gun, may not exactly follow the direction of the bore; or on quitting the gun, it may take a different direction.

104. 2. The powder may not be equally well collected in the piece, so that charges though equal in quantity, have not the same figure: large charges are more liable to this accident than smaller ones, particularly when rammed

rammed with the same force. In this case the quantity of powder fired in the larger charge, varies in proportion to the disposition of the grains to inflammation; for instance, in guns laid above the horizon, more powder ought to take fire, as the resistance to the explosion is greater. The larger the charges, the more frequent are the inequalities in the ranges independent of the violent concussion of the carriages.

105. Wherefore, the two extremes of very large or very small charges should be equally avoided; for the first does not compensate for the uncertainty of their ranges, or the great increase of recoil, by the additional velocity and force given to the shot: and with very small charges, the least difference in the size of the wads or ramming, causes a great alteration in the impulsion of the shot and ultimately in the range; as is often seen in ricochet-firing, and in mortars loaded with small quantities of powder.

106. This object of ascertaining the charges that give the longest ranges, has engaged the attention of the French, as well as the Piedmontese artilleryists; and the result of their experiments appears to be, that in cannon of large calibre, the charge ought to be about $\frac{3}{8}$ of the weight of the shot.

The knights of Malta, on seeing the report of the French experiments, were induced to direct Sig. MARANDONE, engineer of the order, in the month of August, 1747, to repeat them. He sent to the regiment of artillery at Turin a detail of his practice, and asked the opinion of the officers on the conclusions to be drawn from it. Having observed, that on using larger charges than $\frac{3}{8}$ of the weight of the shot, the ranges still increased proportionally; he did not think it necessary to pursue his experiments for finding the charge that would give the longest range; and judging that the French powder was weaker than his, he concluded that when cannon of a large calibre are charged with a stronger powder than the French use, the charge which ought to produce the longest range, must exceed $\frac{3}{8}$ of the weight of the shot: this conclusion is conformable to our theory, and the results of our practice.

It is clear then, that the artilleryists in former days, consumed a superfluous quantity of powder, in making the charge equal to the weight of the shot: it even sometimes exceeded it, as their powder was much weaker than that now in use.

107. The charges we have laid down as giving the longest ranges (89, 102) are under similar circumstances, the same in all guns of the same calibre, whatever be their length; since the increase of length does not generally cause the inflammation of a greater number of grains (71) the charge which in one gun will give the longest range will give it equally in a shorter one of the same calibre: very short guns are indeed an exception to this rule; for in them the action of the elastic fluid upon the shot in two unequal charges that all take fire, is at least equal, or even greater, in the smallest charge; as the shot having a greater length of the bore to pass through (80) is longer impelled by the elastic fluid.

108. It only then remains to ascertain the best charges for service; we should previously recollect, that the great utility of fire-arms consists in two points: the first and principal one is, to strike the object aimed at; the second is, to strike it with a due degree of force. The first is ever indispensable; the second admits of certain modifications: for the greatest force that fire-arms can produce is not always requisite; and even when it is (Philos. Instit.) it is better to diminish the charge, and lessen the effect of the shot, than run the hazard of missing the object, from the uncertainty of using very large charges; this needs no illustration. Beside, brass guns fired frequently with large charges are in a few days rendered unserviceable; wherefore the advantages and disadvantages attending the use of them should be fully weighed, as upon the preservation of the guns may entirely depend the success of an enterprise.

109. To apply these considerations to practice, and combine the justness of the range with the necessary force, and with the preservation of the gun and carriage; the charges of powder for sixteen and thirty-two pounders, ought never in the attack and defence of places to exceed half of the weight of the shot, if the gun be properly proportioned (89) and fired at the distances set down in the second and third book of Military Architecture, and the Treatise of Artillery; this we will call the largest service charge, and should only be used in cases of necessity: the smallest service-charge should not be less than $\frac{1}{4}$ of the weight of the shot, and the medium charge $\frac{1}{3}$ or $\frac{2}{3}$ of its weight.

The charge for eight and four pounders should vary according to circumstances, from $\frac{1}{4}$ to $\frac{2}{3}$ of the weight of the shot: the wads in these pieces and in thirty-two and sixteen pounders,

pounders, should be rammed in proportion to the weight of the charge, in order to produce the proper effect; perhaps too much force cannot be used, provided that the grains of powder are not crushed and beat so close as to prevent the fire from penetrating. The charge for ricochet and red-hot firing, is very small in proportion to the calibre; it depends in sieges on the situation of the gun, as the distance from the enemies batteries is the only point to be considered. The charges for field artillery in general actions, in affairs of posts, in attack and defence of intrenchments, &c. should be between $\frac{1}{4}$ and $\frac{3}{5}$ of the weight of the shot, according to the calibre and weight of the gun.

110. Though our observations have been hitherto confined to the proper charges for guns; yet those for mortars may be easily ascertained by knowing the quality of the powder, and the form of the chamber. All the mortars now in use, in which the communication between the chamber and the chase is narrower than the greatest diameter of the chamber, as the spherical, elliptical, parabolic, and those in form of a pear, always range the farthest, when the chambers are filled with the common cannon powder, and the shell closely confined by well sifted earth rammed upon it; it is clear in this case that the charge cannot be augmented. Beside the concussion is more violent, and the ranges are less exact, when the chambers are not filled; therefore, to throw a shell to a certain point, the chamber should be filled, and the range regulated by the degree of elevation.

111. We will conclude this chapter by shewing experimentally how much the difference in the size of the vent affects the force of the shot. A musquet was taken $\frac{5}{16}$ of an inch in diameter, and 33 inches in length of barrel. The axis of the large screw which closes the breech, was perforated with a hole $\frac{5}{16}$ of an inch in diameter, with spiral sides to receive a smaller screw; one end of the smaller screw was armed with a little piece of red hot iron, to set fire to the powder in the barrel; to the other end a winch was fixed to screw it up; at the part where the vent is generally placed, a circular hole with spiral sides was drilled $\frac{5}{16}$ of an inch in diameter, to which three screws were successively applied; the first exactly closed the opening, and consequently forced all the fired powder to pass through the muzzle. The second had in its axis a hole or vent $\frac{1}{16}$ of an inch in diameter, through which a part of the fluid might escape; and the third had a vent of $\frac{3}{16}$ of

of an inch in diameter. The musquet thus prepared was loaded each time with 10 drachms of fine powder put into cartridges, and with an iron ball $1\frac{1}{2}$ oz. in weight; the wads were rammed down with equal force by the same man.

The experiments began by firing the musquet with the screw that entirely closed the vent; it was then fired with the screw $\frac{1}{10}$ inch in diameter; afterwards with that of $\frac{2}{10}$, and at length without any screw. The charges were fired by the hot iron screwed into the breech: the object was a plank placed at 5 feet from the muzzle of the musquet.

The medium of the penetration of the balls in 24 rounds is as follows:

		<i>Inches.</i>	
In the dis- charges	{	with the vent entirely closed - - -	6
		with the vent $\frac{1}{10}$ of an inch in diameter -	8
		with the vent $\frac{2}{10}$ of an inch in diameter -	$6\frac{5}{8}$
		with the vent $\frac{3}{10}$ of an inch in diameter -	4

It results from this experiment, that when there is no vent less powder is fired, and that which does take fire burns more slowly. If the large vent be left open, and a sheet of paper stretched at 2 feet from it, the paper will be pierced full of holes by the powder forced through the vent at the explosion. Soldiers firing in line are often pricked in the face by grains of powder driven with force from the musquets on their left; the common opinion that these grains are a part of the prithing is erroneous.

S E C O N D P A R T .

OF THE FORCE OF FIRED GUN-POWDER.

112. **I**T was shewn in the former part of this work that the principal properties of powder are subject to many modifications, even in experiments conducted with the utmost care. How much more important and frequent then must they be when powder is employed in military operations; where, from the nature of things, there can neither be so much attention paid to prevent irregularities, nor so much accuracy

accuracy in the construction of the machines. In calculating effects deducible from physical causes, a precise solution of the problem can never be obtained; it is always comprised within limits more or less distant from the absolute truth, in proportion to the number of causes that conduce to the same effect. Consequently in measuring the force of powder fired for military purposes, no precision can possibly be expected; and from the nature and number of adventitious circumstances, the limits that comprehend the solution of the problem must necessarily vary; sometimes even a general principle will be only applicable to particular cases. Besides, as artilleryists frequently prefer observations drawn from practice to rules deduced from theory, it is necessary to divide the problem into distinct parts, and consider each of the conditions separately, in order to combine as much as possible theory with practice. In the course of this examination we shall prove, that this combination is in all cases advantageous, in some indispensable.

These preliminary remarks lead to the subject of the chapter. Since the inflammation of the grains, and the total destruction of each is effected successively, and in a time proportionate to the quality of the powder, the size of the grains, &c. and since on the other hand the force of powder depends principally on a permanent fluid generated at the explosion, the elasticity of which is increased by the presence of fire: it follows that this force increases continually from the instant that the inflammation commences, till all the powder be consumed, and then is quickly reduced by the decrease of heat, to the simple elasticity of the permanent fluid. There is then a period when the degree of heat is most intense; but this varies even in powder of the same quality, when fired under different circumstances. As no general and constant law can therefore be established, we must be content with ascertaining the greatest degree of force in particular cases; which founded on certain data, may be usefully applied to the various services of artillery. But that none of the most material points involved in the solution of this problem may be passed over in silence, nor any vain hypotheses and chimerical suppositions formed; let us in the first place examine the force of powder in its most simple state, that is, when reduced by the temperature of the air, to the elasticity only of the permanent fluid, and afterwards in its most complex state, that is to say, at the instant of explosion.

C H A P. I.

THE METHOD OF MEASURING THE DENSITY AND ELASTICITY OF THE PERMANENT FLUID, GENERATED FROM FIRED POWDER, WHEN REDUCED TO THE TEMPERATURE OF THE ATMOSPHERE.

114. **T**O measure the absolute elasticity of the permanent fluid, there should be no communication between the powder and the atmosphere, either during or after the explosion. But it is impossible to ascertain the exact degree of pressure of the fluid in a close vessel the instant after the explosion, as its force is then increased by the heat that remains in the vessel: nor can a more precise knowledge be obtained by delaying the experiment, till the internal air be reduced to the same temperature with the external; as a part of the fluid is absorbed by the smoke and vapour: the absolute force therefore cannot be ascertained, but the following experiment will give the most accurate approximation.

FIG. VI. This machine separates as much as possible, the permanent fluid from the smoke, sulphureous vapour, and caput mortuum of the powder, and diminishes considerably the action of the heat that remains in the vessel.

A A B B, is a cube of brass, of which the two sides **A A B B** are cylinders terminated by portions of spheres: **A A**, is made to receive the screw **E E** of another hollow cylinder **E D D E**. **F G L** are copper vessels of different sizes, which screw on to **B B**; **H I H** is a small cylinder of brass fastened to the cube **A B**, by two screws **H H**; within it is a piston **K**, nicely fitted, which by means of the screw **I**, opens or shuts the pipe *oo, pp*, that communicates between **A A**, **B B**. **M N N M** is a parallelepipedon of brass fixed to the cube **A B** by the screws **M M**, and the little pipe *qq* corresponds to *rr*. **S R S** is another parallelepipedon of the same metal, hollowed in the form of a cylinder; the opening *tt* is filled with a glass vessel, containing a coloured liquor, the surface of which, &c
 D may

may be distinguished through the glass. At the upper part of the parallelepipedon is an aperture R, by which the external air communicates with the inside of the vessel. V W is a long glass tube, open at both ends; it is attached to a plate of brass X X which is fastened to S R S, and graduated in the same manner as a barometer: y y is a screw made to turn very nicely in the lower part S S of the parallelepipedon S R S, by means of which the surface & of the liquor contained in the glass vessel can be raised or lowered at pleasure. When S R S is fastened to M N N M by the screw 16 of an iron pipe 2, 3 screwed on to M N N M at 4, 4, the hole R corresponds exactly with q: 10, 12, 10 is a solid cylinder of brass, with a little cavity 12 to hold the powder for the experiment; it is placed in the hollow cylinder E D D E, so that its base 10, 10 rests upon the ledge 11, 11, in A, 11, A: its diameter 17, 17 ought to be about $\frac{1}{2}$ of an inch less than the interior diameter 18, 18 of the cylinder E D D E: 5, 7, 9 is a piece of iron that screws into D D at 7 7; the inside is spirated to admit the screw 8, 6, 8 at 5.

For the sake of making the experiment with more ease, the cube A B is fastened to a circular bar T T of any metal, made as high as may be necessary for the purpose of applying the different vessels F G L and screwed on to a table or other convenient place at m m.—

115. For the experiment, apply R S to N N and screw on the recipient F G L to B B. Place the cylinder 10, 12, 10 upon the ledge 11, 11, and having put the proper quantity of powder into 12, screw the cylinder E D D E to A A. At q of the piece of iron 5, 7, 9 lay a thin sheet of lead, and when 5, 7, 9 is screwed on to D D let fall in 5, 9 a hot ball of iron, which will be retained at q by the sheet of lead. Instantly screw 8, 6, 8 into 5 by the handle 13, 13, so that 8, 8 may exactly fit 14, 14; the point 6 pushes the iron ball into the cavity 12 containing the powder, and 5, 9 is exactly closed by 8, 6 before the explosion can take place. When the powder is totally consumed, draw back the piston K by means of the screw I which opens the pipe oo. The elastic fluid generated at the explosion, soon spreads from the upper cavity into the pipe oo, passes through p p into B L B; thence rising through r, r, q, q it

it passes through the hole R into the glass vessel, and presses upon the surface & of the liquor contained in it. This pressure makes the liquor rise suddenly in the tube V W, after some undulations it fixes at a height proportionate to the quantity of powder.

116. If the height of the water in the tube when the undulations cease be remarked, and the machine remain in the same state, it will be found on observing it, after equal intervals of time, that the water continues sinking; but less after the second interval than the first, and less after the third than the second, till at length the alteration becomes imperceptible, except a very long interval be suffered to elapse. At the end of twenty-four hours, the liquor remains stationary in the tube, affected like the thermometer, only by heat.

These undulations arise from the smoke of the sulphur and the caput mortuum of the powder, having absorbed a part of the elastic fluid: the absorption is considerable at first, but its effects gradually diminish. On comparing the height of the water when it becomes stationary with its height, when the undulations ceased, the difference will denote the quantity absorbed by the smoke, &c. If the instant the undulations cease, the communication between the upper and lower cavities be closed by the piston K, the water stops suddenly, and never varies in height, unless affected by some alteration in the temperature of the atmosphere; if, after some time, the communication be again opened, the water will suddenly sink in the tube, because the elastic fluid contained in the lower cavity, rises to re-establish an equilibrium with that in the upper one, a part of which has been absorbed by the smoke and caput mortuum.

117. It will not be amiss previous to the experiment, to make a few physical observations on the effects observed above, and give some of the motives that influenced the particular construction of the machine. When the quantity of powder consumed in the experiment is $\frac{1}{300}$ of what the upper cavity could contain, if the cylinder E D E be taken off when the machine is perfectly cool, the smoke and caput mortuum will be found attached to the upper part D D of the cylinder E D E, and to the upper part 12 of the other cylinder 10, 12, 10; the action of the fire will have changed the colour of the latter, from its extremity 12, to about one third of its length, while no mark of the fire or smoke ap-

pears at the other extremity A 10 A, nor in the recipient FGL. This proves that when the communication between the two cavities by the piston K is opened, the elastic fluid spreads itself without mingling with the smoke; therefore, the sinking of the surface of the water in the tube, when the communication between the two cavities is open, and its sudden fixation when it is shut, can only be attributed to the absorption of a part of the elastic fluid, by the smoke and caput mortuum (116): it was necessary then to form a communication between the cavities, by this or some similar contrivance.

If instead of $\frac{1}{300}$ of the powder that the upper cavity could contain $\frac{1}{100}$ be burned, the only difference will be, that the mark of the fire and smoke will descend nearer to the ledge 10, 11, 10, yet without entering the pipe oo. But, if a much greater quantity of powder be used, a part of the smoke will accompany the fluid into the recipient, on the opening of the communication, absorb a part of the fluid, and diminish its pressure on the surface of the liquor.

The cylinder 10, 12, 10, is designed to lessen the action of the heat upon the fluid, and prevent the smoke from penetrating into the recipient; for,

1. If the powder be fired in A 11 A instead of 12, a part of the smoke and caput mortuum, would readily pass through the pipe oo into FGL, and not only absorb a part of the elastic fluid, but also clog up the piston K when wanted to stop the communication.

2. The cylinder 10, 12, 10, increasing the superficies of the upper cavity, and the fire acting upon a greater number of physical points, the heat being thus communicated to a larger mass is less, as is shewn in the 1st part, chap. 1.

3. As the heat arising from the inflammation of the powder, and the hot ball is almost entirely concentrated in the cavity 12, D, E, and consequently acts upon a part only of the internal air and the elastic fluid, it increases the elasticity much less than it would do, if communicated to the fluid and air contained in the whole cavity. This is not only agreeable to the preceding theory of fire, but may be further proved by this machine, in the following manner. Having disposed all the parts of it properly, without putting any powder in 12 open the communication, and let
fall

fall into 12 a red hot ball; the heat expands the air in the cavity, and makes the water rise in the tube. Having remarked its height, take away the cylinder 10, 12, 10, and repeat the experiment, the ball in passing through A D A to fall into A 11 A, rarifies the column of air that it contains, so much that the water rises in the tube 15 or 20 times higher, than in the former experiment; but descends suddenly, and fixes at a point only three or four times higher.

118. Having explained the construction of the machine, the combination of its parts, and the effects that powder has on it, is necessary to examine;

1. If the elastic fluid can escape. This may be ascertained, by condensing a certain quantity of the air in the machine, and observing while it is in that state, if the alterations in the height of the water in the tube, and those in a thermometer placed near the machine, differ.

2. The quantity of saltpetre equal to the contents of the upper cavity to the piston K, and of the lower one from K to the surface of the water contained in the glass vessel taken together should be known. To find this, weigh the quantity of water that will fill the two cavities: in our machine, it was equal to 16580 grains. Now as the specific gravity of water is to that

of saltpetre as 10 : 19, the last term $\frac{19 \times 16580}{10}$ expres-

ses the quantity of saltpetre equal in bulk to the contents of the two cavities.

119. To begin a course of experiments; put so small a quantity of powder into 12, that the smoke will not pass from one cavity into the other; then having properly arranged all the parts of the machine, and closed the communication, drop the hot ball into the canal 5, 9, where it will be retained by the sheet of lead. Instantly screw on 8, 6, 8 which exactly closes up the canal 5, 9 and pushes the ball into 12 to fire the powder: then open the communication between the two cavities, and when the undulations of the water in the tube subside, close it again. When the water rises in the tube, the surface &c in the glass vessel sinks: raise it by turning the screw y y, till it reaches the point it was at before, in order always to preserve

the lower cavity in the same state. Observe the height of the water in the tube VW , measuring it from the surface & deducting the augmentation proceeding from the attraction of the glass. The effects of this attraction are known previous to the experiment, by noting how much the water contained in the tube, is higher than the surface & This experiment should be repeated several times in the same manner, with equal quantities of powder of the same quality, in precisely the same state of the atmosphere, observed by a very accurate thermometer; and the elevation of the water in the tube at each time remarked. Neither the recipient $FG L$ nor the cylinder $E D E$ should be ever touched with the naked hand, but with a folded napkin, for the contact even of a finger would in a short time excite a degree of heat sufficient to raise the water in the tube. After several repetitions, take the mean height; thus the varieties occasioned by the absorption of a part of the fluid, and the heat remaining in the machine may be accounted for. Call this mean height a , and the mean height of a barometer filled with the same kind of liquor as the glass vessel

A ; the fraction $\frac{a}{A}$ will express the ratio between the elasticity of the fluid produced from the powder, and that of the atmospheric air.

120. In small quantities of powder the proportion between the saltpetre and the other ingredients may not be exactly the same as in a larger mass; which in a series of experiments may cause a considerable variation in the elevation of the water in the tube. To remedy this inconvenience, grind some saltpetre, sulphur, and charcoal separately; weigh the saltpetre and mix it with such a quantity of the other two ingredients as will most quickly consume it. The mixture need not be granulated, as the elasticity and density of the fluid are the only objects of research in this experiment; the phlogiston being only employed as the means of decomposing the nitre.

121. The elasticity of the fluid, though very much dilated in the two cavities is exactly proportionate to its den-

sity: thus the fraction $\frac{a}{A}$ expressing the elasticity = n will also

express the density. Now supposing the contents of the two cavities

cavities taken together = $c = \frac{19 \times 16580}{10} (118) = 31502$ grains,

and the saltpetre made use of in each of the experiments = f ;

then $\frac{nc}{f}$ will express the density of the fluid contained in a

space = f . But the non-elastic substances = m which are in the saltpetre must be deducted from f , call their bulk = rm ;

then $f - rm$ will express the quantity of the fluid, and $\frac{nc}{f - rm}$

will express the density of the elastic fluid when confined in the saltpetre.

122. The specific gravity of the fluid generated from nitre is supposed to be equal to the atmospheric air. Then since the specific gravity of air to saltpetre is as 1 : 1520, and the contents of the two cavities taken together are equal to a quantity of saltpetre = c ; the quantity of air in the machine (Fig. 6.) capable of producing an effect n equal to that of the fluid $f - m$ will be represented by the expression $\frac{nc}{1520}$. Then

$f - m = \frac{nc}{1520}$; and substituting in this equation, the known

values $c = 31502$, $f = 6$ grains, $n = \frac{2}{21}$, that of m will be

= 4 grains; and as the quantity of elastic fluid contained in nitre is proportionate to its mass (57), it will be expressed by

the ratio $\frac{f - m}{f} = \frac{1}{3}$ of the mass of saltpetre. It does not

follow, because the specific gravity of this fluid is equal to the atmospheric air, that it has all the other properties of it; much less that it is pure air: For it has been proved in the former part of this work, that the greater the rarefaction of the air, the more difficultly powder is fired. Now the elastic fluid generated from the first burnt grains not supplying the want of natural air, we must at least allow, that at the first instant of its generation it is deprived of the property which the aerial fluid possesses, of accelerating the burning of combustible bodies. It would be a research foreign to our purpose, to enquire whether the elastic fluid does or does not acquire this property some time after its production.

123. In the theorem $\frac{nc}{f-rm}$ (121), if the known values of c , n , f , m be substituted, and $r = \frac{19}{27}$; that is to say, if the density of the non-elastic substances be equal to the density of the fixed nitre, $\frac{nc}{f-rm} = 942$; the density of the elastic fluid is then 942 times greater when inclosed in the saltpetre, than when in equilibrio with the pressure of the atmosphere.

124. The quantity and density of the elastic fluid contained in saltpetre being known, it will be easy to find the density of that generated from a quantity of powder fired in a close vessel. Suppose the vessel be expressed by a mass of saltpetre, the weight of which = G ; the elastic fluid will = $\frac{G}{3}$ the non-elastic substances = $\frac{2G}{3}$, and their mass = $\frac{38G}{81}$ (122). Thus $G - \frac{38G}{81} = \frac{43G}{81}$, will be the volume of the fluid $\frac{G}{3}$.

If the quantity of powder fired in the vessel G be expressed by $b+p$, where b denotes the quantity of fluid contained in the powder, and p the sulphur, charcoal and fixed nitre; and after the explosion, the mass of non-elastic substances = qp , then the volume of the fluid, after the powder is fired,

will be $G - qp$. Now, if the value of this fluid was = $\frac{G}{3}$,

its density in the volume $G - qp$ would be to its density in the volume $\frac{43G}{81}$ as $\frac{nc}{f-rm} : \frac{nc}{f-rm} \times \frac{43G}{81 \times (G - qp)} :: 942 :$

$942 \times \frac{43G}{81 \times (G - qp)} = \frac{500G}{G - qp}$. But if the volume of the fluid

be only b , then the proportion will be $\frac{G}{3} : b :: \frac{500G}{G - qp} : \frac{1500b}{G - qp}$ the density required. For example, suppose the ves-

Vessel G be filled with war powder: From the composition of this powder $p = 3b$, and a vessel which could contain a quantity of saltpetre = G is filled with a quantity of powder weighing $\frac{15G}{38}$, and the value of q is known by other experiments = to about $\frac{7}{9}$: then $b + p = 4b = \frac{15G}{38}$; now substituting in the place of b the numbers and values of G and p ,

$$\frac{1500b}{G - pq} = \frac{1500b}{G - 7b} = \frac{1500}{\frac{152}{3} - 7} = 192, \text{ that is to say, the density}$$

of the fluid produced in the vessel G is equal in this case to 192 times the density of the same fluid when its elasticity is equal to the mean pressure of the atmosphere.

To determine the elasticity of the fluid generated from a given quantity of powder fired in a close vessel, one of these two theorems

$$288 + 9962nS; \quad 288 + 9962Sx \sqrt{\frac{3}{2}m - \frac{3}{2}\sqrt{m \times m - n^2}}$$

may be used: the first when the density of the fluid is less than 20; the second when it exceeds 20: in the first case, it will be sufficient to find, according to the method laid down in the preceding paragraph, the value of the density of the fluid, then substituting this value in the place of n in the first theorem, the pressure of the fluid against a superficies S will be expressed in pounds. In the second theorem, instead of m insert 942, which expresses the density of the fluid when enclosed in the nitre (123); and instead of n , the value of the density of the fluid generated from the nitre found as in the preceding paragraph. Then the pressure of the elasticity of the generated fluid on a superficies S will be expressed in pounds.

C H A P. II.

THE METHODS OF MEASURING THE GREATEST FORCE
OF FIRED POWDER AT THE INSTANT OF EXPLOSION
IN A VESSEL THAT CAN NEITHER INCREASE IN SIZE
NOR ALTER IN FORM.

126. **I**F it be so difficult to measure the elasticity of the permanent fluid in its most simple state, how little reason is there to expect, that its force at the instant of explosion can be ascertained with precision, when the fluid is greatly complex, and when from various causes, its elasticity may be increased or diminished. In fact, it is impossible to define either the quantity of fluid generated at each instant of the inflammation, the intensity of the fire, or the manner in which it spreads and propagates itself among grains of different kinds of powder, or even of the same, when used under different circumstances; the degree of rarefaction in the common air contained within and between the grains, the elasticity of the smoke, and the increase of elasticity in the permanent fluid arising from the pressure of the substances, relatively considered as non-elastic, when expanded by the action of heat, are equally unknown.

The solution of so involved a problem would seem to surpass human skill, since from the short duration of the phenomenon, the numerous circumstances that affect it cannot be analysed; as no method can be devised of assigning the exact quantity and force of each, either by separating at the instant of inflammation the smoke from the other parts, preventing the expansion of the non-elastic substances, or observing the law in which the fluid is generated. The utmost we can do is to ascertain the greatest force resulting at the instant of inflammation from the reunion of all these causes, by the help of such principles as we may be able to establish. To avoid entering into too long a discussion, let us suppose the powder to be fired in a vessel so completely filled, that no void space be left, except the interstices between the grains. There are three different cases in which powder may be fired :

1. In

1. In a vessel that cannot increase in size or alter in form, with the vent closed at the beginning of the explosion.

2. In a similar vessel, with an aperture left for the escape of the fluid.

3. In a vessel which by the force of the explosion expands or increases in size, and affords an issue to the fluid.

It is evident, that on firing equal quantities of powder of the same quality, in vessels perfectly equal in every respect, the degree of force will be greater (113.) in the first case than in the second or third, and in the second than in the third.

127. The first case can never occur in the uses to which powder is applied in military operations. The second happens sometimes in the chambers of mines, where the surrounding substances do not yield to the explosion; and in shells and grenades, whose resistance is sufficient to put them in equilibrio with the action of the powder. The third case arises in the chambers of mines, made in substances susceptible of impression, and in fire-arms loaded in the customary manner.

The principal methods of measuring the greatest force of fired powder in the second case will be treated of in this chapter, and in the subsequent ones; the method of measuring it in the third case: confining our observations however to its effects on fire-arms; since in the third book of Military architecture, and in the Treatise of Artillery, the application of powder to mines is amply discussed.

128. To measure the greatest elasticity of the fluid produced from fired powder, it may be compared with the three following resistances, the weight, cohesion, and elasticity of bodies. It has been found from experiment, that the greatest elasticity of powder fired in an invariable vessel, from which the elastic fluid can escape by the vent (126. N^o 2.) is equal to about 1800 times the mean pressure of the atmosphere: the machines therefore for measuring the greatest force of different powders (40.) must be capable of a very great resistance, and the weight to express the force, very considerable, which renders it extremely difficult to construct such complicated machinery, with the requisite exactness and accuracy.

129. If to reduce the weights, or simplify the machinery, the quantity of powder be less than the vessel could contain, the fluid produced at the commencement of the inflammation, being diffused through the whole vessel, will not be exposed to the same degree of heat, as if the vessel were full, and the powder burning in each point. Thus with equal quantities of powder, the elasticity will be in proportion to the size of the containing vessels; and in vessels of equal contents, in proportion to the quantity of powder. Therefore, to ascertain the greatest elasticity from the effects of a small quantity of powder fired in a large vessel, it will be necessary to repeat the experiment with different quantities of powder, till the maximum be discovered.

130. The form of the vessel should be such, as to admit of the powder being so collected, that the whole may take fire in the shortest time possible, and act instantly upon the surface of the resisting body, whose motion is to determine the pressure of the fluid: For if it be not in contact with the mobile, instead of an action of pressure, it will be an action of impulsion, and the force communicated will be much greater, than is the present object of this research: to render the experiment conclusive, this circumstance must be carefully attended to.

131. In the common mode of proving powder with the small mortar, the weight of a globe is opposed to the explosion: but this method cannot ascertain the greatest elasticity, for the globe being proportionally too light, is put in motion before the full force of the powder is produced.

The *eprouvette*, is a vertical machine invented long ago, for comparing the force of different kinds of powder by means of weight. But to ascertain (Fig. 7.) the greatest elasticity, the weight $QMNQS$ ought to be much heavier than it generally is; it should only yield to the impelling power when the elasticity is at its highest degree, and be raised just enough to shew that it has given way to the action of the fluid. The weight may be increased or diminished at pleasure, by making it hollow in QSQ and putting in any heavy substances that can be uniformly arranged, as small shot, &c. which will preserve the centre of gravity in the vertical axis ST of the cylinder: at the sides of the *eprouvette* two channelled uprights should be placed so that when the body $QMNQ$ is raised, the teeth LL may slide perpendicularly in the grooves.

132. The

132. The theorem $9962 n S = P$ where n expresses the elasticity of the fluid, and S the surface acted on, shews that if in this eprouvette the diameter EF of the cylinder be $\frac{1}{4}$ of a foot, S will be $= \frac{1}{774}$: then substituting 1800 in the place of n , $9962 n S = 9962 \times 1800 \times \frac{1}{774} = 23048$ lbs: the weight $QMNQ$ should not be less, that it may just yield to the action of the fluid in its highest state of elasticity; but as such a weight is very ponderous and unmanageable, it may be measured by a lighter mass, by lessening the value of S without diminishing the size of the cylinder, as follows:

133. In the eprouvette $ABCD$, make a hollow cylinder $CIKD$ of such a depth, (Fig. 8.) that on applying the screw $GCPDH$ of a sufficient length to resist the greatest efforts of the powder, the height GI of the space $IKGH$ be nearly equal to the diameter GH . In the centre of the screw drill a cylindrical canal OP , and introduce a pin of polished iron of the same form, fitting so exactly that the fluid cannot pass between it and the sides of the canal, with a ledge at P to prevent its falling into the chamber where the powder is lodged; the axis VP of the cylinder being vertical, place upon the head of the iron pin a weight of which the centre of gravity is in the axis VP with teeth to slide up and down in the grooves of two uprights parallel to VP as in (Fig. 7.) Having filled the space $GIKH$ with powder, and applied fire by the vent X , the elastic fluid acting on every point of the superficies, will raise up the pin OP , and consequently the superincumbent weight; which may be increased or diminished (131) till the force of the powder be only just sufficient to raise it. The height to which it is raised, will shew the pressure of the fluid, for the weight being expressed in pounds, the value of S is equal to the base O in the pin OP . Thus the value of n expressing the elasticity of the fluid may be easily found.

134. There are different methods of ascertaining the greatest force of powder, by the cohesion of the constituent parts of bodies. For example, fill with powder a cylinder of homogeneous metal, the sides of which are of equal thickness, secure the ends so firmly with strong screws that they will resist the utmost force of the fluid, and set fire to the powder by a small vent made in the middle of the length of the cylinder, that the inflammation may be as sudden and general as possible. The vessel will then burst longitudinally

nally, and the equilibrium between the resistance of its sides, and the greatest elasticity of the fluid will be known.

The theorem for finding this equilibrium is $996 \pi r = m q$ where r represents the radius of the cylinder, m the thickness of the sides, q the number of pounds requisite to make a breach of a foot in length, whatever be the cohesion of the metal that the cylinder is made of. Now as r and m are known quantities, and the value of q may be known by experiments on the pieces of metal broken off from the cylinder, by substituting them in the theorem, the value of π which expresses the greatest elasticity of the fluid will be found. It may be observed, that these experiments succeed better, when the cylinders are at first thicker than necessary, and are thinned a little after each discharge, till they are so reduced as to yield to the explosion of the powder.

135. With the following machine, the elasticity of powder may be measured upon the principles of cohesion. $A B C D$ is a cylinder of bronze or iron, (Fig. 9 and 10.) within which is a cylindrical cavity $E F G H$ to contain the powder, it can be closed by means of the screw $L E F K$, equal in length to about $\frac{2}{3}$ of the diameter $E F$, and perforated with the vent $L M$. Put into a cylindrical canal made at $G H$ an iron pin $O P$ well tempered and polished to press perpendicularly on a piece of tempered iron $Q Q$. $S S$ is a bar of iron thinner in the middle $X Y$ than at the extremities, which are pierced with two holes, 8, 8, to admit the iron legs $R T$, firmly united to the cylinder $A B C D$. Below the iron bar is laid a plate of lead $W W$, covering another bar of iron $V V$, and the whole is firmly screwed together by the nuts $Z Z$. On setting fire to the powder inclosed in the space $E F G H$, the inflated fluid presses on the head O of the pin $O P$, and consequently on the piece of iron $Q Q$, which resting on the thin part of the bar $S S$, endeavours to break it; which it effects when the action of the powder is greater than the resistance of the bar. The plate $W W$ and the bar $V V$ stop the iron pin $O P$ when the bar is broken; thus $E F G H$ is altered as little as possible.

Repeat the experiment with an equal quantity of the same powder, but make the bar $S S$ at each time of a different thickness in $X Y$, till it yields with great difficulty to the action of the fluid; then apply a bar equal in thickness to the last, and raising the machine by the trunnions 10, 10, fasten it

it at a proper height; suspend from oo by the hooks $12, 12$, and the chain 11 , a balon loaded with different weights till the bar breaks. The weight necessary to overcome the cohesion of the bar SS being thus known, in the theorem $9962nS = P$ put its value expressed in pounds, and substitute in the place of S the value of the pin OP , then the value of n will be found.

136. This machine may be combined in another manner. Instead of the canal OP , and the other parts placed below CD ; $2, 3$, is a cylindrical cavity, which is exactly filled with an iron pin $2, 3$, in contact with an iron plate, $5, 5$, let into the thickness of metal of the cylinder, the exterior side of which, $4, 4$, is even with the superficies of the cylinder. $6, 7$, is an iron ring which goes round the cylinder $ABCD$, fitting it exactly opposite to $2, 3$, and so proportioned that the interior surface touch the plate of iron $4, 4$. After each discharge, the ring is filed in the part $7, 7$, till it gives way to the action of the powder; taking care to place the machine contiguous to a solid body, that it may confine the plate $4, 5$, and $2, 3$, after breaking the ring, for reasons already pointed out. The proper thickness for the ring having been determined, find the weight that can break another ring of the same metal and equal to it in thickness; for this purpose, apply the ring to a short cylinder of hard wood of proper dimensions; let the plate $4, 4$, be longer than the wooden cylinder that the iron hook $O, 11, O$ may be hung on the ends. Make use of the same plate, $4, 4$, and the same ring, that the part which presses the ring may not be altered in form from the action of the weight that is to break it. When the weight $= P$ is thus found, to know the elasticity $= n$; a particular theorem must be constructed, in which must be inserted the values of the pin $2, 3$, of the radius of the interior circumference of the ring, and of the thickness of metal at the part where the ring broke.

137. It results from these experiments (133, 134, 135) that if a vessel be filled with small-grained powder without being compressed, the greatest elasticity $= n$ will be equal in dry weather to 1000 hundred times the mean pressure of the atmosphere, and only 1400 when the air is much loaded with vapour; powder is therefore a kind of aerometer.

In this machine the diameter and height of the hollow cylinder were each $\frac{1}{2}$ an inch, and the contents about 3 drs.
From

From the principles established in the former part of this work, it may be inferred that by increasing to a certain point the size of the vessel, and filling it with powder without increasing the size of the vent, the elasticity of the powder will be much greater than that found by the last experiments, as the fire will be more intense, and less of the elastic fluid in proportion to its mass will escape. To ascertain to what degree the elasticity will increase when powder is fired in a vessel with the vent closed, a similar method may be used (III).

FIG. IX. Perforate the screw IEFK with a canal LM, to receive the screw G&, which may be turned with velocity by the winch NN. The screw G&, must be longer than the canal LM, that as soon as its head exactly corresponds with the superficies IK, the point & which has been heated red hot, passing through the orifice M, may fire the powder contained in EFGH.

138. From these methods of proving the force of powder by weight and cohesion, added to the observations on the subject in the Philos. Instit, there will be no difficulty in applying elasticity to the measurement of this force (127). A spring strongly bent opposed to the movement of the iron pin will suffice for this purpose; but the greatest force of the powder ought only to increase the tension of the spring enough to make an impression on soft wax, or some similar substance.

139. We will conclude this chapter with remarking the difference observable in the activity of fire on burning equal quantities of powder in vessels of different sizes. Fit a screw EMNF to the part CDHG of the eprouvette, (Fig. 8.) and perforate it with a small canal TY; at the bottom of the screw make a cavity in form of a truncated cone MRSN, and fill it with tin perforated through the middle, so as not to stop up the cavity TY: having closed the vent XI, and filled IKGH with powder, apply the screw EFMN, and set fire to the powder by TY, through which all the elastic fluid must of necessity pass. On unscrewing EFMN, a part of the tin will be found melted. To collect the quantity melted in this experiment, a rough plank should be placed about a foot distant from TY, and after the explosion, the melted substance will be found sticking to it. On burning the same quantity of powder in a vessel much larger, the tin will not melt, and if it be burned in the open air upon a sheet of paper,

per, the paper will sometimes be but little-damaged. This difference of effects proves how much the activity of the fire varies; hence, also the elasticity of the fluid must have altered very considerably during the course of these experiments. This will explain the reason why fire-arms soon become heated, and the vents enlarged after firing several rounds with wads strongly rammed; while the same effects do not take place when the wads are lightly rammed, though the same quantity of powder be used with the same intervals of time between the discharges.

By the experiments with the screw EFMN, the metal best adapted for making bouches for guns might be ascertained. Make a truncated cone of each of the metals intended to be proved, and place it in MNRS; that which sustains the action of the powder, with the least alteration, is the best.

CHAP. III.

OF THE MODIFICATIONS IN THE GENERATION OF THE ELASTIC FLUID IN THE CYLINDRIC BORE OF FIRE-ARMS, WHEN AN OBSTACLE IS PRESENTED TO IT'S PASSING THROUGH THE MOUTH OF THE PIECE.

140. **W**HEN the charge is not too small, nor the gun too long; the shot in passing from the charging cylinder to the mouth of the piece is impelled by fresh elastic fluid, which is continually generating. This accelerated motion is the effect of the pressure of the fluid, whenever the shot has been strongly rammed upon the powder; when it encounters other obstacles as in rifled barrels; or, when at the commencement of its motion, the resistance is equal or superior to the impulsion of the fluid, which endeavours to expand itself towards the mouth of the piece. But if there be no resistance; or only such as the impulsion can easily overcome, as when the charge is not wadded, or but slightly; or when the wad over the powder is made of substances easily penetrable by the elastic fluid, as twisted hay or straw, the movement will then be the effect of impulsion. In the first case the velocity at each point of the length of the bore is in the subduplicate ratio of the superficies, that expresses the sum of the pressures in the spaces passed through by the shot; but in the second

it is compounded of this subduplicate ratio added to the constant quantity communicated to it by impulsion. (Philos. Instit.) The former as being of most general use (109) merits the first attention.

141. If the law of the generation of the fluid were constant, and the intensity of the fire uniform, the scale of pressures might be easily determined, and applied to fire-arms of all calibres; but these are so modified from a variety of circumstances, that the result of all experiments affords a solution adapted but to particular cases. Before we descend to particulars, let us examine under a general point of view the modifications that arise from the different degrees of resistance opposed to the fluid; and adduce a few simple experiments to demonstrate that the production of the fluid varies according to the resistance opposed to its explosion.

142. These varieties arise not only from the mass of the shot and wad, but also from their friction against the part of the bore contiguous to the charge. To increase the friction, they make use of wads that enter with difficulty into the gun, and are strongly rammed upon the powder. By these means the powder is collected into a very small space close to the vent, and burning with more rapidity, the force of the fluid is greater; provided that a sufficient interval be left between the grains for the propagation of the fire.

143. Some dry reeds were cut into lengths and placed in three rows, each was numbered; and No. 1 of the first row was of the same length and diameter as No. 1 of the other two rows; and so of No. 2, 3, &c. They were charged with a quantity of musquet powder equal to one diameter; thus the three of the same number had an equal charge. A bit of rag was lightly pressed into those of the first row; over the same kind of wad a leaden bullet was put in those of the second row; and into those of the third, a similar wad was strongly pressed without a bullet. The explosion burst all the reeds in the third, and more than half of those in the second row; but those in the first remained entire, though they were fired four or five times in the same manner. Effects almost similar took place in small tin guns $\frac{1}{2}$ of a foot in length, and equal in diameter to a ball weighing $\frac{7}{8}$ of an ounce.

Now the only difference between these discharges was in the resistance opposed to the issue of the fluid through the
mouth

mouth of the piece; the weight of the bullet in the second row, and the increase of friction in the third making the resistance greater than in the first: whence, the greater the resistance the greater quantity of the fluid is produced; and it may be further inferred from these experiments, that the resistance from friction may exceed the resistance proceeding from the *Vis Inertia* of the bullet. The usual method of blowing rocks, proves how powerful a resistance friction presents: The miners after drilling a hole 6 or 8 inches deep, fill about half of it with powder, and the remainder with earth strongly compressed; and set fire to the powder by a little saucisson that passes through the earth. The friction and the adhesion of the earth to the sides of the hole are so great, that the powder not being able to force a passage bursts the rock.

144. In the preceding experiments it was proved from the resistance of cannon, that the elasticity of the fluid is in proportion to the obstacles opposed to the explosion; this will be further demonstrated from the velocity of the shot.

FIG. XI. Take three pistol barrels equal in length; let the bores of two of them be exactly of the same diameter, but that of the third equal in diameter to the other two only in the part AB, which contains the charge, and diminishing in diameter from B to C, so that the leaden bullet P cannot pass into BC without changing its form. To load this last pistol, which we will call No. 3. unscrew AF, and holding the pistol vertically, put in the bullet and as much powder as will fill the chamber to A and all take fire; then screw on AF: put into the other two pistols equal quantities of powder of the same quality, and bullets of the same diameter and weight as in No. 3; in No. 1. press a wad lightly over the powder; but in No. 2. ram down a very high wad, to touch the powder but not to compress it so as to diminish its bulk, which should be equal in the three barrels. On firing them against the same butt, the bullet from No. 2 will penetrate deeper than that from No. 1; and the bullet from No. 3. much deeper than that from No. 2.; the bullet of No. 3. will penetrate as deep as a bullet fired from a pistol twice or thrice as long and charged as No. 1.

145. Having thus shewn that alterations in the resistance produce very considerable modifications in the production of

the fluid, in proof of which many other experiments might be adduced, let us now examine them; and for the sake of rendering the research less difficult, suppose;

1. That the charge is always collected together in the same manner at the bottom of the cylinder; the gun always fired in the same direction; and the resistance opposed to the explosion expressed by the weight of a cylindrical body, of a calibre exactly fitted to the bore of the gun: then the resistance will be in proportion to the length of this body.

2. That all the grains take fire, but are not totally consumed before the resisting body begins to move; which experience proves to be the case with moderate charges, when a sufficient resistance is opposed to the explosion.

FIG. XII. Let the part AE in the cylinder ABCD, closed in AC, be filled with powder; and R express the resisting body contiguous to the powder in E. If all the elastic fluid be generated before the body R begins to be sensibly in motion, and in passing from E to B preserve the same degree of heat; the pressure of the fluid in AE would be the strongest possible. Expressing this pressure by the line EF, drawn at right angles to AB, the pressures of the fluid in the spaces AH, AG, AI, will be expressed by the perpendiculars HL, GM, IN, &c. which with EF will respectively be in the reciprocal ratio of the distances AE, AH, AG, AI, and a line passing through the extremities F, L, M, N, O; will be an equilateral hyperbola between the asymptotes AB, AW; supposing the fluid to be subject to no other modification than expansion.

146. It has hitherto been supposed that all the elastic fluid is generated before the projectile begins to move, and that the intensity of heat caused by the entire consumption of the powder suffers no diminution. But the second part of this supposition is evidently impossible, for in powder of a good quality all the fluid is not disengaged before the whole of the nitrous and combustible particles are consumed, the heat must therefore decrease, as soon as the fire is extinct, in proportion to the expansion of the fluid. Wherefore, the pressures in the points H, G, I, K, will be necessarily less than the corresponding perpendiculars HL, GM, IN, KO, &c. The first position is only admissible when the resistance of the body
R is

R is equal to, or greater than the greatest pressure of the fluid in A E: but if R be not capable of resisting the action of the fluid, it will begin to move towards B as soon as there is a sufficient quantity of elastic fluid produced to overcome its resistance. Thus, not only the pressure on each physical point of the space A C E will be expressed by a right line shorter than E F; but if the weight of R be so diminished, that it makes the least resistance possible, the line that will express the pressure of the fluid when R begins to move, will be the shortest of all the lines that can be drawn between E and F.

147. The column of air contained in the bore of the gun, and communicating with the external air, is the least resistance which can be opposed to the expansion of the fluid.

Now expressing by E V the pressure of the fluid that begins to move the resisting body, and by H T its pressure in the space A H, the line H T will be longer than a fourth proportional to A H, A E, E V, since the fluid in passing from E to H is continually acquiring greater elasticity from the successive generation of fresh matter. It will be the same with the lines that express the pressure in the spaces A G, A I, &c. till the powder be entirely consumed: thus the line V T S₂ passing through the extremities of these perpendiculars, will be a scale to determine the limit of the weakest pressure that the fluid can exert in the space A B C D.

148. But when the powder is entirely consumed, the proportion between the lines that express the pressure of the fluid will be changed. Suppose that all the grains are consumed when the fluid reaches I, and that the pressure in the space A I be expressed by I₂, this line will be necessarily shorter than I N; for according to supposition, I N represents not only the effect of all the fluid, but also of the greatest degree of heat that can be produced by the entire consumption of all the combustible substances: but in I₂, if the mass of the fluid be the same, the degree of heat is less, whence its elasticity and of course its pressure will be less: the scale V T S₂ can never touch the hyperbola F L M N O, which may therefore be considered as the limit of the greatest pressure of the fluid. When the fluid reaches K, the pressure K Q will be less than a fourth proportional to A K, A I, I₂; for as no fresh fluid will be generated between I and K, and the heat is decreasing, the elasticity will be less. At 3 and the other points in succession, the same reasoning will hold good.

The scale of pressures $V T S_2 Q P$ beginning to form a curve at 2, the part $2 Q P$ will always approach the right line $A B$, till the fluid be equal in elasticity to the atmosphere; to establish this equilibrium the gun would require to be of a very great length, if no part of the fluid could escape through the vent.

149. The scale will necessarily diverge from V towards 2; afterwards it will continue to diverge from, become parallel to, or converge towards $A B$, according to the quality of the powder, and other circumstances that tend to modify its effects.

150. A greater number of grains are consumed in $A E$, as the resistance of R is the greater (145); thus the heat being increased in this part, the powder will be consumed more rapidly, and the nearer to $A E$, will be the point where all the combustible substances are consumed. The true scale of pressures will then be between the assigned limits (147, 148, 149), without touching them, till the powder be totally consumed. No general rule can be laid down for the proportion in which the increase of heat accelerates the burning of the powder in passing along the bore of the gun, from the many circumstances that concur to modify its effects, and the impossibility of ascertaining some of them. Vide 1st part.

151. The pressure of the fluid in $A E$ being proportionate to the resistance of R ; if the weight of R remain the same, the pressure by which it will be set in motion without regard to the more or less rapid production of the fluid will not vary, whatever be the quantity and quality of the powder.

152. But the pressures in the spaces $A H$, $A G$, $A I$, will be modified, not only by the quantity of elastic fluid generated in $A E$, but also by the quantity and quality of the powder and the size of the grains. Suppose that the charge $A E$ has given a scale of pressure $X Y Z$ (Fig. 13.): reduce $A E$ to $K E$ and fill $K E$ with powder of the same quality, and equally collected as $A E$; there will be the same pressure $E X$, if R present the same resistance (151). But in the spaces $K H$, $K G$, the pressures $H L$, $G M$ will be less than $H Y$, $G Z$. This equality of pressure $E X$ in the two charges arises from the same quantity of fluid being generated in the two spaces $A E$, $K E$ before R began to move: if no fresh fluid were produced between E and H , supposing $E H =$

$EH = AE$, and $KE = \frac{AE}{2}$, the pressure of the charge AE

in the space AH , would be to the pressure of KE in the space HK as $\frac{1}{2} : \frac{1}{3} :: 3 : 2$; since the elasticity is in

proportion to the density. But between E and H a fresh accession of fluid is produced in both charges, and the greatest quantity in the largest charge; so that the pressure of the smallest charge in KH will be proportionally less than the pressure of the larger in AH ; the same may be observed of GZ , GM . If, on the contrary, AE be increased to EP , and filled with powder of the same quality, and equally collected as before, the resistance of R remaining the same, the pressure of the fluid EP will always be equal to EX ; but the pressure in PH , PG will be expressed by HN , GO longer than the corresponding lines HY , GZ .

153. On firing two powders of different qualities, AE and R remaining the same, the scale of pressures produced by the first kind of powder being XYZ , that produced by the second will likewise begin at X (151); but the remainder of the scale will pass above or below XYZ , according to the rapidity with which the powder is consumed in equal times, or to the greater or less production of the fluid.

154. From these remarks may be deduced the difference between two scales that express the pressures of the fluid in two guns of different calibres, charged with proportional quantities of the same kind of powder.

FIG. 14. Let $ABCO$, $DHPM$, be the cylindric bores of two guns, the calibre DM of the one γ the calibre DB of the other: express DM by D and DB by d ; then the resistance of the shot contiguous to the powder in N will be as $D^3 : d^3$; and the charges HN , CN will be in the same proportion: the perpendiculars that express the pressures NV , NX , will be as $D : d$; that is, as the diameters of the shot. For the number of physical points in the superficies of the shot against which the elastic fluid acts, is in the duplicate ratio of the diameters, that is as, $D^2 : d^2$, thus, in the state of equilibrium $NV \times D^2 = D^3$ and $NX \times d^2 = d^3$; then $NV : D :: NX : d$, and by transposition $NV : NX :: D : d$. But the ratio between the corresponding

ordinates LI , LY will be greater than between NV , NX ; for supposing the fluid in the spaces HPN , ACN to have the same degree of elasticity, and the fresh fluid produced by the successive inflammation of the grains between N and L to be proportional to the charges, a greater pressure would be exerted in HPL than in ACL , as the fluid is more dense in the former than in the latter: but the pressure in HPN is already greater than in ACN , since they are in the proportion of NV to NX . Thus the pressures being greater, and consequently the fire being more intense, a greater quantity of elastic fluid will be generated in the larger cylinder between N and L ; and at L its pressure will be much greater than that in the smaller cylinder at the same point; consequently the ratio of LI to LY , will be greater than of NV to NX . This reasoning is equally applicable to the point D in both cylinders: hence it may be inferred that the point where the powder is totally consumed, is under the preceding circumstances much nearer to the place occupied by the charge, in guns of large than of smaller calibre.

155. When the pressure EX is equal to the resistance R this latter may be expressed by (Fig. 15) EX ; and will be proportional to the height of the resisting cylinder (145, No. 1) in guns of the same calibre, or to the diameters of the shot in guns of different calibres. With low wads not rammed with force, the line XFZ expressing the scale of pressures will from the beginning sensibly diverge; but with wads strongly rammed, the friction increasing the resistance, the scale of pressures will be the line KHY ; in which the first pressure EK is greater than EX , in proportion as the friction of the wads exceeds their weight; and all the scale KHY will be farther distant from the axis EG than the scale XFZ : but though at the commencement of its motion KHY diverges more from EG than XFZ , yet it soon converges towards it; thus its greatest ordinate is much nearer the point E , than the greatest ordinate of the scale XFZ .

It would be too tedious to enter into a detail of the several experiments that might be made in confirmation of what has been advanced since the 150th paragraph; the reader by a little reflection will readily discern the principles on which our reasoning has been founded; and from the sequel, a simple practical

practical method may be devised of proving their force and justness.

156. Since the cylindrical bore of fire-arms should be in equilibrio with the action of the fluid generated from fired powder, the thickness of metal must at every point of their length be proportioned to the ordinates of the scale of pressure: this may be reduced to the four following cases;

1. When the scale is parallel to the cylinder, the thickness of metal should be the same throughout the whole length of the gun.

2. The scale may diverge from the axis A E G in advancing from E to G; or after diverging it may run parallel to the axis; in both these cases there should be the same thickness of metal from the breech to the muzzle, since the sides must be in equilibrio with the greatest ordinate.

3. It may from the point E diverge from the axis to a certain point, and then converge towards it; in this case, the metal should be of equal thickness to the point of the greatest ordinate, with which it must be in equilibrio; thence it may diminish in the ratio of the corresponding ordinates.

4. It may from the point E continually converge towards the cylinder; then the thickness of metal should diminish proportionally from the breech to the muzzle.

157. The entire scale of pressures can be deduced from the thickness of metal only in the fourth case; in the third case, that part of the scale only is known that converges towards the cylinder; in the two first, the greatest pressure of the fluid is only pointed out.

158. In musquet charged with fire-work, fowling, or cannon powder, and the wads well rammed, the scale of pressures is found to correspond with actual experiment in the fourth case; and likewise in the third, if the wad be rammed with less force; since the greater this force, the farther from E where the charge is lodged, is the greatest ordinate of the scale.

In the following chapter will be pointed out the method of determining experimentally the scale of pressures in fire-arms of all calibres.

C H A P. IV.

OF THE INITIAL VELOCITY OF PROJECTILES, AND
THE LAW UNDER WHICH THEY ARE IMPELLED
FROM FIRE-ARMS OF CYLINDRIC BORES.

159. **T**HERE are three methods of determining the initial velocity of projectiles: by deducing it from a knowledge of the line they describe in their flight; by measuring it instrumentally near the muzzle of the gun; or by a third mode, which may be adopted whenever the thickness of metal is proportional throughout the length of the cylinder to the pressure of the fluid. The first method has been already treated on (Philos. Instit.) and there will be occasion to mention it again in the following chapter; the second and third will be for the present the objects of consideration.

160. **BENJAMIN ROBINS**, an English Engineer, was the first person who thought of applying instruments to measure the initial velocity of a ball of small calibre, near the mouth of the gun. His method consists in firing against a pendulum, moveable upon its axis of suspension, which describes an arch proportionate to the shock of the ball. The exact measure of the chord of the arch, the weight of the ball and pendulum, the centre of gravity and oscillation, and the distance from the axis of motion to the point of impact, shew the absolute velocity with which the ball impinged on the pendulum.

FIG. 16. To apply this instrument *C E* for measuring the initial velocities of balls from musquets or wall-pieces; it should be made of iron, and hung at right angles to the axis of suspension *A B*, which must be about a foot in length; to *D E* is screwed a plank of about nine inches square, and of such a thickness that the ball cannot penetrate to the iron. For the experiment, the pendulum is suspended (*Fig. 17.*) from a triangular frame; underneath it, is placed a piece of wood cut in the arch of a circle, of which the circumference is described from the centre *C* with a radius greater than *C E*; and in the plane of the vibrations of the

the pendulum, a stylette F is fastened in E, to trace upon the fine dust, with which the circumference G K H is covered, the arch described by the first vibration of the pendulum. Instead of the arch of the circle, ROBINSON used a ribband attached to E, which the motion of the pendulum drew between two iron plates fixed to a wooden bar that was between the legs of the frame, and measured the arch described by the pendulum, by the length of the ribband drawn between the plates.

161. The instrument being placed as above directed, if we know;

1. The weight P of all the parts of the pendulum.
2. The distance from the point C in the axis of suspension or motion to the centre of gravity L, or $CL = a$.
3. The distance from C to the centre of oscillation M, or $CM = d$.
4. The length $CF = b$ of the radius with which the arch G K H is described.
5. The weight of the ball = q .
6. The chord of the arch = c described by the first vibration of the pendulum, and measured upon G K H; then the motion communicated to the pendulum, and consequently the velocity with which the ball impinged on it will be found.

Find the distances C L, C M: it is proved, (Philos. Instit.) that the vis inertizæ of a body moving freely round its axis, is equal to the product of its weight multiplied by the distance from the centre of gravity to the axis of motion, and by the distance from the centre of oscillation to the same axis; and the quantity of its motion is equal to the product of the vis inertizæ multiplied by the velocity of the pendulum, which is equal to the square root of the versed sine of the arch described by the centre of oscillation.

Fire a ball against the centre of oscillation M. To find the velocity communicated to this point, make the propor-

tion $b : c :: d : \frac{cd}{b}$, the last term is the chord of the arch described by this point: The versed sine of which is $\frac{c^2 d}{2b^2}$, and the uniform velocity of M during one second will be

$$\sqrt{\frac{64 \cdot 36 \cdot c^2 d}{2 b^2}}$$

$\sqrt{\frac{64 \cdot 36 \cdot c^2 d}{2 b^2}} = \frac{c}{b} \sqrt{32 \cdot 18 d}$ (Philos. Inffit.) which multiplied by the weight of the pendulum and ball, since this

does not rebound, i. e. by $Pa d + qd^2$, will give $\frac{c}{b} \times \overline{Pa d + qd^2}$

$\times \sqrt{32 \cdot 18 d}$ for the quantity of motion. Let u be the uniform velocity with which the ball impinged on the pendulum; as from the moment it entered the pendulum, it followed the direction of its motion, uqd^2 will express the quantity of the motion of the ball: thus in a state of

equilibrium $uqd^2 = \frac{c}{b} \times \overline{Pa d + qd^2} \sqrt{32 \cdot 18 d}$, and $u =$

$\frac{c \times \overline{Pa d + qd^2} \sqrt{32 \cdot 18 d}}{b q d}$ will be the velocity sought.

162. In the second place, let the ball strike a point D, not in the center of oscillation: (Fig. 18) then if f express the perpendicular distance from the point D to the axis of motion, and x the uniform velocity of this point, the quantity of motion of the point D will be $x \times \overline{Pa d + qf^2}$, and if the ball impinged on the pendulum with the velocity u , its quantity of motion will be $u q f^2$. Then the equation will be

$x \times \overline{Pa d + qf^2} = u q f^2$, and $x = \frac{u q f^2}{\overline{Pa d + qf^2}}$. Now as the

motion of a pendulum is as great, as if its whole mass were united to the centre of oscillation, and as this centre changes whenever the ball impinges on any other point; by expressing its distance from the axis of motion by the vis inertiae $Pa d + qf^2$ divided by $Pa + qf$, the distance of CG from the point G taken as a new centre of oscillation to the axis

of motion will be $CG = \frac{Pa d + qf^2}{Pa + qf}$. But the radii CD,

CG, are proportional to the velocities of the points D, G, since they describe the archs DO, GH in the same time;

then $CD : CG : f : \frac{Pa d + qf^2}{Pa + qf}$ as the velocity of the

point D = $x = \frac{u q f^2}{\overline{Pa d + qf^2}}$ is to the velocity of the point

G = $\frac{u q f}{Pa + qf} = \sqrt{64 \cdot 36 GI}$ where GI expresses the versed sine of the arch GH.

To

To find the velocity u with which the ball impinged on the pendulum, another value of $\sqrt{64.36 \text{ G I}}$ must be sought: As the chord = c of the arch FGH described by the stylette, and radius $\text{CF} = b$ are known, the versed sine of this arch will be $\frac{c^2}{2b}$: Then radius CF is to its versed sine as radius CG is to its versed sine GI or

$$b : \frac{c^2}{2b} :: \frac{\text{Pa} + qf^2}{\text{Pa} + qf} : \frac{c^2}{2b^2} \times \frac{\text{Pa} + qf^2}{\text{Pa} + qf};$$

and thus the uniform velocity of the point G will be expressed by

$$\sqrt{\frac{64.36 c^2}{2b^2} \times \frac{\text{Pa} + qf^2}{\text{Pa} + qf}}; \text{ and on comparing the two expressions of these velocities}$$

comparing the two expressions of these velocities

$$\frac{u qf}{\text{Pa} + qf} = \frac{c}{b} \sqrt{32.18 \times \frac{\text{Pa} + qf^2}{\text{Pa} + qf}} \text{ and } u = c$$

$$\sqrt{32.18 \times \frac{\text{Pa} + qf^2 \times \text{Pa} + qf}{b qf}} \text{ the velocity sought.}$$

163. The weight and length of the pendulum should be such that its vibration may not describe an arch of more than five degrees; and as the balls fired into it increase its weight and alter the centres of gravity and oscillation, the values of P , a , d . should be corrected after each discharge.

164. SIG. MATTEI, mathematical instrument-maker to the King, has invented a machine for finding with facility the initial velocity of balls measured near the mouth of the gun.

FIG. XIX. AB is a horizontal wheel with a vertical axis CD turned by the weight Q , appending to the rope GG and raised by the winch N . It may be turned in any other manner, provided that its motion be perfectly uniform and rapid. AE , BF is a circular band of writing paper about 6 inches high, fixed round the circumference of the wheel. The gun for the experiment is immovably fixed at 20 feet distance, and pointed so that the axis of the gun produced would pass through the points H , K , the exact diameter of the wheel. R

is a

is a block of wood placed two or three feet from the wheel to receive the balls; it is of elm, that the penetrations may be uniform.

In using this machine it is requisite to ascertain when the motion of the wheels is equable, and how time long it takes in each revolution; for this purpose various expedients may be devised. At TURIN we fitted a little excentric wheel IL to the axis CD , which at each revolution gave a vibratory horizontal motion to a tongue of wood at the extremity of which appended a common pendulum that was shortened or lengthened till its vibrations were isochronous to those of the tongue: the length of the pendulum will shew how long the wheel is in making each revolution. So soon as the isochronism between the pendulum and the tongue is established, fire the gun and stop the wheel; the two holes made in the rim of paper by the ball, will be easily distinguished from each other by the edges being turned to the point that the ball went out at. Stretch a thread in the direction MR , passing through the centre of the hole H where the ball entered the paper. The distance of the other hole K from the point B will be then known: this distance shews how much one point of the wheel turned, while the shot was traversing the diameter AB .

165. If the mechanism and use of this machine be well understood, it will be easy to find the uniform velocity with which the shot passes through the diameter AB of the wheel, and consequently its uniform velocity during one second of time. Let D be the diameter of the wheel, c its circumference, t the time that the wheel takes to make one revolution, m the distance that a point of the circumference of the wheel turns, while the shot is traversing the diameter; then

$m : D :: C : \frac{CD}{m}$, the last term will express the space passed

through by the shot with an uniform velocity during one revolution of the wheel: then expressing by u the space that the shot passed through with an uniform velocity in one second,

or its initial velocity, $t : 1 :: \frac{CD}{m} : \frac{CD}{tm}$; the last term = u

will express the velocity sought. With this machine, when the wheel turns with an equable motion, $t = \frac{1}{3}$ of a second,
 $D =$

$D = 10$ feet, and consequently $C = \frac{22 \times 10}{7}$; then substituting these values in the expression of the velocity, $\frac{CD}{tm} = u$; if the value of m be the fraction of a foot, the velocity u will be expressed in feet. For instance, if m be found experimentally $= \frac{1}{4}$ of a foot, then 1571 feet will be the value of u .

166. This machine was used in making the following experiments which lead to the solution of several very important problems in the theory and practice of artillery.

1. The first gun was 5 ft. 6 in. in length of bore, and the weight of leaden bullets was $2\frac{1}{2}$ oz.
2. The second was 5 ft. 10 in. in length of bore, and the weight of bullet $3\frac{1}{2}$ oz.
3. A rifled barrel 3 ft. 5 in. in length of bore, and the weight of bullet $\frac{7}{8}$ oz.
4. Several musquet barrels of different lengths; the leaden bullets weighing 1 oz.

The powders were those described in the fortieth paragraph. the wads were of parchment torn in several places, that they might not damage the rim of paper fastened round the circumference of the wheel; and lightly compressed by the same man. During these experiments particular attention was paid to moisture of the atmosphere, as its variations sensibly affect the force of powder (137).

167. The following is a table of initial velocities deduced from experiments with a musquet 3 ft. 6 in. in length of bore, under three different states of the atmosphere.

VELOCITY OBSERVED.

The charge of Powder was 7 drams.	Very moist Weather.	Under a mean state of the at- mosphere.	Very dry Weather.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Common War Powder	1392	— 1542	— 1618
Fine Ditto	— 1569	— 1736	— 1829
Fowling Ditto	— 1566	— 1703	— 1784
Fire-work Ditto	— 1566	— 1706	— 1779
			Beside

Beside the observations on the hygrometer it was remarked, that when atmosphere was very much loaded with vapour, the bore of the gun was so moist five minutes after the explosion, that the fixed nitre fell in deliquium; and the tow used in cleaning it, was covered with a number of saline particles; but on a dry day no moisture could be perceived after an interval of several minutes, and the tow came out almost unsoiled. It results from these experiments.

1. That the velocities of shot in very dry weather exceed by nearly $\frac{1}{7}$ the velocities, when the atmosphere is loaded with vapour.

2. That fine war powder produces in musquets the greatest effect that can be obtained from a combination of saltpetre, sulphur and charcoal. It is essential to add, that with the same kind of powder, the velocities were nearly equal in moist, heavy weather; under a mean state of the atmosphere they varied about $1\frac{1}{2}$ in the 100; and in very dry weather, their difference amounted to 4 in the 100.

168. The following experiments made with guns of different lengths and calibres, under a mean state of the atmosphere are a proof that fine war powder is the strongest.

Nature of Guns.	Kind of Powder.	Weight of Powder. <i>Drachms.</i>	Initial velocity. <i>Feet.</i>
A Musquet 1ft. 10 in. length of bore.	Fine War Powder	7	1390
	Fowling Ditto	7	1367
	Fire-work Ditto	7	1372
Rifled Carabine	Fine War Powder	7	1956
	Fowling Ditto	7	1920
	Fire-work Ditto	7	1934
A Wall-piece carrying a leaden bullet, in weight $2\frac{1}{2}$ oz.	Fine War Powder	20	1956
	Fowling Ditto	20	1928
	Fire-work Ditto	20	1923
A Musquet 3 ft. 6 in. in length of bore.	Fine War Ditto	7	1736

The experiments with a mortar made by Major RONZINI in the month of August 1761, likewise prove the excellence of fine war powder. The proportions of the mortar were very exact; it was laid at 45° , fixed in an iron bed weighing 616 lb. and projected an iron shot 27 lb. in weight, the chamber

chamber contained one ounce of powder, the same charge was used each time without a wad, that there might be the least difference possible. The following table shews the result.—

Kind of Powder.	Length of Range
	<i>Yards.</i>
Musquet Powder	— 249
Fine War Ditto	— 298
Fowling Ditto	— 294
Fire-work Ditto	— 296

169. To ascertain the effect that a difference in the weight of shot and windage have on the velocity, three bullets were fired from a wall-piece, and two from the musquet 3 ft. 6 in. in length of bore. The first bullet with which the wall-piece was loaded weighed $3\frac{1}{4}$ oz. the second weighed 3 oz. the third was equal in diameter to the first, but equal in weight to the second, a small pebble having been put into the centre when it was cast.

The musquet bullets were 1 oz. and $\frac{7}{8}$ oz. in weight: in order to have a third kind, cartridges like those used by the Infantry, which drop without ramming to the bottom of the barrel when the musquet is clean, were made with carabine balls.

The wall-piece was charged each time with 23 drachms, and the musquet with 7 drachms of fine war powder. The experiments were made under a mean state of the atmosphere, and the following table shews the result.

	Balls.	Initial Velocities,
		<i>Feet.</i>
Wall-piece	{ First kind	— 1770
	{ Second ditto	— 1855
	{ Third ditto	— 2068
Musquet.	{ First ditto	— 1736
	{ Second ditto	— 1834
	{ Third ditto	— 1863

In these two cases, the initial velocities of the shot of the second kind exceed those of the first, though a greater quantity of the fluid must necessarily have escaped owing to the windage; and the shot of the third kind from their greater diameter,

diameter and less weight have a still greater initial velocity.

170. The following experiments made under a mean state of the atmosphere, shew the initial velocities of shot impelled by different charges of fine war powder.

	Weight of Powder.		Initial Velocities.
	<i>Drachms.</i>		<i>Feet.</i>
Musquet, length of bore 3 ft. 6 in. {	5	—	1399
	7	—	1736
	10	—	1984
Wall-piece, weight of bullet 2½ oz. {	11½	—	1504
	18	—	2056
	25	—	2060

A musquet fired with the ordinary charge of 7 drachms of powder does not range so far, as if the charge were larger; but as the barrel would soon become too hot, the smaller charge is preferred. From the experiments made with the musquet (167, 168, 169,) it will be easy to deduce by analogy, the velocities of other fire-arms discharged in very moist or very dry weather. For example, to know the initial velocity of a shot from a wall-piece fired in very dry weather, with a charge of 25 drachms of fine war powder: as its initial velocity under a mean state of the atmosphere is 2060 feet, and that of the musquet 1736 feet; and the initial velocity of the same musquet in very dry weather is 1829 feet, by making a proportion of these values 1736 : 2060 :: 1829 : 2245 feet, which is the velocity of the wall-piece in very dry weather.

171. Since the initial velocity of fire-arms of all lengths may be thus found, it will be easy to ascertain the scale of pressures which the elastic fluid exerts upon the shot in different points of the bore of the gun. For this purpose, fire three or four guns differing in length but equal in calibre, charged with the same quantities of powder: having measured the initial velocities of the shot, set off from A to R (Fig. 20.) on the line AR the lengths of the guns taken from the part of the cylinder where the shot is lodged to the mouth of the piece; and supposing AC to be the length of the shortest gun; AD that of the second, and AB that of the longest; make the perpendiculars CE, DF, BG equal to the initial velocities of the respective shot; then a line passing through the points A, E, F, G will be the scale of velocities in the spaces AC, AD

A D, A B, which the shot has passed through with an accelerated motion. The equation of this scale may be found in the manner laid down in the preceding chapter for finding the corresponding scales S M N O of the pressures of the fluid.

172. To obtain the initial velocities, four musquets of different lengths, carrying a 1 oz. ball, were fired with 7 drachms of fine war powder (166), under a mean state of the atmosphere.

Length of Barrel from the Ball to the Muzzle.			Initial Velocities.
Fect.	Inches.		Fect.
0	11	—	1037
1	10	—	1390
3	8	—	1736
4	8	—	1815

FIG. 20. Then constructing a figure according to the directions given in the preceding paragraph, and examining the proportion that the ordinates bear to the abscissas; the scale A E, F G of the velocities is an ellipsis whose semi-conjugate axis A R is 4 feet 8 inches, and semi-transverse axis R H about 1815 feet. Hence it results;

1. That the scale of pressures S M N O is in this case a right line, which when produced cuts the line of direction in the centre R of the ellipsis.

2. That the initial velocities of guns fired under the preceding circumstance, are not increased by making the barrels longer than A R.

To give a theorem for finding the initial velocities of musquets shorter than A R, fired horizontally with 7 drachms of war powder, under a mean state of the atmosphere, it must be remembered that as the sum of the pressures

pressures $A R S = \overline{R H^2}$, then $\frac{A S}{2} = 690312$ feet,

Now let A D be the length of any gun; then the superficies of the rectilinear trapezium A D N S which expresses the

sum of the pressures will be $\frac{A S \times \overline{A R^2 - D R^2}}{2 A R}$, but the ini-

tial velocity DF corresponding with this trapezium is expressed by the square root of the same superficies :

For example, Let AD be $\frac{1}{3}$ of a foot, DR will be 4 feet 6 inches or $\frac{27}{6}$, which substituted in the theorem, will

$$\text{give } DF = u = \sqrt{1479.26 \times \frac{784}{36} - \frac{729}{36}} = \sqrt{1479.26 \times \frac{55}{36}} =$$

475 feet for the initial velocity.

173. This method of finding the scale of velocities in the spaces, may be practised when the wad is strongly rammed on the powder ; for then the greatest ordinate of the corresponding scale of pressures is at, or very near to the place occupied by the shot, in the bore of the gun : and there is no difficulty in reducing by approximation the line of the velocities to a regular curve, from which, expressed geometrically may be deduced the scale of pressures. But when the greatest ordinate is distant from the part occupied by the shot, as with weak powder or low wads ; then to find the curve line of velocities, it is not only necessary to make experiments with the guns mentioned in the preceding paragraph, but with others in which the shot has a very small space to pass through, as 2 or 3 calibres : thus the curve line may be described from its origin, and any irregularity corrected by approximation.

174. If the scale of pressure only be sought ; as the velocities are in the sub-duplicate ratio of the sum of the pressures, whenever the proportion of two velocities CE , DF is less than the sub-duplicate ratio of the spaces AC , AD , or of the length of the part of the bore from the shot to the muzzle, then the corresponding part SMN of the scale of pressures will converge towards the mouth of the gun : when the ratio of the velocities is equal to the sub-duplicate ratio of the corresponding lengths, the scale SMN will be parallel to the directrix AD ; and when greater, it will diverge from it.

175. Having ascertained the initial velocity $=u$ and the scale of pressures, the value of n , which expresses how much the greatest elasticity of the fluid acting on the shot exceeds the elasticity of the atmospheric air, may be found by means of

of the theorem $u = \sqrt{\frac{96.54 \pi p l A}{2 r}}$ where A expresses the

height of a barometer made of the same metal as the shot; l the length of the fire-arm measured from the shot to the mouth of the piece; p the ratio between the area $A S N D$ and the rectangle $A S \times A D$; and r the radius of the shot. For example, take a musquet (172) 3 ft. 8 in. in length of bore = l ; as in this case $A = 2$ ft. 10.84 in. $r = .243$ in.; and

$u = 1736$ feet; suppose $p = \frac{19}{30}$: then by substituting these va-

lues in the theorem, $1736 = \sqrt{\frac{96.54 \times 3.8 \times 2.10.84 \times \frac{19}{30} \pi}{.587}}$;

whence $\pi =$ nearly 280 times the mean elasticity of the atmosphere.

176. The initial velocity of cannon balls may be easily found by this method of determining the velocities of bullets projected from fire-arms of small calibre: not only the charge that gives the longest range, and the law of pressure of the fluid on the shot in passing along the bore may be ascertained; but the greatest elasticity of the fluid, and the point in the length of the bore where it is produced, may be determined: in a word, all the solutions of the problems relative to small pieces from the 167 paragraph to the present, are equally applicable to the largest cannon.

To determine the initial velocity of cannon balls, there must be a large homogeneous butt: if necessary, one must be made of earth, cleared of stones, sifted and well rammed. The guns must be placed near the butt, and at such a distance from each other, that the loosening of the earth from the penetration of one shot may not facilitate the entrance of the other. The depth of their respective penetrations must be measured, and the values substituted in the place of S in the theorem $S = g D \pi^2$, where D expresses the diameter of the shot, g its specific gravity, and π its velocity, then

$\pi = \sqrt{\frac{S}{g D}}$ which is a known quantity.

Let a wall-piece, whose initial velocity is known, be fired against the same butt; measure the penetration of the

shot, and substitute it in the place of S in the theorem

$u = \sqrt{\frac{S}{gD}}$: In the room of g and D insert their known

values, which will give the relative value of u : then by analogy, the relative velocity of the bullet is to its initial velocity, as the relative velocity of the cannon shot is to its initial velocity. Suppose, for example, that the leaden bullet fired from the wall-piece be 1 inch in diameter = D and that its penetration $S = 4$ feet; as the specific gravity of lead is

$g = 9060$ then $u = \sqrt{\frac{S}{gD}} = \sqrt{\frac{48}{9060}}$. Suppose again, that

the cannon shot be 6 inches in diameter = D and its penetration into the butt 14 feet = S , as the specific gravity of iron

is 6115; $u = \sqrt{\frac{S}{gD}} = \sqrt{\frac{28}{6115}}$. Then if the known initial

velocity of the bullet fired from the wall-piece be 2023 feet,

$\sqrt{\frac{48}{9060}} : \sqrt{\frac{28}{6115}} :: 2023 : 1880$ feet, which will be the

value of the velocity sought.

This theorem will serve to resolve other problems; for instance, by knowing the diameter, density, velocity and penetration of one shot, the penetration of the other shot differing in density, velocity and diameter into the same butt may be found.

177. From a series of experiments made according to the foregoing principles, under a mean state of the atmosphere with guns, (89) charged with a quantity of common cannon powder, equal to about $\frac{1}{3}$ of the weight of the shot in 32 and 16 prs; and to $\frac{1}{2}$ its weight in 8 and 4 prs: it results that 1349 feet will be the mean initial velocity of 32 prs; 1433 of 16 prs; more than 1517 of 8 prs; and less than 1517 of 4 prs.

Lieut. DE BUTET invented in 1764 a very simple machine for measuring the initial velocity of projectiles. He applies a little plate of metal provided with a moveable index to any wheel that turns with an equable motion, and sufficient velocity; the index is held at some distance from the circumference of the wheel, by a thread that is stretched across the mouth of the gun. When the gun is fired, the shot breaks the thread, and sets at liberty a spring, which instantly

instantly presses the index against the wheel, upon which it describes an arch, till it is checked by the impact of the shot against a moveable butt, placed at the distance of a few feet : to this effect one extremity of a rod is fastened to the butt, and the other to the plate ; thus the index is drawn back by the rod, which follows the movement of the butt, and ceases to describe the arch on the circumference of the wheel.

The motion of the wheel, the distance from the muzzle of the gun to the butt, and the arch described by the index being known, it is easy to ascertain the space that the shot passes through in one second of time with an uniform velocity ; or in other words, its initial velocity. To diminish the friction as much as possible, a small groove is made in the part of the wheel that receives the index, and filled with grease, which presents a very slight resistance. By means of this instrument the time of the shot's passage along the bore of the gun, the initial velocity of shells, and the resistance of the air to their motion may be determined ; if allowance be made for the modifications that must ensue.

178. In ascertaining the initial velocity of shot projected from fire-arms of cylindric bore in the third method (159) ; it must be remarked, that so soon that the shot begins to move, it continually acquires fresh velocity as it advances from E to G (Fig 13), and losing a part of the pressure of the fluid is only impelled by the excess of the velocity of the fluid over its own velocity : this diminishes as the shot approaches the muzzle ; the action of pressure against the shot would be totally lost if the gun were very long, but it would continue against the sides of the gun. Whence it results, that the ordinates H Y, G Z of the scale X Y Z of the pressures of the fluid against the shot, which commences at the same point X as the scale X N O of the pressures against the sides of the gun, are shorter than the corresponding ones H N, G O, and their differences N Y, O Z become greater as the shot approaches G. Thus, when the several points of the cylinder are proportioned to the different pressures of the charge, there are always two scales ; one, expressing the pressure of the fluid against the sides of the gun in each of the physical points of its length ; the other expressing the pressures against the shot in the same points. When the first of these scales is continually converging towards the mouth of the piece, its figure is determined by the length of the gun ;

and it may be considered as the limit of the greatest velocity of the shot.

179. In fire-arms of all calibres fired with large charges and wadded, so that only the necessary interstices for the propagation of fire remain between the grains, the thickness of metal must be increased gradually from the muzzle to the breech, that the gun may be enabled in every point to resist the actual pressure of the elastic fluid: wherefore the scale of pressures against the sides converges toward the mouth of the gun, and the greatest ordinate of the scale is very near the place occupied by the shot. Then,

FIG. XV. In order to find the equation of the scale of pressures, draw the right line KI parallel to the directrix EG , considered as the axis to which the ordinates are perpendicular: let the pressure $KE = p$ and the abscissa $EL = KI = x$. As the ordinate IH of the segment KHy appertains to the abscissa KI , IH may be expressed by nx , and multiplying nx by the abscissa, $= x$ and by m denoting the fraction that squares the surface KIH the product nmx^2 will express the surface KIH : now the rectangle $EKL = px$, therefore the superficies $EKL = px - nmx^2$; and call the velocity LB that answers to this superficies V , then $V =$

$$\sqrt{px - nmx^2}.$$

180. Since musquet barrels were first made in **PIEDMONT**, none have been received at the Arsenal before they had been proved in the presence of some officers of artillery. More than a hundred thousand barrels have been proved in the following manner: they are charged with 17 drachms of common cannon powder; over which is put a very high wad of hard tow, that is with difficulty pressed into the barrel, and is afterwards rammed down with all the force that the armourer can exert: a leaden bullet weighing $18\frac{1}{2}$ drachms is then put in and wadded as before. The barrels thus loaded, are placed horizontally with the breech against a strong beam of wood, and each of them is fired twice. At every proof some of the barrels have burst, and the crack is sometimes at the breech, at other times at the middle of the bore, or near the muzzle: but as it is not found to have happened more frequently in one part than another, the officers and manufacturers have deemed it unnecessary to make any alteration in the thicknesses of metal; so that they may be reasonably regarded as proportionate to the pressures of the elastic fluid

fluid generated during the proof, allowing for the proportion that escapes by the vent, and the windage. Thus the shape of a gun being known, the limits of the greatest velocity of the ball in each point of the length of the bore may be found (179).

181. The thickness of metal in each point of the length of the cylinder is determined by a (Fig. 21) right line FD , drawn from the breech to the muzzle obliquely to the axis; thus the lengths BE , BH , and the corresponding thicknesses EF , HL of a gun $ACBD$ being known, the inclination of the right line MON which is the scale of the pressures of the fluid against the sides of the gun may be determined, the ordinates EM , HO , BN , being in the ratio of the corresponding thicknesses EF , HL , BD . If the right lines EB , FD be produced, they will meet at the point R , where the line MON will always terminate, even when FLD and MON are curves. Thus $ER = b$ will be known and

considering $p = EM$, the value of n will be $\frac{p}{b}$: then $\phi o = \frac{px}{b} = nx$ and $m = \frac{1}{2}$ since $M\phi O$ is a triangle. Hence nmx^2

$$= \frac{px^2}{2b} \text{ and consequently } V = \sqrt{px - nmx^2} = \sqrt{px - \frac{px^2}{2b}}$$

which is an equation to the ellipsis to be constructed in the manner already pointed out (172).

Take $p = 2b$, then $V = \sqrt{2bx - x^2}$ is an equation to a circle whose radius $= b$; from the point R taken as centre with a radius $RE = b$ describe the arch EKG , then the ordinates HG , BK , will express the relative velocities which the bullet would have at the points H , B , if the line MON were the scale of pressures of the fluid. It should be remarked;

1. That on diminishing the charge of powder in these barrels without weakening the resistance of the shot and wads, the pressure of the fluid at the point E will remain the same, but it will be weaker at the points H and B , (152); the velocity therefore of the bullet at the same points will be less.

2. That on diminishing both the charge and the resistance, either by using smaller wads or by ramming them down with less force, the pressure of the fluid will be less at the point E , as well as at H and B .

3. That

3. That on altering the resistance, the ratio of the pressures will vary also. These consequences are deducible from the preceding theory, and are confirmed by experience.

182. By the theorem $V = \sqrt{2bx - x^2}$ it may be ascertained with tolerable accuracy, how much the length of the gun affects the range. Take, for example, the gun ADP , (Fig. 21) in which the thicknesses from E to the muzzle, proportionate to the largest charges; are determined by a right line. To find the difference between the velocities of the shot; or in other words, the length of the ranges, by firing a shorter gun as AH , or a longer one as AQ with the same charge as ADP , the right lines EB , FD must be produced till they meet in the point R , and from R taken as centre with the radius RE , describe an arch EKG : draw to AR the normals HG , BK , QT , which will express the ratios of the length of the ranges, corresponding to the lengths of the gun. It was observed that this theorem would only give an approximation; in fact the line MON being the scale of pressures against the sides of the gun; MYZ which is the scale of pressures against the shot, sooner falls on ER , which it cuts in the point S . Thus the true scale of velocities is $EIVX$ in which the difference between the velocities at the points H , B , Q is less than in the other scale EKG . But whatever be the nature of the line MYZ , it must necessarily when produced cut the right line RE in some point S ; for as the fluid expands in a space which is continually enlarging, and partly escapes by the vent and windage, its velocity will be at length so much diminished, that it will no longer impel the shot. The point S is always the centre of a re-entering curve line $EIVX$, of which SE is the semi-axis, and EM the parameter; and by it may in all cases be determined the greatest length that ought to be given to cylindric fire-arms, since beyond this point the shot receives no increase of velocity. From these premises may be likewise inferred, that in the same gun the point S will be more or less distant from A , in proportion to the quantity and quality of the powder, and to the windage and density of the shot.

183. Since the radius $\frac{BP}{2} = r$ and the thickness of metal $EF = m$ are known, and its tenacity may be determined

mined by experiment, the elasticity = n of the fluid may be found by the means of the theorem $9962 nr = mq$; and by

substituting in the theorem $V = \sqrt{\frac{96.54 n p l A}{2 r}}$ the values

of $n, r, l, = E B, A =$ the height of a barometer made of the same metal as the shot, and p the ratio between the trapezium $E M N B$ and the rectangle $E M \times E B$, the value of the initial velocity = V of the shot will be likewise found.

FIG. 21. For example, suppose $D A P$ to be a wall-piece, whose thicknesses of metal are in equilibrio with a given charge; let the diameter $D P = 2 r = 2$ inches, $E F$ the greatest thickness of metal in the place where the shot is lodged = $m = 2$ inches, and the tenacity of metal = $4723200 = q$; by substituting these data in the

theorem $9962 nr = mq, n 9962 \times \frac{1}{12} = \frac{1}{6} \times 4723200$: the

greatest elasticity of the fluid = n is therefore nearly equal to 800 times the mean pressure of the atmosphere.

To find the initial velocity of a leaden bullet fired from this wall-piece let $E B = l = 3\frac{1}{2}$ feet, and $p = \frac{2}{3}$; A will be about 3 feet; then substituting these values in the theorem $V =$

$$\sqrt{\frac{96.54 n p l A}{2 r}} \text{ it will give } V = \sqrt{\frac{96.54 \times 800 \times \frac{2}{3} \times 3\frac{1}{2} \times 3}{\frac{1}{6}}}$$

= 1800 for the initial velocity of the leaden bullet.

But if an iron shot be fired from it, A will be equal to $4\frac{1}{2}$ feet, and the initial velocity will be

$$V = \sqrt{\frac{96.54 \times 800 \times \frac{2}{3} \times 4\frac{1}{2} \times 3}{\frac{1}{6}}} = 2043.$$

C H A P. V.

OF EXPERIMENTS FOR ASCERTAINING THE RESISTANCE OF THE AIR TO BODIES PROJECTED FROM FIRE-ARMS.

184. **T**HE initial velocities of shot projected on a horizontal plane from guns, equal in length, but differing in calibre, fired with charges proportioned to the weight of the shot, with powder of the same quality and wads equally well rammed, are greater in proportion, as the calibre of the piece is less. But if the same gun be fired on an inclined plane, the difference between the ranges will diminish in proportion to the inclination and extent of the plane, till at length the guns of large will range farther than those of smaller calibre.

185. From the longer range of guns of small calibre, it may be inferred that the ratio of the sum of the pressures to the diameter of their shot, is greater than in guns of larger calibre. When the resistance to the explosion consists only of the weight of the shot and wads, the pressures must be proportionate to the diameter of the shot, and of course, greater in guns of large calibre; but in the present case, the resistance arises principally from the friction which must necessarily be greater in the smaller guns, since they are both equally rammed: from the same cause also the powder being more compact in the small guns, the explosion takes place more instantaneously, wherefore the ratio of the sum of the pressures to the diameter of the shot must be greater: the shot likewise in passing through a greater length of bore in the guns of small calibre, will be impelled by the fluid for a longer space of time, whence its velocity must be increased.

186. The second effect (184) proceeds solely from the resistance of the air to the motion of the projectile: this resistance is very considerable when projectiles move with great velocity, and is the greater as the diameter of the shot is less.

The following is a result of experiments made in June 1764, on the Banks of the Po, and a comparison between the actual and potential ranges. The charges were such as would give the velocities marked in the table, and the

the guns were laid with every necessary precaution. The medium of several rounds was taken, and the direction was along that part of the Po, which runs almost in a right line from the mills of *Rocca-Franca* to the *Chapel of the Crucifix*.

Comparison between the actual ranges of shot measured in June 1764, along the Banks of the Po, and those which a given initial velocity would produce, if there were no resistance in the air to the motion of the shot.

		Ranges.				
		Initial	Eleva-	Experi-	Potential.	
		Velo.	tion.	mented.		
		Fect.		Yds.	Yds.	
Rifled Carabines bullets weighing $\frac{1}{4}$ of an ounce.	}	1956	15°	901	19903	
			24° 20"	938	29854	
			45°	895	39806	
Mufquet, weight of bullet 1 oz.	}	1736	7° 15"	948	7845	
			15°	1305	15691	
			24° 20"	1335	23337	
			45°	1181	31383	
Wall-pieces.	}	1855	15°	1433	17897	
			24° 20"	1753	26734	
		1770	46°	1629	35794	
			3 oz. Balls weighing 3 oz.	15°	1699	16307
					3 oz. Balls weighing 3 oz. but equal in diameter to 3½ oz. balls.	1630	22268

N. B. During the five mornings that these experiments were carrying on, the barometer at the battery was stationary at 29 inches, except towards the end of the third morning when it rose a little.

This comparison shews that the rifled carbine with an initial velocity of 1956 feet only ranged 895 yards, at the elevation of 45°; while that from the theory of projectiles moving in vacuo, it should have ranged 39806. Now as the only difference between the range calculated from the initial velocity measured near the mouth of the piece, and the actual range at the elevation of 45°, is in the space passed through by the shot; it must be owing to the mass of air displaced by it, and consequently to the resistance that the air opposes to its motion.

187. The following experiment proves that the resistance of the air to a projectile, is greater in passing over water than land. In June 1764, several rounds were fired from the mill of *Rocca Franca* over the Po, from a wall-piece carrying a $3\frac{1}{8}$ oz. bullet, at the elevation of 15° , with a charge that gave an initial velocity of 1770 feet; the mean range taken with the greatest accuracy was 1799 yards, the same gun was afterwards fired in the same manner along the road leading to *Stupinigi*, and the mean range was 1863 yards.

188. From the preceding comparison are deduced some of the corollaries in the theory of the air's resistance (Philos. Instit.)

1. That the air's resistance is greater in shot of small than of large diameter, provided the specific gravity be the same.

2. That in shot of equal diameters the most dense ranges the farthest.

3. That when the gun and butt are in the same plane, the elevation that will give the longest range with a given charge is less than 45° .

4. That the less the diameter and density of the shot, the more the elevation that gives the longest range, is under 45° .

5. That the longest range to be obtained with the largest charge, depends on the direction of the gun, the initial velocity of the shot, its diameter and weight, the density of the air, and the equality or difference between the planes of the gun and butt. Hence, (102, 103, 104,) in measuring the ranges to ascertain the charges that will impel the shot with the greatest velocity, the results are liable to such modifications, particularly when the first graze of the shot is at a distance from the gun, that it requires a series of experiments, before any one point can be accurately determined.

189. In this comparison between the actual and potential ranges, it was supposed that the charge that gives a certain initial velocity when the gun is laid horizontally, would give the same at different degrees of elevation. To prove that this supposition is true with regard to shot of small diameter, a musquet (169) was directed against a block of wood equally porous, placed at the distance of 5 feet, it was fired horizontally with a charge that gave an initial velocity of 1736 feet: it was again loaded in the same manner, and fired in a vertical

tical direction against the same block placed at an equal distance, the shot each time penetrated to the depth of 12 inches.

190. Since the initial velocity of shot of small diameter, is the same whatever be the elevation of the gun, it follows that the increase of the elastic fluid produced when the piece is at the highest elevation, is in the increase of resistance arising from the elevation, in the same ratio as these two forces are, when the piece is fired horizontally.

191. Let AE be a horizontal line making with the lines AF, AG, AH, AK the same (Fig. 22) angles as the guns were fired under in the preceding experiments: set off the lengths AB, AC, AD, AE of the corresponding ranges, and erect the perpendiculars BF, CK, DG, EH ; the lines AF, AG, AH, AK , will express the spaces that the shot passed through by the impulsion of the elastic fluid, and the perpendiculars BF, CK, DG, EH the spaces passed through by the power of gravity. Thus it will be easy to lay down the curve that the shot described in its flight, either geometrically or by *Dulac's* instrument.

192. A line drawn through the points A, F, G, H, K , will be a curved line of projections, and will shew the point where the shot will strike the horizontal line AE when the elevation is less than 45° : on the contrary, if the point of the line AE which it ought to strike be given, the proper degree of elevation may be found without tracing the curve described by the shot in its flight. If the guns in June, 1764 had been elevated above 45° , in order to know the corresponding length AN of the ranges, the curve $AFGHKML$ of projections would have been complete.

193. This method of finding the curve described by projectiles, may be used when the initial velocity remains the same, though the elevation be altered; but when both the velocities and elevations are different, the following method may be adopted. (Fig. 23) Choose a piece of ground on which the guns may be placed at the different heights A, C, D ; fire some rounds from A , charging and laying the piece always in the same manner; which in the present case will be supposed to be horizontally, and mark at each discharge the first graze of the shot: then fire from C, D, E with exactly the same direction, elevation, and charge, and mark the first grazes L, B, Q . Erect the perpendiculars $I H, L K, B M, Q F$ which will be the abscissas of the curve described

described by the shot, and the horizontal lines AH , CK , DM , EF will be corresponding ordinates; then from the value of these lines the nature of the curve may be deduced, or traced mechanically; and will be most applicable to those elevations where the initial velocity remains nearly the same. If the ground at the points I , L , B , Q be such that the shot can penetrate in the same direction with which it impinges, the holes being the tangents of the curves, the sub-tangents and sub-normals that correspond with these points may be likewise known. Thus an equation to the curve may be found by the inverse method of tangents.

194. The curve thus found may be resolved into the simple movements of which it is compounded, by knowing the time that the shot is passing from the mouth of the piece placed successively in A , C , D , E , to the points I , B , L , Q , where it touches the ground; for this purpose, a common pendulum or watch that marks very small divisions of time as $\frac{1}{2}$ or $\frac{1}{3}$ of a second will answer. Place it near the men who are stationed to observe the first grazes, and let them begin to reckon the instant they perceive the flash of the gun. Suppose that the (Fig. 24.) time of the shots flight from A to $I = a$ from C to $L = b$, from D to $B = d$, and from E to $Q = f$; mark on the line AE , the times $AB = a$, $AC = b$, $AD = d$, $AE = f$, and make the ordinates BH , CI , DK , EL , equal to the spaces that the shot acted on by the impelling power has passed through in the corresponding times (193); $AHIKL$ will then be the scale of spaces passed through in these times, from which may be deduced the scale of initial velocities; and again from this last, the scale of momentaneous resistances of the air to the motion of the shot.

FIG. XXV. Mark in the same manner on the directrix MV , the times $MR = a$, $MT = b$, $MS = d$, $MV = f$ and erect the ordinates Rr , Tt , Ss , Vv , each equal to the spaces that the shot has passed through by the power of gravity (193.); $Mrtssv$ will then be the scale of velocities, and give the scale of momentaneous resistances opposed by the air to the movement of gravitation.

195. If the law of the air's resistance only be required, one of the following methods may be used, and will give results more accurate than any of the former ones (186, 193, 194.): the first consists in finding the scale of spaces that the shot

shot acted on by the impelling power has passed through in corresponding times. The second is to find by means of this movement of impulsion, the scale of retarded velocities in corresponding spaces. To find the first scale, fire some (Fig. 26.) rounds from the point S, in the direction S r with equal charges, against a butt placed at the several distances S o, S l, S m, S n. Now as two points on the surface of this butt will be always known, viz. the point where the line of direction S r falls, and that which the shot strikes, the spaces o a, l b, m c, n d, passed through by the gravitating principle, and the corresponding spaces s o, s l, s m, s n passed through in the same time by the movement of impulsion will be known, and the curve S a b c d described by the projectile will be found. If the butt be placed at such a distance that the longest line n d of descent does not exceed 150 feet; the resistance of the air to the movement of gravitation will be inconsiderable, and the theorem

$$S = \frac{32.18t^2}{2}$$

is passing through the spaces o a, l b, m c, n d in its movement of gravity; and also through the spaces S o, S l, S m, S n in its movement of impulsion.

FIG. XXIV. Draw the directrix A E, making A B

$$= \sqrt{\frac{2}{32.18} oa}, AC = \sqrt{\frac{2}{32.18} lb}, AD = \sqrt{\frac{2}{32.18} mc}, AE = \sqrt{\frac{2}{32.18} nd},$$

and erect at the points B, C, D, E, the perpendiculars BH = S o, CI = S l, DK = S m, EL = S n; then a line passing through the points A, H, I, K, L, will be the scale of spaces passed through by the shot in corresponding times, in its retarded movement of impulsion. From this deduce the scale of corresponding velocities M N O P Q, and that of the momentaneous resistance of the air to the motion of the shot; thus the retarding force of the air will be known.

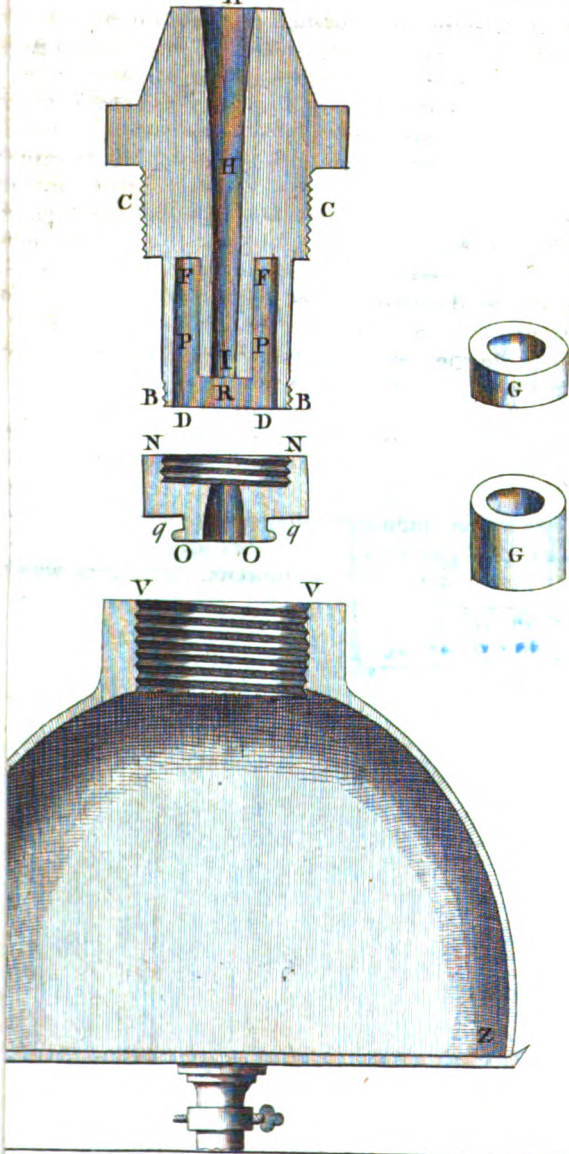
196. It has hitherto been supposed that the shot is projected in the direction of the axis, but this does not always happen. To remedy this inconvenience; fire the gun with a charge that will produce a given initial velocity, place the butt (Fig. 26.) at different distances S o, S l, S m, S n,

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taken at pleasure, and measure the velocity with which the shot impinges on the butt, either by measuring its penetrations (176), or by some machine proper for the purpose. On a line, set off the abscissas $S o$, $S l$, $S m$, $S n$, equal to the spaces that the shot has passed through by its movement of impulsion; and let the corresponding ordinates equal the experimented velocities: then by making the longest ordinate equal to the given initial velocity, and erecting it at the beginning of the abscissas, we shall have the scale of velocities in corresponding spaces with a retarded movement of impulsion; from this scale may be deduced that of the momentaneous resistances of the air to the motion of the shot; it is a matter of no consequence for these experiments, whether the shot be projected in the direction of the axis or not.

197. There are other methods of ascertaining the path described by projectiles, and the retarding force of the air; but it is to be presumed that the principles laid down in the course of this treatise will, from their practical utility and easy application, induce the students to exercise themselves in the theory of gunnery, whence they may derive from the use of fire-arms, particularly of mortars, advantages which can by no other means be obtained.

Fig. 3.



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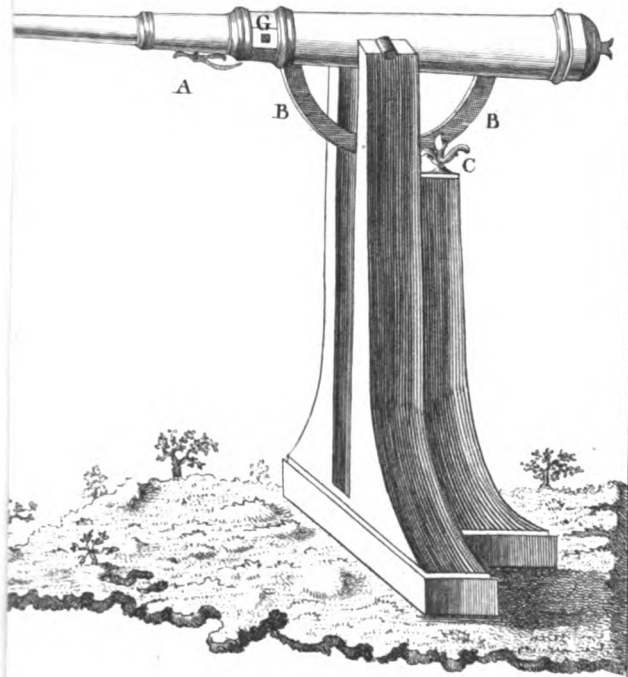
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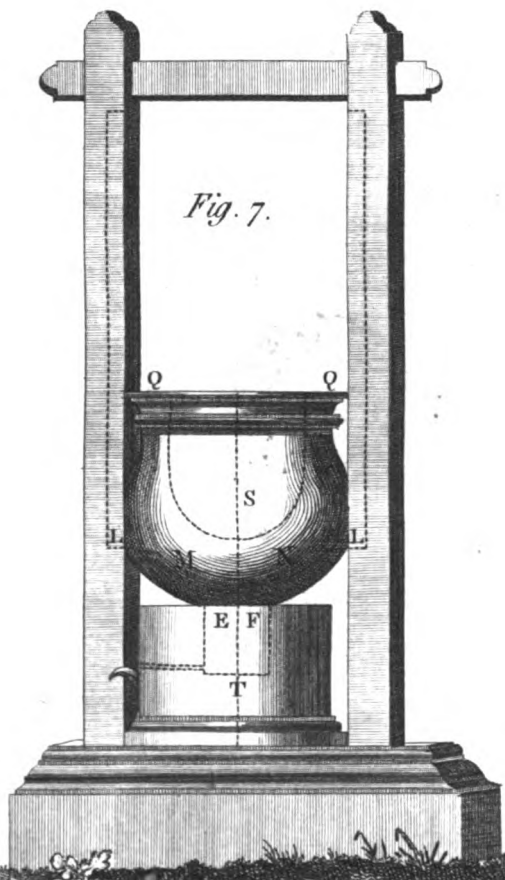
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Fig. 5,

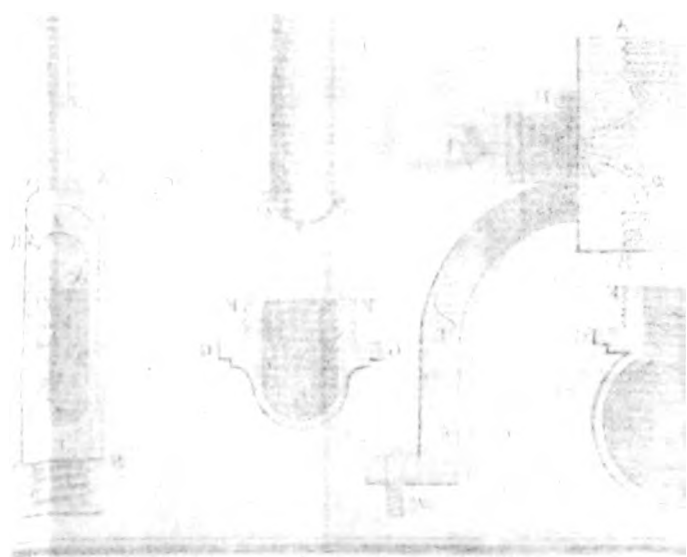


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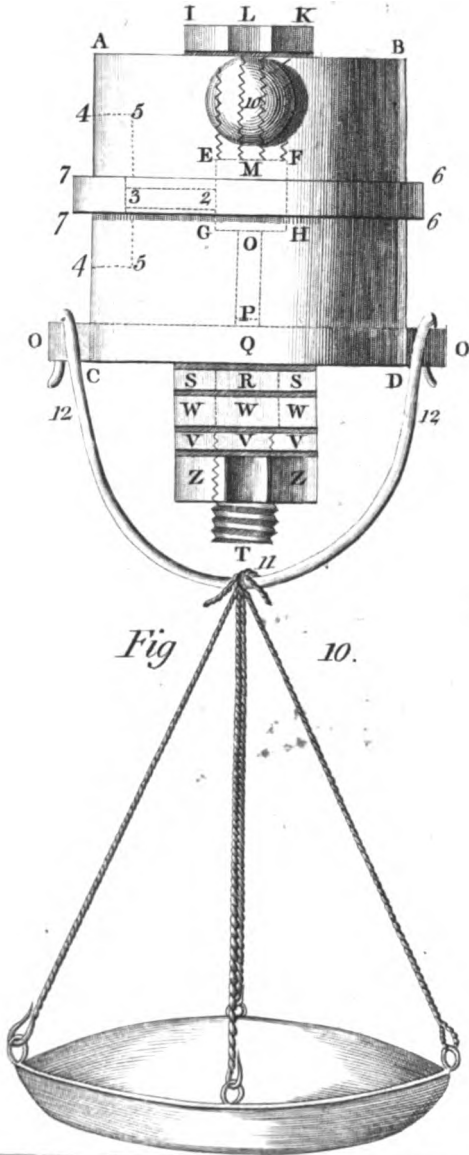
Fig. 7.



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Fig

10.





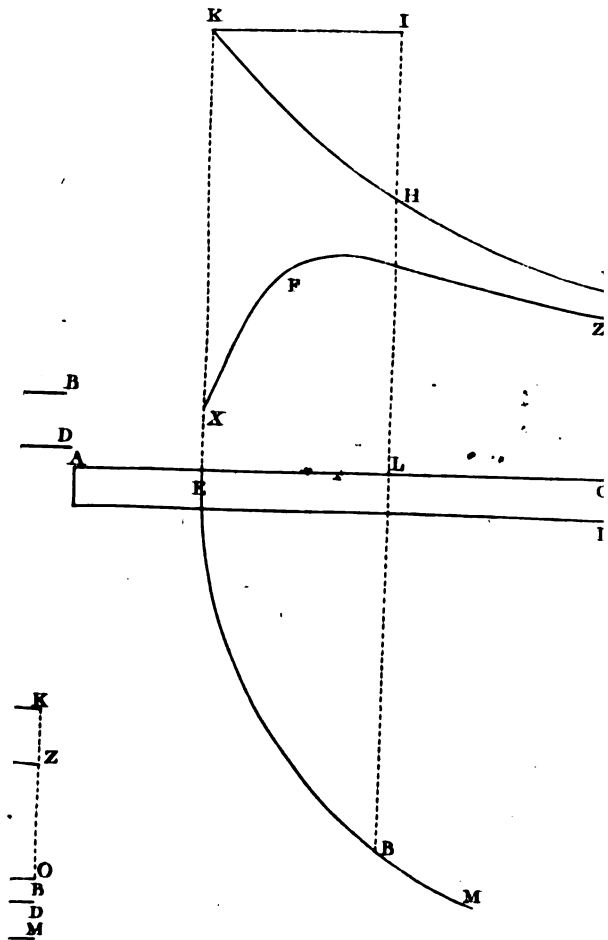


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Fig. 15.

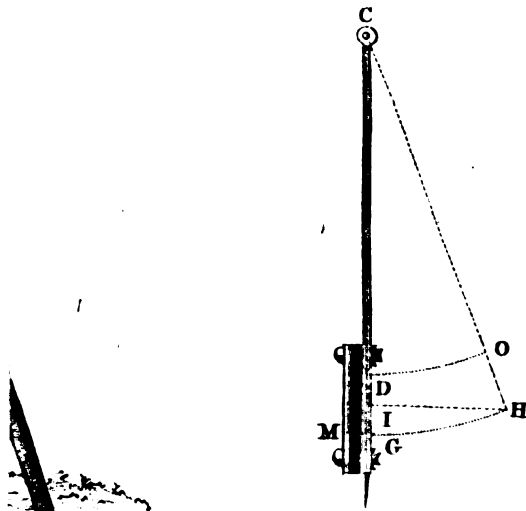


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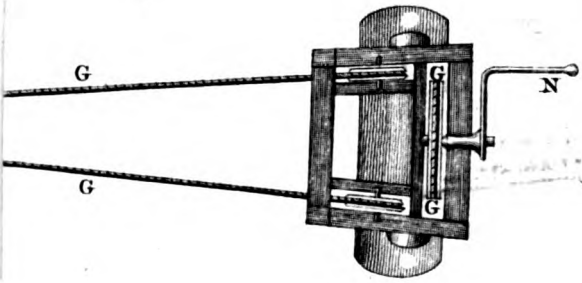
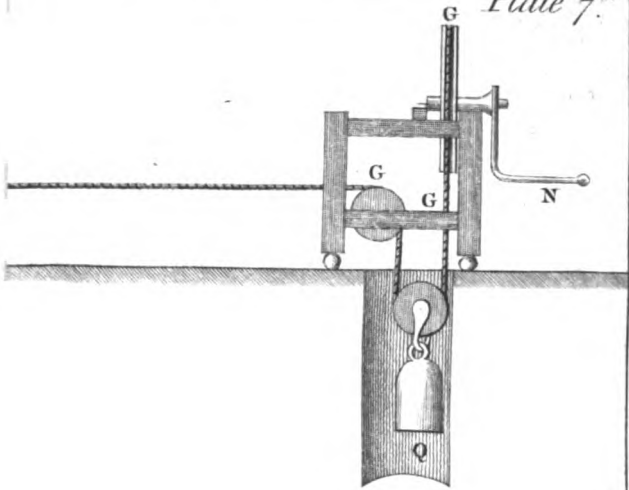


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Fig. 18.



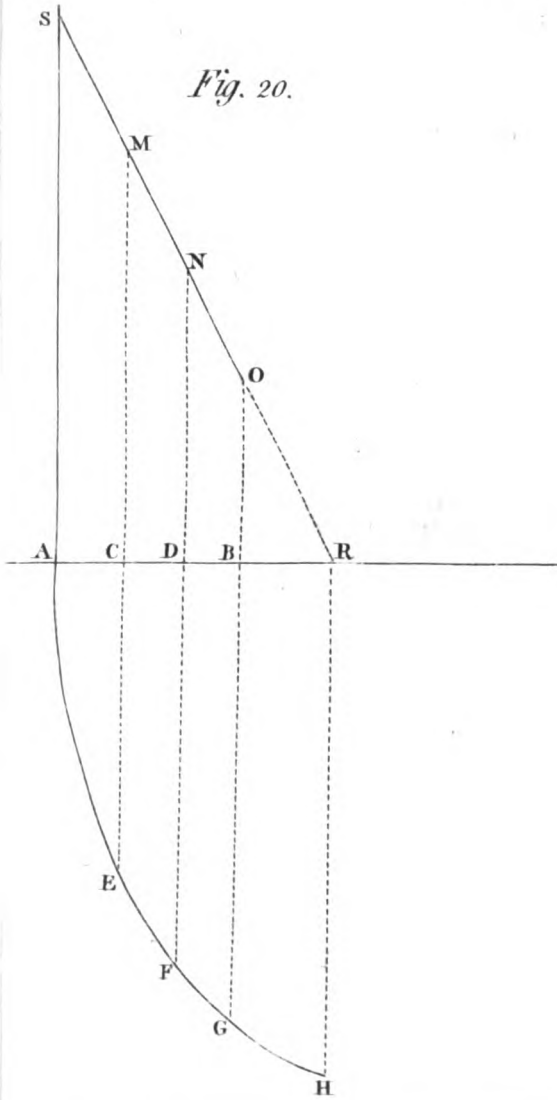
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Fig. 20.



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T R E A T I S E

O N

F I R E - A R M S .

F I R S T P A R T .

OF THE RESISTANCE OF FIRE-ARMS TO THE ACTION
OF POWDER.

The Metal of which any Fire-arm is made ought to have certain determined Physical Qualities, combined in so just a manner with the Thickness of the Piece, that it may be able to resist the Explosion of the Powder, without being unnecessarily heavy and unweildy.

THE earlier ARTILLERISTS, convinced from experience of the justness of this remark, substituted in the room of iron ordnance, guns and mortars cast of BRONZE, a metal composed of tin and copper; to which they sometimes added a proportion of brass: hoping that this mixture would possess the several qualities in which the iron ordnance had proved defective.

2. Bronze was in use before the invention of gun-powder. It had long been known that a mixture of tin with copper was less tenacious and malleable, but harder than pure copper; and that it even became short and brittle, if the tin were in too great a quantity. Wherefore the two metals were pro-

G 2

portioned

portioned according to the different uses for which the bronze was designed: for casting statues, machines, &c. which required nice workmanship, the tin was generally between a 20th and 50th of the copper, and to give this soft metal a fine colour, they added a proportion of brass, between a 3^d and 5th of the whole. For bell-metal, which should be very hard and entirely free from the separations of the particles of metal found in bronze containing too little tin, no brass was used, and the tin was in the ratio of 22 to 27 in the 100 of copper.

3. PETER SARDI, an *Italian*, who fully knew the properties of simple and compound metals, published in the beginning of last century, some observations on the damage that cannon sustain from the explosion of powder: wherein he pointed out the necessity of having a metal that should be *uniformly hard, firm and resisting, not brittle like glass, soft like copper, nor liable to corrode like brass, but which should be able to stand repeated firings without sustaining the least injury.* These ideas from their justness and accuracy soon spread from ITALY, in that day the school of military science, throughout all EUROPE; and the *Pyrotechnica* of *Vannuccio Biringuccio* had already passed through several editions: it was natural therefore to suppose that the quality of bronze most proper for artillery would have been universally adopted, and a certain proportion of the component metals fixed on. On the contrary, the most enlightened and warlike nations proceeded without any determined principles, and various compositions were in use till the middle of this century; as may be gathered from the numerous publications on the subject.

4. This variety of opinions gave rise to two parties: the *Italians*, desirous of having a gun-metal hard and free from cavities, mixed the tin and copper in the ratio of 12 to 20 in the 100; and by applying a *bouch*, repaired the guns when the vents had run. The *opposite party*, considering tenacity as the most essential quality, mixed the tin with the copper in the proportion of 4 to 8 in the 100; and maintained that this composition was the best, as the vents were not so soon affected by the fire; and attributed the alteration in the bores of the guns, whence they were soon rendered unserviceable, to any other than the true cause, which was the softness of the metal. So long as powder was made of a weak quality, and the guns were not over-heated by too quick a succession of

of discharges; as formerly in the hottest sieges the firing having been kept up for some time in the morning was discontinued on both sides for three or four hours; this question remained undecided: but since the powder has been made stronger, and the firing has continued incessantly from morning till night, so many accidents have happened owing to the softness of the metal, that there has been an absolute necessity for increasing the quantity of tin.

5. On surveying, after the peace of 1713, the artillery in the several fortresses in PIEDMONT; it was found that the vicissitudes of the preceding war had introduced guns of all natures, cast by founders of different nations. In the wars of 1733 and 1742, some of these pieces continued perfectly good after 1000 rounds; while others became unserviceable after 500, or even fewer discharges: as the shot in striking against the sides had considerably altered the figure of the bore. Many experiments have been made in this capital since the peace of 1749, both by the officers of the royal corps of artillery, and by individuals appointed for the investigation of particular points, to ascertain the cause of this great diversity of effects. This treatise being only an application of the principles of natural philosophy to artillery, it will be best to pursue the method adopted in the preceding works, and refer to the maxims already established; that the artillerist may take in at one point of view their rise, connection and deduction, and be thereby enabled with the greater readiness to apply them to practice.

6. Before we attempt to ascertain the best construction for fire-arms, it will be proper to consider in what their perfection consists; that from a clear discrimination of the necessity and importance of each particular point, we may avoid the error into which many have fallen, of paying attention to some circumstances while they neglected others equally essential; thus losing the advantages resulting from a combination of the several parts of the subject: hence their labours have only tended uselessly to multiply the species of ordnance, which has been already observed by some excellent writers; who from the badness of the inventions have inferred the want of talents in the inventors.

7. There are two principal conditions which constitute the perfection of every fire-arm: the first requires *that it be so constructed that the men who work it may run no risk of being*

hurt by it : the second, that it be manageable and adequate to every purpose for which it is intended.

8. To be possessed of the first condition (7); the quality of the metal, of which any gun is made, should be in such a just combination with its thickneses; that if by any extraordinary accident it burst, it may not be shivered into pieces. This property is obtained by mixing the metals in a due proportion.

2. The bore of the gun should be free from cavities, particularly in the charging cylinder; and of such a figure, that with the sponge the gunner may be able to extinguish any fire that hangs in the piece, in order to avoid the dreadful accidents that sometimes happen in reloading.

3. Guns intended for works or batteries should be of such a length that the explosion may not damage the embrasures, and that there be no necessity for making the inner part of them too wide; which greatly exposes the artillery men to the fire of the enemy's musquetry, to the evident detriment and delay of the service.

9. The second condition (7) requires;

1. That the metal be of so tenacious quality that the gun may with a moderate thickness for a long time resist the force that tends to burst it: as guns of large calibre may on this principle be made lighter, and be consequently more easily worked and brought into action. The metal should likewise be of so hard a nature, that the bore of the piece may sustain without alteration a long continued firing.

2. That in diminishing the weight of metal, such regard be paid to the figure of the gun, and the position of the trunnions, that no irregularity of movement can take place at the discharge, sufficient to damage the bore of the gun, or alter the direction of the shot.

3. That all the parts and ornaments be so proportioned and situated as to be of service in laying the gun and firing with precision.

After these preliminary observations, let us proceed to examine separately the several causes that conduce to the perfection of fire-arms.

C H A P. I.

OF THE METALS OF WHICH FIRE-ARMS ARE MADE.

10. **T**HE simple metals used in casting cannon, are *iron, copper and tin; brass*, which is a composition, is sometimes added. As the proprietors of mines find it too expensive to perform all the operations necessary for the thorough purification of the metals, the iron and copper usually met with in commerce, are not sufficiently refined for the purpose of the founder. The subsequent remarks on the method of using these metals will also point out when they are properly purified.

11. *Iron ore* is generally found in the form of an indurated earth, and is fluxed in contact with charcoal, with a very strong heat kept up by means of large bellows: during this operation the greater part of the volatile particles contained in the ore, as sulphur and arsenic, exhale in form of smoke, and the phlogiston uniting itself intimately with the ferruginous particles, the iron appears in fusion at the bottom of the furnace; whence it is run into a trough prepared with sand of a demi-cylindrical form, and is by the workmen termed *a pig*. This is called iron of the first smelting, and is always unmalleable.

12. This iron is again smelted by a similar process, and is then called iron of the second smelting, which though purer than the first, is still unmalleable. In proportion as the ore is more purified and has been oftner smelted, it fuses with more difficulty; and the fusion does not at length commence till the heat be very intense.

13. The iron procured from foreign countries, as an article of commerce is generally distinguished into two sorts. The one does not yield to the hammer when cold; but when red hot, it easily breaks into pieces, which is owing to the quantity of heterogeneous substances it contains, principally arsenic and sulphur; the other kind is malleable when red-hot; a certain sign that it is well purified and of a good and tenacious quality.

14. For iron guns, the ore of the most tenacious quality is the best. English ore is in the highest estimation; it has

a sufficient degree of hardness, since in firing with shot, the bore of the gun is never injured; but as it is not sufficiently tenacious to resist the force of powder in very long sieges, it becomes necessary to supply this defect by adding to the strength, and consequently to the weight of the guns, to prevent their bursting: wherefore 32 pounders with proper reinforces are too heavy, and are only used on board of ships of war, 24 pounders being the largest piece of iron ordnance that is used in land service.

15. The iron of the second smelting is heated and welded with a forge hammer to increase its malleability and tenacity: this operation is frequently repeated to separate the earthy heterogenous particles. When thus worked, it obtains the name of forged iron, and is less hard but much more tenacious than before. It is esteemed of the best quality when malleable, both hot and cold, and when it yields to the file; but when it breaks and splits under the hammer, it is not so good. A very violent and long continued heat is necessary to fuse forged iron; and from its softness, it is only used in the construction of fire-arms of small calibre, from which leaden bullets are projected, as wall-pieces, musquets, pistols, &c. since from its great tenacity the barrels may be made very thin.

16. Copper is generally found mixed with other metallic and volatile substances; according to the nature and proportion of which the operation of purifying must be varied. It sometimes happens that a vein of a copper mine will furnish for a considerable time, an ore easily refined; but at length its quality alters, which induces a necessity of multiplying and even diversifying the processes of refining. In all cases it is first fluxed; whence a *regulus* or mixed metal, called *black copper* is obtained; which is unmalleable and of different qualities according to the nature and proportion of the heterogeneous substances.

17. To purify black copper, the chymists use the *capel* almost the same manner as the refiners of gold and silver: but the common method is to roast and afterwards smelt it; that during the roasting, the volatile particles may be sublimed; and that when in fusion the other heterogeneous substances may be converted into scoriæ: the metal obtained from this process is called copper, and is generally run into thin cakes, which are very full of cavities and spongy.

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The copper met with in commerce is generally designed of three qualities, viz. *pure*, *common*, and *impure*, as in some mines the metal will not defray the expence of purifying it. For some years past the merchants have imported copper from GERMANY, SAVOY, and JAPAN, which is very well purified: that procured from AOST and SWEDEN is harder and less malleable; but the copper brought from MEXICO is of a very inferior quality, being crude and totally unfit for wire-drawing.

18. Pure copper is red, tenacious, ductile and malleable; it is drawn into very small wire, as the strings of musical instruments; and beat into very thin vessels without breaking or splitting: this is a certain method of proving its purity. This copper requires a very strong and long continued heat to melt it. If it be fused without being in contact with any phlogistic body, and the fire be stronger than is necessary to keep it in fusion, small particles will be seen successively to calcine; and if the same force of fire be continued, these calcinations will appear in the form of scoriae floating on the surface of the melted metal. If the scoriae be scummed off, pounded and mixed with a quantity of charcoal, they will when exposed in the furnace to a strong blast revivify and resume the metallic form. (Philos. Instit. 91, 116.)

The flame that breaks out at the fusion of pure copper with charcoal, is of a fine green colour; when dissolved by oil of vitriol, it exhibits a blue flame.

19. Common copper is that in which the heterogeneous substances are in small quantity, and do not much affect its tenacity and ductility; so that though it cannot be drawn into very fine wire, kitchen utensils are made of it.

The copper of the third kind is of an inferior quality; less tenacious and ductile: it is brittle under the hammer, or when offered to the wire-drawer, it is a proof that it contains many ferruginous or arsenical particles. If there be much arsenic, the copper fuses easily; and if there be any antimony it accelerates the fusion: but then the flame instead of being of a greenish is of a whitish cast, and is loaded with smoke. If the flame at the solution of copper by oil of vitriol be yellow, it is a sign that the ore contains iron; and if the colour become green, the iron is in great quantity. Impure copper ought never to be admitted into founderies for cannon, as the bronze made of it is short and brittle.

20. *Tin* is the lightest of metals; yet its ore is very ponderous when mixed with arsenic: it is therefore easily separable from other heterogeneous substances that are lighter, either by picking or washing, after it has been pounded in a mortar: the ore is then roasted to clear it of the arsenic, and afterwards smelted in contact with substances abounding with phlogiston; in order to prevent the great calcination to which tin in fusion is liable.

21. Tin well purified is not very ductile or tenacious; and a creaking noise on bending it different ways is heard. A very moderate degree of heat fuses it long before it becomes red, and the more it is exposed to the air the sooner it calcines: on combining the calx with a phlogiston, and exposing it to a proper degree of fire, it readily resumes the metallic form. Purified tin is miscible with other melted metals, and diminishes their ductility and tenacity, excepting lead. On the other hand, a mixture of 20 parts of tin and 1 of copper, is more solid than pure tin, and yet preserves its ductility; of this kind is the fine English tin.

22. *Zinc* is a semi-metal found in *Calamine*, *Lapis Calaminaris*, and the substance called *Cadmia Fornacum* which attaches itself to the mouth of furnaces, in which metals containing zinc have been smelted. This semi-metal easily inflames, when exposed to a sufficient degree of heat, sublimes in the form of white flowers, called *philosophic wool*, and is dissipated. As zinc is found mixed with different minerals, the operation of purifying it varies according to their several qualities.

23. The combination of *zinc* with *copper* is called brass. When the substances are of a good quality, the brass is malleable when cold; brittle, when very hot: but if composed of impure materials, it is brittle when cold: from this property its quality is easily ascertained. Brass is yellow and more fusible than copper: if fused in a crucible with a strong heat, the melted metal will inflame and a great many flowers of zinc be seen to rise from its surface; so that if it be kept a long time in fusion, it will lose all its *zinc*, and the residuum will be simply copper.

24. If a quantity of copper be heated, and a proportion of tin thrown into the furnace, the two metals will sooner become fluid: if copper, or a mixture of it with tin be already melted, an addition of tin will render the fusion thinner; tin is then the menstruum of copper: but this property does
not

not suffice to make a thorough and exact mixture of the two metals in large furnaces; a motion infinitely greater than that which is sufficient to keep them in fusion must be for this purpose excited. If the metals be well mixed together and drawn from the furnace so as to be suddenly condensed; the particles will retain their intimate connection when perfectly solid: but if the quantity of melted matter be very great, and the receiver of such a form that it is some time before it sets, on examining it when cold, the tin will be found to abound most towards the bottom, particularly in long receivers, like the moulds of cannon. The calcinations (18, 21) which take place while the composition is in fusion, are of different characters according to the quantity of melted metal, the exposure of its surface to the air, and the time that it remains in fusion: these changes are almost imperceptible in the more minute processes of the metallurgists; but when in large furnaces a great quantity of metal is suffered to remain a long time in fusion, and the fire is increased, it will be found that the metal produced from the revived calcinations, contains the tin in a greater proportion, than when put into the furnace; as is seen in the refined cakes, which the founders of artillery draw from what they call *the operation of the handle*.

25. The mixture of copper with tin is called *bronze*, whatever be the proportion between the component parts, provided that the excess be on the side of the copper. In proportion to the quantity of tin, the composition (2) is harder and less subject to cavities; it even loses its tenacity and becomes crude and brittle, if the quantity of tin be too great; the addition of a considerable proportion of brass renders it a little harder, and even more brittle when heated (23) though the brass be of the best quality. Since the use for which the bronze is designed must determine the proportion between the component parts, in order that it may have the physical properties requisite for the intended work (2, 3), it follows that guns may be cast from bell-metal, and statues, &c. from gun-metal, on adding certain quantities of copper or tin.

26. It will be shewn in the following chapter that the metal for casting cannon, particularly battering cannon, must (8, 9) indispensably be of a hard and tenacious nature. To this end it is necessary;

1. That the metals be of a good quality and well purified.

2. That

2. That their proportion be comprised within certain limits.

3. That their natural hardness and tenacity be increased by compression.

27. Pure copper (18) is the best for artillery; as is the English tin (21) on account of its superior quality. Tin in which there is any *lead* should be absolutely rejected, since this metal diminishes both the tenacity and hardness. That gun-metal may have all the requisite properties (26), the quantity of tin should be between a 6th and an 8th part of the copper, when the powder is as strong as that now in use: it would be injudicious to diminish the proportion, as was done when the powder was weaker. If the copper be very well purified, and consequently very soft and ductile, the quantity of tin should be nearly 16 in the 100 of copper; but not more than 12 in the 100, if the copper be of an ordinary quality; 12lb. of tin mixed with 100lb. of impure copper form a crude and brittle bronze, and should never be used. In order to increase by compression the natural hardness and tenacity of the metals, the moulds of guns should be so made, that the superincumbent mass, commonly called the *head*, be as long as possible.

28. Whenever brass enters into the composition of gun-metal, it should be in small quantities; since, as has been already observed, it tends to render it brittle, particularly when the gun is heated by frequent firing (23, 25): besides, as it must be put into large furnaces by small quantities at a time, the zinc of the brass first introduced will be sublimed (23); which causes an uncertainty with regard to the just proportion of the materials. The advocates for the use of brass think that it assists and preserves the perfect mixture between the copper and tin; but this opinion is not sufficiently warranted by experience.

29. To the remarks already made on the hardness of some particular metals (Instit. Phys. Mec. 66), let us add the result of experiments made on several compositions in 1759 by MAJOR RUNZINI, director of the royal laboratory of metallurgy. In these experiments, several rods of metal were exposed to the force of a piece of iron weighing $8\frac{1}{2}$ lb. which falling from the height of $1\frac{3}{4}$ foot, on the head of a steel punch with a conical point drove it into the rod of metal, upon which it rested; the effects are therefore expressed by the size of the holes made by the punch, which from the similarity
of

of the figures, are in the triplicate ratio of the penetrations, marked in the first column; and the relative hardness of the rods are expressed in the inverse ratio of these holes; for example, the hardness of the bronze A is to the hardness of the bronze F as 173 to 51.

Result of experiments made in 1759 to compare the relative hardness of the following metals:

The relative Penetrations of the punch into the Rods.		Effects expressed by the relative sizes of the holes made by the punch.	
<i>First Column.</i>		<i>Second Column.</i>	
Fine tin of England	—	92	1216
Pure copper of Germany	---	66	450
Small pieces of copper coin		58	301
Brass of Germany, malleable when cold		54	246
A mixture of 100 parts of copper, 12 of tin, and 2 of zinc, the zinc being previously mixed with the tin	}	42	116
A mixture of 100 parts of brass and 12 of tin.		35	68

Bronze formed of good Materials in the following Proportions.

	Copper.	Tin.	Brass.	1 st . Col.	2 ^d . Col.	
Different Mixtures.	A	100	25	32	51	
	B	100	20	35	66	
	C	100	16	37	78	
	D	100	14	40	100	
	E	100	12	42	116	
	F	100	8	48	173	
	G	100	24	100	37	78
	H	100	20	5	34	62
	K	100	16	28	36	73
	L	100	14	8	37	78
	M	100	12	6	40	100
	N	100	10	12	42	116
	P	100	9	20	44	133
	Q	100	8	28	47	162
R	100	5	20	49	184	
T	100	2	20	52	220	

30. We

30. We gather from these experiments;

1. That tin is the principal ingredient towards rendering the bronze hard.

2. That the holes made in the metals A, B, C, D, E, F, composed only of copper and tin are nearly in the reciprocal ratio of the quantities of tin.

3. That by adding a quantity of brass, the proportion of the ingredients may be diversified, yet retain the same hardness, as appears from G and L.

4. That the metals C, D, whose component parts are within the limits assigned (27) may serve as a rule to judge whether the other metals have the requisite hardness for artillery. For example, to compare the hardness of a bronze Z with that of C or D; let the penetration of a punch falling on a piece of fine English tin of a determined quality = 1, then find the penetration of the same punch into the bronze proposed, and ex-

press it by Z; $\frac{1}{Z}$ will be the proportion between these penetrations. But by the experiments in the preceding

paragraph $\frac{92}{40}$ is the proportion between the penetra-

tions into the tin and the bronze D. If then $\frac{1}{Z} = \frac{92}{40}$, the proposed bronze Z will be as hard as the given

bronze D; If $\frac{1}{Z} > \frac{92}{40}$ Z will be harder than D, and if

$\frac{1}{Z} < \frac{92}{40}$, D will be harder than Z.

31. There are different methods of finding the proportion of tin in any bronze, but they give at best but an approximation.

In the first place, the composition of a bronze may be determined by finding experimentally its hardness and tenacity, and comparing them with the hardness (29) and tenacity (Instit. Phys. Mic. 64.) of a bronze given as a rule; if they correspond in these two properties, they may be said to be of the same quality; but if one be equally tenacious, but less hard than the other, or equally

equally hard and less tenacious; it will be a proof that the proportion or quality of the component metals is different.

In the second place, the composition of bronze may be nearly ascertained by sound and colour; for if on striking it with a hammer, it be very sonorous, the tin abounds, and vice versa. When the filings of bronze appear red, it contains but little tin; when they appear sparkling and whitish, the tin is in great quantity: a yellow colour denotes that there is a great proportion of brass. If a piece of bronze be broken off with a hammer, and at the point of separation hardly any particles of copper can be perceived, it is a sign that the proportion of tin is about $\frac{1}{2}$ of the copper; greater than $\frac{1}{2}$ when the section appears of a whitish cast; and less when many particles of copper are perceptible.

In the third place, some idea may be formed of the proportion between the tin and copper, by knowing the quality of each, and ascertaining their specific gravities; but this method is not accurate, on account of the sponginess of the copper.

C H A P. II.

OF THE HARDNESS AND TENACITY OF GUN-METAL.

32. **T**O prove more clearly the necessity of having a hard and tenacious metal for casting guns, and be enabled to assign certain limits to these two properties, so that the pieces may be sufficiently strong, without unnecessarily increasing their weight or incurring other inconveniences (8, 9), the forces that tend to destroy the guns, and the manner in which these forces act, should be considered.

Fired powder tends to destroy guns in three different ways.

1. By the pressure of the elastic fluid against the inside of the cylinder.

2. By the effects produced by a wad, or other similar substance, when placed at a considerable distance from the powder, if the charge be small, or contiguous to it, if the charge be superabundantly large: for in
either

either case, the elastic fluid generated at the bottom of the cylinder, is so much accelerated in its motion before it reaches the resisting body, that it acts with great force, and meeting with obstruction exerts against the sides of the gun, a power much greater than that proceeding from the pressure alone.

3. By the irregular motion of a shot, which striking against the sides, makes cavities and furrows, and alters the figure of the cylinder; which would render the gun liable to burst, if the metal were not much thicker than necessary to resist the pressure of the elastic fluid,

33. To know how far tenacity combined with the thickness of metal can resist the force of powder (32 No. 1, pl. 1, Fig. 1.) Let the figure represent a section of the charging cylinder at right angles to the axis of the piece, and $AB = r$ the radius of the bore $BFGD$, and $BC = m$ the thickness of metal: suppose $m =$ the diameter BD , the theorem 9962 $\pi r = mq$ is the expression of a cylinder, which bursts longitudinally, and $m = 2r$; then substituting this value, and correcting the expression 4981 $\pi = q$; π shews how often the fluid generated from powder is more elastic than the natural air under a mean state of the atmosphere, and q expresses in pounds the weight requisite to overcome the tenacity of the metal. Suppose the elasticity of the fluid be at the highest degree, *viz.* equal to that produced under a very dry state of the atmosphere, in a vessel that invariably preserves its form, whence it can only escape by the vent, $n = 1900$ (Treatise on Powder 137): then $4981 \times 1900 = 9463900$ lbs. which is the tenacity represented by q in a thickness of metal equal to the diameter of the bore and in equilibrio with the given pressures. The tenacity of bronze composed of common copper and $\frac{1}{8}$ of tin is 12909386; and of bronze containing $\frac{1}{6}$ of tin 11881360 (Philos. Instit. 64); hence if either be used for casting cannon in the proportions of heavy artillery, the tenacity will be greater than is requisite; particularly as in practice, the greater part of the fluid escapes through the mouth of the gun, where it encounters no other resistance than the friction of the wads, and weight of the shot, so that the elasticity never amounts under the most favourable circumstances to $\frac{3}{4}$ of the greatest elasticity 1900. Wherefore gun-metal may be composed of copper and $\frac{1}{6}$ of tin, without any risk of the gun's bursting.

34. THE OFFICERS OF ARTILLERY, in order to ascertain whether guns cast of the mixture M (29) opposed sufficient resistance to the greatest pressure of the elastic fluid, made choice of a 32 pr. called the *Invincible*, in which the thickness of metal at the breech was equal to one diameter of the bore, and the thickness at the end of the first reinforcement equal to $\frac{15}{16}$ of that diameter. In the month of MAY,

1771, this gun was loaded with 16 lb. 6oz. of fine war powder, the wads were of twisted hay, rammed down by six strokes, from two gunners; the rest of the cylinder was filled with clay very closely pressed, and a tompon of wood wedged into the muzzle: the gun thus loaded was placed in a ditch, prepared for the purpose, and strong stakes driven on each side to prevent the least motion; a heavy beam was fixed behind the breech, and another before the muzzle, to force all the fluid to escape by a hole made in the axis of a bouch screwed into the vent. The charge being set fire to, all the substances were forced through the mouth of the piece, and the beam placed there blown into the air. The gun was carefully examined, but not the least flaw discovered, though every instrument and method were used for that purpose: it was afterward filled with water, and suffered to remain in that state for five hours, at such an elevation as to cause a strong compression, yet not a single drop oozed through.

35. It has been already observed that metals lose their tenacity when heated, and compound metals more than simple ones; wherefore *the oftener the guns are fired the less tenacious the metal becomes*. This heat however is never so great as to fire the powder in loading the piece; beside the artillery men either cease firing or cool the gun with a wet sponge, when they are apprehensive of its being too hot: wherefore we will consider this heat as the highest term in comparing different tenacities. Bronze containing $\frac{1}{8}$ of tin loses at most a third of its tenacity, when heated so as to fire powder; or in other words, its tenacity is only equal to 7358758; and bronze containing $\frac{1}{4}$ of tin and heated to the same degree loses only a fourth of its tenacity, which is thus reduced to 9682040: then, if in the theorem $4981n = q$, 1200 be substituted in the place of n ; (since (33) in the common firing $n < \frac{2}{3} \times 1900$), $4981 \times 1200 = 5977200$ equal to the
H pressure

pressure of the fluid: wherefore the tenacity of these metals heated so as fire powder, is still greater than is necessary, when the thickness of metal at the charging cylinder is equal to a diameter of the bore.

36. The following experiments made by the OFFICERS OF ARTILLERY, in the spring 1770, at the PRACTICE BATTERY will prove the above propositions. A 32 pr. called the *Sarcophagus* constructed on the same model and of metal of the same quality as the *Invincible*, was fired 800 times with shot, the windage of which was agreeable to the present establishment: the charge of 8 lb. 12 oz. of fine war powder was used; two gunners gave five strokes to the wad over the powder, and three to that over the shot; the gun on its carriage was placed upon a horizontal platform; 100 rounds a day were fired at the rate of 12 in an hour, which is more frequent than in the hottest firing at sieges, as on an average seldom more than 9 rounds can be fired. After the experiment, the piece was carefully examined, but no flaw discovered; the part of the cylinder from the muzzle to the wad over the powder was perfectly smooth, and the gun having been each time pointed to the *butt*, the shot were all thrown in a direct line; the inside indeed of the charging cylinder was become rough; but this could not affect the service of the gun, and was attributed to the liquefaction or calcination of the particles of tin that lay on its surface. It has often happened that on heating the breech of a gun, to repair the vent which had been enlarged by firing, the exterior surface has become very rough, and when the tin has not been properly mixed with the copper, little cavities have been formed: the irregular enlargement of the vent further proves a want of due exactness in mixing the metals.

The *Sarcophagus* had a chamber at the bottom of the cylinder, the upper part of which was considerably corroded by the powder that escaped through the vent; this will be accounted for in the eighth chapter.

37. Having thus considered the resistance of guns with respect to their tenacity combined with the thicknesses of metal, let us examine why hardness is likewise necessary, and how far this property should be carried. For this purpose, the action of the fluid on the sides of the gun, particularly at the part where the wad is placed between the powder and shot, must be known (32, No. 2). The easiest and most effectual method

method of ascertaining this, is to make experiments with two guns of the same calibre, but cast from different mixtures: Let one gun be cast from a soft mixture, in which the tin does not exceed $\frac{1}{10}$ of the copper; (Pl. 1, Fig. 2,) let the charge be equal to $\frac{1}{3}$ of the weight of the shot, and be wadded as usual; after the discharge it will be seen that from A, where the shot was lodged, towards B the bottom of the bore, the sides are distended all around, and the orbicular cavity A C D in shape of a pear is formed, whose greatest depth is at C where the wad was placed between the powder and shot; that it diminishes gradually towards B, and ceases entirely at D, at the distance of about two diameters from B. On charging this gun with a quantity of powder equal to the weight of the shot, the cavity will be increased, but its greatest depth will still correspond with the situation of the wad between the powder and shot. If, instead of being constructed according to the proportions of heavy artillery, the thicknesses of metal be only in equilibrio with the fluid; the gun will burst at the point of the greatest depth of the cavity; or at least the metal, if soft and ductile, will bulge out.

Let another gun be cast on the same model from a harder metal, in which the tin is equal to $\frac{1}{8}$ of the copper, and undergo the same proof: after repeated firings no cavity or other alteration will be found, provided that it was properly reinforced; but if the thicknesses of metal be only proportionate to the pressure of the fluid, the gun will burst where the wad is placed between the powder and shot. Other experiments will be adduced in the course of this work, more fully to evince the necessity of combining hardness with the thickness of metal.

Sportsmen know by experience, that though the barrels of their fowling-pieces may resist strong charges when the wad is contiguous to the powder; yet when a high wad is placed half a foot from it, even if the powder be of a weak quality, that they will burst at that part. People unacquainted with the theory of the elastic fluid generated from fired powder, pretend that the bursting of the barrel is owing to the rarefaction of the atmospheric air intercepted between the powder and wad; but whoever knows how to estimate the force of this air, and compare it with the force which the fluid exerts against the wad, will be convinced that the action of the latter is the true cause.

38. The necessity of casting guns of hard metal, in order to avoid the cavity (37) formed in the bore, is further demonstrated by the following experiments made in June 1759, by the OFFICERS OF ARTILLERY. Three 16 prs. were constructed with the common proportions of battering guns, but each was cast from a different composition; the first was the common mixture, that has been in use among our founders for several years, and contained tin in the ratio of 8 to 10 in the 100 lbs. of copper: the second was the mixture R; and the third T (29). Three rounds being fired from these guns, under an angle of 15° with 8 lb. 12 oz. of powder; a cavity was found in each of them; with this difference, that its depth was greater in proportion as the metal contained less tin; for on measuring the cavities, the one in the gun cast from the common mixture was $\frac{1}{12}$ of an inch, that in the gun from the mixture R $\frac{4}{12}$, and that in the gun from T $\frac{5}{12}$. Two short 4 prs. one of which had been cast from the common mixture, and the other from the mixture R, were likewise fired with 1 lb. 10 oz. of powder; the cavity in the former was $\frac{1}{24}$ of an inch, and that in the latter $\frac{2}{24}$.

39. The results of these experiments induced the officers to examine twenty 32 prs. which had been proved in the common method, by firing three rounds from each. They made use of the instrument invented by SIG. MATTEI, mathematical instrument-maker to the king, for taking the exact figure of the bores of guns. Ten of these guns had been proportioned on a scale made from the diameter of the shot, and cast from the mixture R: they were fired with shot at the elevation of 15° with $16\frac{1}{2}$ lbs. of war powder; on examination they were all found to have a cavity in the figure of a pear, where the wad was placed between the powder and shot; the cavity was two diameters in length, and $\frac{1}{12}$ of an inch in its greatest depth. The other ten guns had been cast from the common mixture, which was harder than R (29, 38), and proportioned on a scale made from the diameter of the bore: each of them was fired three times with shot at the elevation of $22\frac{1}{2}^\circ$, the first time with $17\frac{1}{2}$ lb. of cannon powder, the second time with 22 lbs. and the third with 26 lb. an orbicular cavity was likewise found after the last discharge in all these guns of about three diameters in length and $\frac{1}{12}$ of an inch in its greatest depth, at the part where the wad had been placed in the last charge. Hence appears

appears the necessity of having gun-metal so hard as not to admit of any cavity being formed by the action of the elastic fluid, which is more violent in proportion, as the charge occupies a greater length of the bore: wherefore, though *cannon powder* is less inflammable than *war powder*, (*Treatise on Powder*) and consequently generates less elastic fluid in equal times; yet, in the guns formed of the common mixture, and fired with $26\frac{1}{2}$ lb. of cannon powder, the less quantity of fluid having a longer space to pass through, acquired greater velocity; so that notwithstanding the superior hardness of the metal, the cavity was of the same depth as in the guns cast from R and charged with $16\frac{1}{2}$ lb. of war powder.

40. To confirm the result of the foregoing experiments, a 32 pr. cast from the common mixture was, in August 1759, fired twice with each of the following charges of saluting powder, which was the strongest then at hand; five strokes were given by two gunners to the wad over the powder, and three to that over the shot: the piece was laid at the elevation of $22\frac{1}{2}^{\circ}$.

EXPERIMENTS IN 1759.

Weight of Powder.		Length of Range,
lb.	oz.	Yards.
9	4	3968
13	2	4456
16	6	4659

After the two first rounds, the gun was examined, but no cavity discovered; after the two rounds with the 13 lb. 2 oz. an orbicular cavity was formed, whose greatest depth was $\frac{1}{12}$ of an inch, at the position of the wad between the powder and shot; and after the two rounds with the 16 lb. 6 oz. the cavity was much enlarged, its greatest depth was $\frac{2}{12}$ of an inch at the place where the wad was lodged at the last discharge.

41. Some rounds were fired in September 1759, from an 8, 16, and 32 pr. cast of a metal similar to D, M, (29); in order to determine the proper degree of hardness for preventing the formation of orbicular cavities, even with extraordinary charges. The charge was of saluting powder, equal to $\frac{1}{2}$ of the weight of the shot; the guns were laid at 15° , and the wads rammed as before: after the experiment,

H 3

not

not the least alteration could be observed in any of the guns; this degree of hardness may then be looked upon as sufficient, and this conclusion has been fully justified by subsequent experience.

42. The third method, by which the powder tends to destroy guns (32, No. 3) now remains to be considered. In the wars of 1733 and 1742, there was an opportunity of examining guns of different nations, that had been rendered unserviceable by the shot striking against their sides, and making cavities, furrows, cracks, and swellings, which had caused some of the shot to break to pieces in the guns, and cut the metal very deep; as appears from the reports made by the officers of artillery, appointed to examine them before they were recast.

These accidents may be accounted for by the general custom the nations of Europe had before the middle of the present century, of leaving it entirely to the founders to mix the metals; they, not aware of the necessity of having a certain tenacity and hardness, proceeded without any regular system: whence frequently arose a remarkable difference in the resistance of guns cast by the same founder. In proving new guns, the charges occupied a great length of the bore; at the first round, the powder was equal to $\frac{2}{3}$ of the weight of the shot; at the second to $\frac{5}{6}$; and at the third, was equal to it in weight: so that if the metal were not of sufficient hardness, an orbicular cavity was formed at the position of the wad between the powder and shot, without the least attention being paid to it: less charges being afterwards used on service, the shot was placed in this very cavity, which caused it to take an oblique direction, and strike against the sides under angles of incidence, so much the greater as the cavity was the deeper; thus by degrees the gun was rendered unserviceable.

43. The result of experiments made in May 1753, and in July 1759, will further shew the inconveniences arising from the formation of orbicular cavities in guns. For the first experiments, three 16 prs. were cast of the common mixture (38) at the same time, and from the same furnace, to render the metal homogeneous, and for greater accuracy constructed with the same proportions; the only difference being in the calibre: for the diameter of the shot being divided into 8290 parts, the calibre of the smallest gun was 8463 of those parts, that of the second 8505, and that of

of the largest 8580. Shot perfectly spherical and well polished were cast for the occasion; none were used that were not exactly 8290 of the same parts in diameter; the proportion between the calibre of the gun and the diameter of the shot was in the gun of the smallest calibre as 31 to 30, in that of the mean as 27 to 26, and in that of the largest as 22 to 21. They were first proved as usual with three rounds, charged each time with 9 lb. 14 oz. of powder and laid at 15° , to see how the casting had succeeded; no flaw appeared on examination, except at the position of the wad between the powder and shot, where there was a small cavity; but its depth was not measured, as the instrument for that purpose had not then been invented (39).

In May 1753, these guns mounted on their carriages, were placed on horizontal platforms, charged with $6\frac{1}{2}$ lb. of powder, and directed towards the butt; fifty rounds were fired in the morning in the space of four hours, and an equal number in the afternoon, in the same time. The principal object being to observe in what manner the guns were rendered unserviceable, they were examined at first after every ten rounds; but so soon as the least flaw was perceptible between the muzzle and the part where the shot was lodged, they were examined after every round. The gun of the medium calibre became first unserviceable; some little cavities were formed between the 40th and 50th rounds: these increasing in number and size, we observed between the 110th and 120th rounds several fissures; the muzzle also began to lose its shape, the number and depth of the cavities increased from the 126th to the 137th; and at the 139th round the shot broke to pieces; the firing was then discontinued, as the muzzle would probably have *dropped* at the next round.

The next gun damaged was that of the smallest calibre; some small cavities were perceived in the bore of this piece, between the 50th and 60th rounds, and several furrows between the 110th and 170th; at the 208th and 214th the furrows were much deeper, and the metal was cracked in several parts entirely through; these fissures increasing between the 220th and 230th rounds, the gun became unserviceable at the 233^d, when the shot came out in pieces.

In the gun of the largest calibre, some cavities appeared between the 30th and 40th rounds, and some furrows at the 130th, which enlarged at the 219th and 230th, with several fissures that penetrated to the exterior surface at the 240th round; and as they were still increasing, it was judged un-

necessary to fire this gun any more, though it was not entirely unserviceable.

44. Other experiments were made in July 1759, with the three 16 pounders, already described (38) charged with $8\frac{1}{2}$ lb. of powder. After the formation of the orbicular cavity, some rounds were fired with $6\frac{1}{2}$ lb. of powder, the shot with this charge lodging in the cavity; the gun cast from T being less hard than the other two, and the cavity deeper, it became unserviceable at the 14th round from the furrows and bulging in the sides: the gun cast from R being a little harder, and the cavity not so deep, became unserviceable at 31 rounds; the third gun being of the hardest metal, was not unserviceable after 146 rounds, though it bore evident marks of the impression of the shot.

45. The experiments with the *Sarcophagus* (36) prove that when no cavity is formed in the bore, the shot do not strike against the sides, but quit the gun in the direction of its axis. The same has been observed of all the guns that from 1760 to the present time have been cast from the new mixture, and used at the *Practice Battery* for the instruction of the artillery-men.

46. To demonstrate that similar advantages accrue from increasing the quantity of tin in the common mixture, to render it of a harder quality than those before described (43, 44) here follows the result of firings from four 16 prs. cast in the royal arsenal in 1748; they had been proved as usual; each having been fired three times at the elevation of $22\frac{1}{2}^{\circ}$, with powder equal to $\frac{3}{7}$ of the weight of the shot at the first round, $\frac{2}{3}$ at the second, and a charge equal to it in weight at the third. After the proof, the bores of the four guns were perfectly smooth and without the least flaw. They were then filled with water, and three out of the four having stood this new proof, were received and named *Argos*, *Hebor* and *Epirus*: they were used several years at the battery, and gave excellent practice; for after having been fired more than 1000 times, their bores were as smooth as at first: the windage of the shot was some years in the ratio of 20 to 21, and in others of 22 to 23. The fourth gun was rejected because some drops of water oozed through under the left trunnion; a small chamber was afterwards made at the bottom of the bore of this gun, and the first vent being stopped, another was drilled corresponding to the top of the chamber; it was in 1749
fired

fired 256 times in three days from a horizontal platform ; the charge was each time $4\frac{1}{4}$ lb. of war powder put into flannel cartridges ; two gunners gave five strokes to the wad over the powder, and three to that over the shot ; the windage of the shot was as 16 to 17, the bore having been made unnecessarily wide. The shot were projected in a good direction, and no alteration was visible in the bore, or at the part where the water had oozed through.

47. To these several experiments may be subjoined a particular observation made in 1737, on the occasion of an order given by the KING, to carry on practice in all the garrisons. In the CITY of VALENTIA, they made choice of a long 6 pr. which had been cast at PAVIA in the preceding century with the arms of SPAIN and bouched, a proof of its having been frequently fired ; the bore was perfectly straight and smooth, except some inequalities at the bottom, which did not however hold the teeth of the searcher. This gun was each time loaded with $1\frac{1}{4}$ lb. of powder with the ladle, and twenty-four rounds fired daily in $3\frac{1}{2}$ hours from a horizontal platform ; 60 shot larger than ordinary were picked out equal in weight and diameter and sufficiently smooth ; they served during the whole summer, being dug out of the butt which was in the plane of the battery : the windage of the shot was as 35 to 36 ; the wads were of twisted hay and rammed as usual. At the close of the practice for the season, the gun was carefully examined and found after 630 rounds not to have sustained the least injury ; the practice had been very good, since at the distance of 300 yards, a fourth at least of the shot had struck a target 3 feet in diameter, and the rest gone very near to it.

48. From these premises may be inferred *the necessity of making gun-metal so hard and tenacious, that on combining these two physical qualities with the thicknesses of metal*, artillery may be sufficiently strong, light and manageable (32), and that by judiciously using moderate charges, the advantages of firing with exactness and execution, and of preserving the guns already insisted on in the Treatise on Powder, may be fully obtained.

C H A P. III.

OF THE CAUSES OF SHOT STRIKING AGAINST THE
BORES OF GUNS.

49. **W**HEN the metal is so hard as even to prevent the formation of orbicular cavities in the bore, the shot may strike against the sides of a gun that is improperly constructed or served. In the preceding experiments the trunnions were properly placed, the bore exactly cylindrical, the wheels of the carriage of equal height and moved on an even platform, and the shot had been carefully selected: but if the bore be not perfectly straight, or the motion of the gun be the least irregular while the shot is passing through it, or the shot be not spherical, it must strike the sides whenever the wads do not closely confine it; and, of course, produce a cavity deep in proportion to the hardness of the metal, the actual velocity of the shot at the instant of percussion, and the angle of incidence under which it strikes.

50. That the shot in passing along the gun may be closely confined by the wads may be inferred from the following observation.

1. The three guns (43) had defects sufficient to occasion every shot to strike against the sides, but this seldom happened during the first hundred rounds; and though at length the bore was so much damaged as to produce a violent shock at each discharge, yet there was no new appearance for several rounds.

2. In other experiments the shot being rough, in a single round cut the bore in a right line for a considerable length; an effect not easily to be accounted for, unless we suppose the shot to be so closely confined by the wads, that it could neither roll nor change its direction. As the wads were of twisted hay, it follows that if they were always made of a soft, in preference to a hard substance, they might sometimes prevent the shot from damaging the bore, if its tendency to strike against the sides be occasioned by the obliquity of its direction.

51. The

51. The shot (43) were sometimes unconfined, and caused in a single round cavities and other flaws, deep in proportion to their obliquity: this occurs when no wad is used, as in firing with red-hot shot, à ricochet or in very quick firing in the field.

52. Guns are cast either solid or with a core; which is of a cylindric form. A bar of iron, supported by two uprights, placed at proper distances from each other, is covered with well tempered clay; and when equal in diameter to the gun intended to be cast, is heated: it frequently happens that the work-men by making the heat too violent bend the bar in the middle, particularly when it is made thin as for 4, 8 and 16 prs. In casting guns with a core thus bent, the bore must be crooked; which defect it is afterwards impossible to remedy with the boring machine, without enlarging it beyond the proper calibre. The officers of artillery having in 1759 examined forty-six 8 and 16 prs. cast with a core, found twenty-two of them bent at the distance of 12 to 13 diameters from the muzzle; the curvatures being in some $\frac{1}{12}$ of an inch, and in others $\frac{2}{12}$. By casting guns solid and boring them afterwards, these inconveniences are avoided, and the bores are perfectly cylindric and concentric, if the machine has been accurately constructed.

53. One of the greatest defects incident to a gun is, when the trunnions are placed too near to the centre of gravity. In guns of this construction, the breech has a tendency to fly upwards, which renders the firing irregular and shortens the range, as the shot often strikes against the upper part of the bore, the movement of the breech is more violent when the coils are made of elastic wood. There are other irregularities of movement even in guns constructed on the best principles, owing to the unequal height of the wheels of the carriages or the unevenness of the ground or platform.

54. Shot which are rough or not spherical, or that have excentric cavities are unfit for service. Irregularity of figure or unevenness of surface are sufficient to change the direction of a shot, as daily experience testifies; the observations already made on moving bodies will explain why internal cavities not concentric with the shot, must produce similar effects. If the shot encounter and pass over any small extraneous body in its passage along the plane of the gun, its primary

many direction will be altered, and it will pursue a fresh one communicated to it by the shock against the side of the gun,

C H A P. IV.

OF THE WINDAGE OF SHOT.

55. **T**HE hardness of bronze and iron, and the great difficulty of making cannon shot perfectly smooth and spherical render it almost impossible that iron shot should be made to fit a gun, with as much justness and precision as leaden bullets fit carabines: it is necessary therefore to allow what is called *windage*; and for that purpose to make the calibre of the gun greater than the diameter of the corresponding shot: the proportion between them must be such as to allow for any little unevenness in the bore of the gun, or on the surface of the shot, and to admit of its being drawn out by the ladle, or other means, if by accident any extraneous body be lodged in the gun.

56. If fired powder followed a constant law, the windage could be reduced to a fixed rule (55), so as to guard against all contingencies; but as this law is subject to great varieties, it is necessary to examine how far the increase or decrease of windage contributes to the more sudden explosion of the powder. Among the many experiments made in the *Treatise on Powder*, to demonstrate the existence of these modifications, there is one (III) which shews how much the force of powder in musquets is affected by the size of the vent; the following experiment proves that its inflammation and effects are also modified by the windage of the shot.

57. In the month of July 1759, the COMMANDER DE VINCENTI, colonel of artillery, made the following experiments with two 16 prs. of the same weight and length, but of different calibres: the calibre of A was divided into 813 parts, and that of B into 819 of the same parts; the guns were fired horizontally mounted on their carriages upon platforms perfectly horizontal. The shot were of two kinds, and grazed on an even piece of ground about 5 feet below the axis of the gun; the shot of the first kind had the diameter = C divided into 784 of the above mentioned parts, and weighed $\frac{1}{2}$ lb. more than the proper weight; the diameter = D

¶ D of the second weighing $\frac{1}{8}$ more, was divided into 774 of the same parts. Common grained powder was used; the charge was 4 lb. 2 oz. put into flannel cartridges in order to collect it exactly in the same manner at each discharge: the wads were of junk; two gunners gave three strokes with a rammer to the one over the powder, and two to that over the shot: the following table shews the result;

		Length of Range.		
		Of the Gun A.	Of the Gun B.	
		<i>No. of Rounds.</i>	<i>Yards.</i>	
With Shot of Diameter = C	}	1	*188	249
		2	198	*197 $\frac{1}{2}$
		3	196 $\frac{1}{2}$	224 $\frac{1}{2}$
		4	198 $\frac{1}{2}$	245
		5	*224 $\frac{1}{2}$	248 $\frac{1}{2}$
		6	197	*213 $\frac{1}{2}$
With Shot of Diameter = D	}	1	221 $\frac{1}{2}$	199 $\frac{1}{2}$
		2	*193	*213
		3	226 $\frac{1}{2}$	199 $\frac{1}{2}$
		4	223	199

After the firings, the bores were as smooth as before the experiment, so that the ranges had not been affected by the shot striking against the sides.

58. On comparing the calibres of the guns and the diameters of the shot, the following are in round numbers the proportions of the windage;

With shot of the first kind. With shot of the second kind.

A : C :: 28 : 27 A : D :: 20 : 19

B : C :: 23 : 22 B : D :: 18 : 17

On placing according to these proportions the number of rounds in two distinct columns; comprehending in the one the irregular firings marked with an asterisk in the preceding table, but excluding them entirely from the other; we obtain the following medium;

MEDIUM

MEDIUM OF RANGES.

Proportion of windage.		1st. Col. including the irregular firings. <i>Yards.</i>	2d. Col. excluding the irregular firings. <i>Yards.</i>
28	: 27	200	197
23	: 22	233	247
20	: 19	216	224
18	: 17	203	199

From this table of comparisons it may be inferred ;

1. That when these guns are fired as above (57) the shot has the greatest velocity when the windage is in the ratio of 23 : 22.

2. That this proportion is the best, since not only the initial velocity is the greatest, but the percussion of the shot against the sides of the gun is avoided.

3. That any deviation from this proportion diminishes the initial velocity.

59. On applying these proportions (58) to a fixed diameter, as to that, for instance, established for 16 prs. supposing the calibre of the guns be to the diameter of the shot, as 23 to 22, it would be found :

1. That on firing from these guns shot of a less diameter, viz. those of $15\frac{1}{2}$ prs. the initial velocity would be diminished by $\frac{1}{17}$.

2. That with shot of 15 prs. it would be diminished nearly $\frac{1}{7}$.

3. That with shot of a larger diameter, viz. of $16\frac{1}{2}$ prs. the loss of velocity would be about $\frac{1}{7}$.

60. By order of the King an invariable rule is laid down for all natures of artillery and shot ; their calibre is precisely determined, and directions given for ascertaining whether new shot and guns have been cast agreeably to the proportion therein established ; to avoid as much as possible the inconveniencies resulting on service from want of accuracy in this particular. There was formerly much confusion on this subject ; especially when the guns were nearly of the same calibre, as 15, 16 and 17 prs. but to take away all possibility of mistake in future, the calibres of our guns were fixed

fixed in 1726, at 32, 16, 8 and 4 pounders. Notwithstanding every precaution be taken to observe the order in its full force, shot are sometimes received which differ in diameter from the established standard (59). Shot of this kind may be used when it is not necessary to project them with the greatest initial velocity; as, for instance, when the besieged fire against the first works thrown up by the besiegers, or to dismount their artillery; and in ricochet firing, or with hot shot.

When there is a number of shot of different diameters, they should be put into separate piles; as by using them indiscriminately, it will be impossible to fire with precision or effect.

61. We learn from the history of artillery, that it has frequently been a subject of discussion among professional men, *what is the proper degree of windage for preventing the shot from striking against the sides of the guns*, which is attributed to the want of a just proportion between the calibres of the guns, and the diameters of the shot; and after long consideration, some concluded that it was owing to the allowance of windage being too great; others to its being too little.

The erroneous idea, that fired powder converted itself into rays of fire, which in their movement followed the law of solar rays, made them imagine in the last century that the figure of burning glasses was the best for the chambers of mortars. The same opinion led them to believe, that shot were impelled by the action of the rays in an oblique direction, if the vents were placed on the upper part of the cylinder, and to obviate this, they made small chambers at the bottom of the bore: but experience has proved, that the percussion of the shot against the sides of the gun, is owing neither to the windage nor to the situation of the vent; since in guns of the same calibre and with equal windage, some have sustained no injury from repeated firings, while others have been unserviceable in a few rounds.

62. The only property of windage is to facilitate the movement of a body lodged in a gun, in whatever direction it be impelled. The experiments (45, 46, 47) prove that without any regard to the proportion of windage, no damage ensues to the bore of the gun, nor is the shot thrown with less justness if the metal be sufficiently hard, if there be no irregularity of motion at the discharge, inaccuracy in the bore of the gun, nor defect in the shot. It results also (42, 43, 44) that

that if the gun have any of the defects mentioned in the preceding chapter, the shot will strike against it, whatever be the windage; but with this difference, that if the shot begin to move in an oblique direction, the less the windage and the longer the bore, the more frequent will be the shocks; this is too evident to need illustration.

63. Our theory of the inflammation and explosion of powder destroys every idea of rays of fire (61), and proves that the greatest force obtained from equal quantities of powder burned in vessels of different figures is in that where all the powder is collected the nearest to the vent, by which means a greater number of grains are fired; or where the fire of the first-generated fluid is reflected which increases the intensity of the heat, and produces more fluid in a given time; or, *cæteris paribus* from a proper combination of these two circumstances: hence, curvilinear chambers in mortars, particularly spherical ones, causing a quicker ignition, ought to give longer ranges than cylindrical chambers. To prove by a simple experiment that the property which burning mirrors have from their figure of concentrating the solar rays, has no effect in increasing the force of powder fired in a vessel of a similar figure; two 16 prs. were constructed on purpose at TURIN in 1730. (Pl. 1, Fig. 3) A parabolic chamber CAD was made at the bottom CD of the bore FCDG of one of these guns, the axis of the parabola was in the triplicate ratio of the calibre of the gun, the vent corresponding to its focus: the other gun was of the same weight and length, its bore cylindrical as FKLG, with the vent placed at the bottom. These two guns were charged with equal quantities of powder, which exactly filled the parabolic chamber and were laid at 3° of elevation; the gun with the cylindrical chamber ranged 414 yards farther than that with the parabolic chamber.

C H A P. V.

OF THE FIGURE AND LENGTH OF THE BORES OF GUNS.

64. **O**UR ancestors wishing to derive every possible advantage from the use of artillery, fixed certain dimensions for the construction of their guns, and established rules for their weights and calibres; which gave rise to the custom among the ITALIANS of distinguishing guns equal in length of bore and calibre, but differing in weight, into heavy and medium artillery.

WEIGHTS OF GUNS.

Nature of Guns.	Heavy Guns.			Medium Guns.		
	<i>Pr.</i>	<i>cwt.</i>	<i>grs.</i>	<i>lbs.</i>	<i>cwt.</i>	<i>grs.</i>	lbs.
32	65	3	16	54	3	18
16	37	2	2	32	0	3
8	20	0	15	17	1	15
4	10	3	26	9	0	19

The heavy artillery is intended for operations that threaten to be of long duration, as the sieges of fortified towns well provided with troops and stores.

The medium artillery is destined to march with armies, and be used in affairs that must soon be terminated; as general or partial engagements, attacks of posts or intrenchments, assaults of towns, houses or villages.

65. The ordinary figure of the bores of guns is cylindric; the length contributes to a certain point to increase the initial velocity of the shot, and give longer and juster ranges. (Treatise on Powder). The length of the battering guns now in use, is not sufficient to project the shot with the greatest initial velocity; but if they were made longer and larger charges used, they would become extremely unwieldy: moreover, experience has proved that these very long guns do not throw their shot with justness; and the shocks against their sides, particularly near the muzzle, are more frequent and violent when charged with modern powder, which is

considerably stronger than that used formerly: the charges then being necessarily larger, occupied a greater space in the length of the bore. Cannon not to be injured by long firing, and to project their shot with justness (9), should be shorter than the guns anciently were: but excess on this side is to be equally guarded against, as on the other; for short guns of large calibre soon damage the embrasures; the initial velocity of the shot, the length of range, and effects on the object are diminished; and there is more probability of error in pointing short guns than long ones.

66. After the various opinions that have at different times been suggested on the proper length of guns, intended to fire through embrasures, all nations seem to have adopted with little variation the following proportion:

Nature of Guns.		Length of Bore.	
Pr.		Feet.	Inches.
32	—	10	0
16	—	9	6
8	—	8	6
4	—	6	9

This is the common length: when longer they are termed *long*, and when shorter, *short guns*. (Pl. 1, Fig. 2.) Set off on the line BF of a gun of any calibre three diameters of the bore, for the charging cylinder; divide the remainder CF into four equal parts at H, G, K, and make FL = FK: BL may be then considered as the greatest length that guns should be ever made of, to avoid the inconveniences pointed out in the preceding paragraph: and if from BF, KF be taken, the remainder BK is the least length for guns with cylindric bores.

67. When 32, 16, 8 and 4 prs. (66) are loaded with the usual service charges of powder and rammed with equal force, the initial velocities will in short ranges increase in proportion as the calibres diminish; but in long ranges, the shot from the resistance of the air will be projected farther from guns of large than of small calibre, in proportion to the distance; as appears by the following experiments. The guns were loaded as above directed, and the shot severally fell on three spots below the plane of the battery.

NUMBER

NUMBER OF YARDS BELOW THE PLANE OF THE BATTERY.

Nature of Guns.	1 st .	2 ^d .	3 ^d .
	1 Yard.	30 Yards.	190 Yards.
	Length of Ranges.		
Pr. 32	219	1045	2023
16	229	1056	1961
8	233	1050	1835
4	238	1003	1703

From the experiments made in the Treatise on Powder, (101) and others related by some FRENCH Authors to have been made at DUNKIRK; it results that *guns of the largest calibre give the longest ranges*. The experiments at DUNKIRK were carried on with 24, 16, 12, 8 and 4 prs. French guns laid at 45° of elevation; the charges of powder were equal to $\frac{2}{7}$ of the weight of the shot; and the length of the guns was 11 feet.

Nature of French Guns.	Length of Range.		
Pr.	Yards.		
24	—	—	4817
16	—	—	4324
12	—	—	4002
8	—	—	3552
4	—	—	3254

68. Hence it may be inferred that common guns of large calibre will range farther than long guns of small calibre; the latter are principally usefull against objects not too distant or solid: of this kind are long 8 and 4 prs. which are placed to great advantage in fortresses situated on plains or gentle eminences, to keep the enemy in respect and command the environs of the place; as fewer men are required to work them, and much ammunition is saved.

69. Long guns of large calibre should only be used in cases of necessity; some 32 prs. for instance, may be placed in works situated on mountains to molest the besiegers, when they can form their magazines and park of artillery out of the reach of smaller guns; and in maritime towns to keep

the enemy's vessels at a distance. Formerly instead of long guns, they used guns of the common length with spherical chambers at the bottom of the bore, larger in diameter than the calibre of the gun; they sometimes ranged farther than long guns; but these chambers should be reprobated on every other occasion, from the great difficulty of loading them: they must be very strongly reinforced, the trunnions placed in such a manner as to prevent any irregular movement at the discharge, and the carriages made to admit a higher elevation than those of the common construction.

70. Short guns of large calibre and cylindric bore may be planted on works, where it is necessary to have guns, but not room sufficient for the recoil and management of longer guns: but as they are destructive to the embrasures, howitzers or *carronades* are preferable to them, if from the point where they are placed, it is only intended to fire case shot, for they do not damage the embrasures so much as short guns; their charges being less in proportion to their calibre, and the diameter of the chamber less than the diameter of the bore.

71. An army destined to act in a champaign country should have a train of artillery (64) composed of medium 8 and 16 pounders. In case it may be necessary during the campaign to occupy a post or attack a town surrounded with occasional works or single walls, some guns of large calibre should be deposited in a secure place within reach of the army. The trunnions of medium guns should be placed nearer the muzzle, which would render them firmer on their carriages and more regular in their movements.

72. When the scene of action lies in a mountainous country, where from the badness of the roads the transport of carriages is almost impracticable; a few pieces of iron ordnance may be placed in the posts of the greatest importance; and the train of artillery left in the rear, till local circumstances or the future operations of the campaign make it necessary to bring it up. Should there be a necessity of having some short guns (66) for opening a passage through defiles, &c. the diameter of the chamber should never exceed the calibre of the gun, as they are very uncertain in their effects.

In the last century very short and light guns of different natures and less in calibre than 4 prs. were invented for accompanying troops through rough and difficult countries; but experience has shewn that they do not produce the advantages

advantages their projectors promised; and that, independent of a heavy and useless expence, they cause much embarrassment in the disposition and movements of an army.

73. Guns cast of iron of a very tenacious quality may be used in places of small importance, field works and those parts of permanent fortifications that cannot from their situation be obliged to maintain a very long cannonade: they are generally two diameters shorter than brass guns of the same calibre, it having been found by experience that when very long the muzzle is soon injured; wherefore *there are no long guns of iron*. Iron guns for ships of war are made nearly of the length of short brass guns (66), for the facility of loading them within the port-holes to shelter the seamen from the enemy's musquetry; for though their initial velocity be less, that is looked upon as a matter of no great moment, since ships can approach near enough to each other to make the shot penetrate the sides.

74. In determining the length of the barrels of musquets, it was not considered which would impel the bullet with the greatest initial velocity, but which was best adapted to the different methods of fighting: for musquets that are too long or too short are equally inconvenient, and the soldier should *never be assured of the goodness and effect of his fire-arm* (7). Dragoons being destined to act occasionally, either as infantry or cavalry, are armed nearly in the same manner as infantry; while that the carbine and pistol of the horse being of no service on a charge, but only on detachments or skirmishes, the facility and ease of managing them on horseback are chiefly attended to.

75. Mortars in the first year that succeeded to their invention, were constructed of different calibres, figures, and dimensions, according to the various services for which they were designed: the bore of the largest was 20 inches in diameter, that of the smallest $5\frac{1}{2}$ inches; the latter were called royal mortars. The largest mortars at present do not exceed 15 inches; those of 13 inches are most commonly used.

76. From the interior figure of mortars, the elastic fluid generated in the chamber is dilated on passing into the chase; its pressure against the shell is still sufficient to give it a proper velocity, unless the charge be too small; as is seen in carro-nades and howitzers, which in respect to their interior figure may be compared to mortars with cylindric chamber. The irregularities of ranges of mortars fired under a larger angle than

than 15° may be owing to the bombardiers that load the mortar; or to the recoil not being in the direction of the range: the too great length of the chase is the cause of both these circumstances; for before the shell can quit the mortar, it has recoiled a space equal to half the difference between the diameters of the mortar and of the shell; the direction of the latter is then altered by striking against the mortar, which is frequently much damaged.

77. The chase should be so short that the bombardier may easily adjust the powder and the shell; and that the shell in quitting the mortar may not be able to strike against it, and alter its recoil. The chase of the largest mortars should be a diameter and half of the bore in length, which would greatly facilitate the loading: upon this principle the chase of small mortars might be longer: but as the striking of the shell against the mortar depends on the difference between their diameters, the length of the chase must in all mortars be proportionate to the diameter of the bore, the proper degree of windage having been previously determined.

78. From the most accurate experiments that have been hitherto made, it appears that mortars will be of the best proportion, when the length of the chase does not exceed a diameter and half of the bore, and when the windage is 23:22. If the windage be lessened, the chase must also be shortened, as in mortars used in proving powder; where very little windage being allowed, the length of the chase is only a diameter and a quarter of the bore.

79. The best length of the chase in mortars, for facilitating the operations of the bombardiers and preventing the shock of the shell, and the obliquity of the recoil being determined; it is necessary to have recourse to expedients to give the greatest initial velocity to the shells, which is often required on service without lengthening the chase: this is effected:

1. By constructing the chamber of such a figure that the powder being collected close to the vent, more of the fluid may be generated in equal times: the spherical figure is the best for answering this purpose, as has been explained in the Treatise on Powder.

2. By opposing a great resistance to the explosion of the powder, without increasing the weight of the shell, by which means more of the elastic fluid will be generated before it is in motion; this resistance may be augmented by placing a tompon of wood over the earth
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that is rammed upon the powder, and by pressing earth close round the tompon and the shell; the initial velocity will be thus increased.

3. By increasing the size of the chamber.

80. Stone mortars are used for throwing troops, workmen, &c. at sieges into confusion: the chamber is in form of a truncated cone, whose least base is towards the vent; they are fired with small quantities of powder, as with large charges the stones would spread so much that few or none would have effect. Their diameter should not be less than 15 inches, nor the chase less than a diameter and a half in length, that it may contain a sufficient quantity of stones: by increasing the diameter and length of the chase, they would contain more stones, and consequently be more destructive; but then from their weight they would be very difficult to transport.

CHAP. VI.

OF THE THICKNESS OF METAL IN FIRE-ARMS.

81. **T**HERE are two extremes to be equally avoided in determining the thicknesses of metal in fire-arms, the one is, making them too thin and light; the other, too strong and heavy: the danger arising from the first is too obvious to need insisting on; the second is comprized within certain limits. The metal proportionally distributed throughout the whole length of the piece, ought to be capable of resisting the forces which at each point tend to burst it; and of such a weight as to prevent any irregularity in the motion of the shot, that would materially affect the justness of the firing (9): we will endeavour to ascertain these limits.

82. No absolute and general rule can be laid down for the thickness of metal in guns, since several physical points are involved in the problem. In a gun of a given calibre, the thicknesses proper to resist the pressure of the fluid, may be known by firing it very strongly reinforced several times with the same charge; then thinning the metal and firing it again with the same charge; and thus successively diminishing the thicknesses, till they be so reduced that the piece burst at once in every point of its length. Such experiments cannot be
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conclusive in all cases, though made with the utmost accuracy; as there may be defects in the mass of metal, for which allowance cannot be made. To avoid such a tedious process, the scale of pressures of the fluid against the shot may be constructed; this method of resolving the problem is the most easy and simple: but the greater the distance of the point where the thickness of metal is determined from the place where the shot is lodged in the gun, the less exact will be the solution.

83. To enable guns to resist the pressure of the fluid, the thicknesses of metal must be determined from the scale of pressures. With respect to heavy artillery (64) several rounds should be fired from three or four guns, differing in length but of the same calibre as the guns whose thicknesses are sought, with the larger service charges; the wads rammed down with more force than with the medium charge; and the initial velocity of each shot measured. (Treatise on Powder.) To construct a scale for estimating the proper thicknesses of medium artillery (71), the largest charges should be used that the guns will bear, and the wads rammed with the same force as the wads of guns more reinforced and loaded with the common charge: it is essential to observe this, as from the different resistance of the wads, a considerable difference arises in the ordinate that expresses the greatest pressure of the elastic fluid, and successively in the other ordinates; as may be inferred from the fourth chapter of the Treatise on Powder, where the modifications of the elastic fluid in the cylindric bores of guns are considered. The initial velocities of the shot being measured, and a line drawn to express the scale of velocities in certain spaces, the scale of corresponding pressures may be found from this line by the method directed in the treatise on moving bodies. It should be remarked that the velocities of shot from guns of large calibre fired with large charges, are produced by the pressure and impulsion of the elastic fluid, which, generated at the bottom of the bore, acts with such force on the shot (37) as to communicate to it a constant velocity, which the second wad however strongly it may be rammed cannot destroy. The scale should then be parallel to the axis of the gun; and its distance from it equal to a right line drawn perpendicularly to the axis, expressing the constant velocity produced by the impulsion of the fluid.

84. This being premised; let a gun (Pl. 1, Fig. 4) $A B C D$ be cast of the same metal, calibre, and length as those of which the thickneses are sought, and its dimensions determined by a right line $C D$ drawn obliquely to $A B$, so that the thickness $A C$ of the breech may resist the pressure of the fluid; the thickness $B D$ at the muzzle will be much less. Suppose this gun (83) burst at the first round in any point between A and B , as at G ; should it burst in several places at once, most attention should be paid to the opening next the breech. Let $F G$ where the metal yields to the pressure of the fluid be thickened in the proportion of the tenacity of the bronze, heated by firing as much as it can be on service (35) to its tenacity when cold, and call it $= m$; then m expresses the proper thickness of metal at the point G of the length $A B$. It is essential to remark, that the fracture in G was occasioned solely by the pressure of the fluid, and not by the percussion of the shot against the sides of the gun, nor by any defect in the metal; as may be known by examination.

85. Let $H E$ represent the bore of a gun, whose thickneses of metal are sought; (Pl. 2, Fig. 5) draw the scale $L O Q R$ (83) of the pressures of the fluid deduced from the rectangular ordinates; make $E P$ equal $A G$ (Pl. 1, Fig. 4) and $P T$ equal to m ; then if $O P$ be the greatest ordinate of the scale $L O Q R$, from the point T draw $T Y$ parallel to $P E$ for the thickness of metal from P to E ; in order to find them from P to H make the following proportions; $P O : N Q :: P T : N V$, and $P O : H R :: P T : H X$, draw a line through the points $T V X$; then $Y T V X$ will be the scale of thickneses sought. But if $K L$ be the greatest ordinate, find $K S$ a fourth proportional to $P O$, $T P$, $K L$; and from the point S draw $S Z$ parallel to $K E$, in order to have the thickneses from K to E ; then $Z S T V X$ will be the scale of thickneses in the whole length $E H$ of the gun.

86. To apply this theory to a particular case; (Pl. 2, Fig. 5) let a 32 pr. be charged with 13 lb. 2 oz. of fine war powder, and the wads rammed so as not to diminish the volume of the powder. Let the proportion of tin in the gun-metal be $\frac{1}{8}$ and the gun be so heated as to fire powder; its greatest thickness in a state of equilibrium will be $K S$. If the gun be fired under the most favourable circumstances to the inflammation of the powder, that is, $n = 1200$ (33) the greatest thickness $K S$ ought to be $\frac{1}{8}$ of the diameter

diameter of the bore, and the least thickness $H X$ between $\frac{1}{7}$ and $\frac{2}{7}$ of $K S$. If the proportion of tin be $\frac{1}{7}$ the greatest thickness $K S$ should be $\frac{2.5}{3}$ of the diameter of the bore and $H X$ $\frac{1}{3}$ or $\frac{2}{3}$ of $\frac{2.5}{3}$.

87. the following consequence may be drawn from a consideration of the theorem 9962 $n r = m q$ (33):

1. That in two guns of equal calibre cast from a different composition, fired with equal charges of powder, and wadded in the same manner; if r and n be constant quantities, the thicknesses $= m$ at points equally distant from the bottom of the bore ought to be in the reciprocal ratio of the tenacity $= q$ of the different metals.

2. That in the same gun on altering the charge, as the pressures of the different points will differ from those produced by the first charge, the corresponding thicknesses should be in the ratio of the second pressures.

3. That in two guns of different calibres, if the tenacity $= q$ and the pressure $= n$ in points equally distant from the bottom of the bore, the same ordinate will express both; the thicknesses $= m$ of the two guns in the same point will be proportional to the radii $= r$ and thence to their calibres.

88. If the thicknesses of a gun correspond with certain determined circumstances; (Pl. 2, Fig. 6) as for example, if $A B C D$ be a 32 pr. of which the thicknesses $H H$, $K K$, $A L$ are as before expressed (86) and it be wished to determine in a gun $D C F G$ of a different calibre, the corresponding thicknesses $M M$, $N N$, $G P$, the problem may be easily solved by the conclusions drawn in the last paragraph, without having recourse to experiment: other problems also that are connected with the modifications of the fluid may be solved by the same method.

89. The rules here laid down for determining the thicknesses of metal in guns of cylindric bores would answer for every possible case, if the shot never struck the sides: but if in a gun thus proportioned, the shot should strike the sides, the metal would yield and the gun burst. These percussions of the shot produce in brass guns two different effects: they cause hollows in the inside, which are always perceptible whatever be the size of the gun; but the harder the metal, the less impression the shot makes: thus they cannot be avoided by adding to the thickness of metal, but may by increasing its hardness; but what is thus gained in hardness, is lost in tenacity.

tenacity. The second effect produced by the shot is the bulging or external swelling of the metal, the cracking and consequent ruin of the pieces: this depends on the combination of tenacity with the thickness of metal; and to prevent it, the thicknesses must be augmented. In iron guns, when the percussions of the shot are very violent, the piece bursts without any hollow being found in the bore, or any swelling on the outside: wherefore, if the tenacity of iron could be sufficiently increased without prejudice to its hardness, it would be preferable to any other metal.

90. To determine the thicknesses from the point T , (Pl. 2, Fig. 7) where the shot is lodged, to the muzzle of the gun, and prevent the metal from bulging; it is necessary to have the scale TLM of the velocities in the spaces TP , TC . The force with which the shot strikes the gun in any point as in V , is expressed by the product of the weight of the shot, multiplied by the corresponding velocity PL , and by the right sine of the angle of incidence KVA . If these shocks proceed from a constant cause, viz. an orbicular cavity in T , the point that the shot strikes is farther distant from T as the cavity is less deep, and the angle of incidence KVA becomes less. But if the shocks proceed from any adventitious cause, which alters the direction of the shot, and gives an irregular motion to the gun (53) then the angle of incidence may be greater, and the force at the different points V will be proportional to the corresponding velocity PL . That the thickness of a gun may be proportionate to the greatest shocks it can receive, experiments should be made with pieces of metal of the same quality as that of which the gun is cast; and the proper thickness at the muzzle to prevent its bursting or yielding in any manner to the shot determined. Suppose this thickness = BN , then $CM:PL::BN:VQ$; the line HQN will be the scale of thicknesses sought, and will cut in the point R the scale $SFRGD$ of the resistance to the pressures of the fluid (88, 89): therefore the line $SFRQN$ will determine the thicknesses throughout the whole length of the piece, capable of resisting the forces that tend to burst it.

91. In thus proportioning the thicknesses of metal to the force of the most violent shocks, the gun would be thicker at the muzzle than at the breech, and of course extremely unwieldy. But as these direct shocks can only arise from some very uncommon cause, and the accelerated pressures
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of the fluid against the shot, act in the direction of the axis; the thicknesses determined by the line R Q N, may be much diminished without any risque of bursting the gun. The following observations made on more than 100 guns that were rendered unserviceable by the shocks of the shot, may be adduced in order to ascertain some limits for this proportion. These guns in respect to thickness of metal, were of three kinds: the first were determined by a scale made from the diameter of the bore; the thickness at the breach was one diameter; at the end of the first reinforce $\frac{1\frac{1}{2}}{8}$; at the beginning of the second reinforce $\frac{1\frac{4}{8}}$; at the end of the second reinforce $\frac{1\frac{3}{8}}$; at the beginning of the chase $\frac{1\frac{2}{8}}$; and at the muzzle $\frac{9}{16}$. The guns of the second kind were in the same proportion, but the scale formed from the diameter of the shot, so that they were not so thick as the first kind. The third kind was as the second, proportioned from the diameter of the shot from the breach to the first reinforce; but, at the beginning of the chase was only $\frac{1\frac{1}{8}}$ of the diameter, and at the muzzle $\frac{6}{16}$. The least thickness of the swell of metal at the muzzle was, including the ornaments, $\frac{3}{4}$ of its diameter in the three kinds of guns. It was observed;

1. That in the guns of the first kind, a very violent shock caused neither crack nor bulge in whatsoever part it struck: the force and direction of the shock being gathered from the form and depth of the cavity.

2. That in the guns of the second kind, the shot having struck violently between the half of the chase and the muzzle, the metal bulged out; and at the succeeding round, the muzzle dropped.

3. In the guns of the third kind, bulges and cracks were observed at about $\frac{2}{3}$ of the length of the chase; and though the exterior of the muzzle did not appear the least altered; yet, at the next violent shock it dropped.

92. From the preceding observations (86) it may be concluded; that if the gun from A to G (Pl. 3, Fig. 8) has its thicknesses A C, G D = $\frac{1\frac{4}{8}}$ or the diameter of the bore, and B F = $\frac{9}{16}$; the right line D F, will express the thicknesses necessary to resist the forces that tend to burst the gun, viz. the action of the fluid at N, and every other point of the length of the bore, and the most violent shocks from the shot; provided that the swell of metal at the muzzle

zle be not less than $\frac{1}{16}$, and be for greater security connected with the muzzle astragal, by the convex line H L K. Gun-metal not being sufficiently hard to prevent the shot from making impression when they strike with great force against any part of the chase, it would be better, as a means of obviating this inconvenience in some measure, if the moulds were placed in a different position from what they are at present, with the breech up and the muzzle down, as in casting mortars: by this method the metal at the chase would be denser than at the breech, and of course more hard and tenacious. This with proper precautions, may be done whether the guns be cast solid or with a core.

93. Guns constructed on these principles (92) tho' sufficiently strong are defective in two points: they are too light, and consequently their motion being irregular, it is impossible to fire with justness; and there is a necessity for placing the trunnions too near the muzzle, that the motion of the breech may not be so violent as to render abortive every attempt to hit the object: from the latter circumstance also, they cannot enter far enough into the embrasures; which are very soon destroyed by the explosion of the powder. The best remedy for these defects is to reinforce the gun particularly at the breech, according to the proportions laid down in the first book of artillery: it will then be sufficiently heavy to prevent any irregularity even with the largest charges; the trunnions may be placed nearer the breech, and the muzzle will enter farther into the embrasures.

94. The dimensions (7, 8, 9,) for the body of the piece being thus determined; the proper position of the trunnions, cascable, base-ring and dolphins must be ascertained. The trunnions should be placed between the centre of gravity and the muzzle, that the gun may be rather heavier at the breech, without rendering it difficult for two gunners to raise it with their handspikes, for the purpose of laying it, and that it may enter far enough into the embrasure; their diameter is equal to one calibre. The position of the dolphins should be such, that when the gun is suspended by them, the breech may preponderate a little, that by taking hold of the cascable it may be the more easily managed. It is customary to engrave on the upper part of the gun, the arms of the king and the master general of the ordnance, with inscriptions, trophies, &c. which obliges the founders to raise the base-ring, and the swell of metal at the muzzle higher

higher than the ornaments, that the visual ray may pass over them. If the base ring be higher than the swell of metal at the muzzle, the visual ray will cut at a small distance the axis of the gun produced; this will make it easy to point at distant objects that are not much elevated above the plane of the gun, when there are no higher objects behind them to fix the eye, as often happens in the attack of citadels. The junction of the muzzle to the neck, will considerably reinforce the gun at that part. The metal at the bottom of the bore is much thicker than at the other parts, the better to resist the explosion: the formula (Philos. Instit.) for measuring the resistance of the bases of cylinders, will exactly ascertain the quantum of this excess.

95. A gun mounted on its carriage is supported by the trunnions, and resists the explosive force of the powder by the tenacity of the metal of which it is cast: the momentum of this force is expressed by the product of the weight of this part of the gun, into the distance from the centre of gravity to the point of support. On applying this principle to our theory (Philos. Instit. 233) it will appear that the metal heated as much as it can be on service is greatly superior in tenacity to the different forces that tend to bend or burst it.

Some guns that had been rendered unserviceable at the attack of SAVONA, were ordered to be brought to PIEDMONT: for the facility of transport they were sawed in pieces, which gave an opportunity, previous to the operation, of ascertaining experimentally the truth of the foregoing principle: A 32 pr. constructed on the same proportions as guns of the first kind (91) was fixed by its trunnions upon a rock; the breech was solidly built into a wall, so that from the trunnions to the muzzle it was suspended in the air; the part not fixed in the wall was heated by a large wood fire, till a stick on touching it smoked, and instantly blazed; a much greater degree of heat than guns ever acquire in the heaviest and longest cannonades. The gun being thus heated, two workmen gave more than 100 strokes with a sledge hammer on the swell of metal at the muzzle, with all their might, without doing it the least injury: from this experiment where the force employed to overcome the tenacity of the metal was so great, we may infer that the chase is capable of sufficient resistance.

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95. From these premises, the following conclusions may be drawn with regard to heavy artillery.

1. That long guns ought to be cast of a harder metal and more reinforced from the middle of the chase to the muzzle, as in that part guns of this nature are most exposed to be struck by the shot.

2. That short guns intended to be fired with large charges should be reinforced as much as guns of the common length, since they have equal forces to resist: for example, if $A T$ be the length of a short gun that has the same thickness of metal as the common gun $A B$; (Pl. 3, Fig. 8) supposing $A B$ to be sawed asunder in T , the swell of metal should be placed at T , and the trunnions fixed nearer to the breech, to make it preponderate.

3. If the medium charge be the largest ever used for these guns, and be rammed in the common method, the thickness $A C$ may be $\frac{1}{8}$ of the calibre, and the other thicknesses diminished from the breech to the muzzle in the proportion of common guns.

4. If these short guns are only intended for firing case-shot without wadding, the calibres may be increased and the thicknesses considerably diminished. A cylindrical chamber made at the bottom of the bore, will lessen the charge of powder and of course preserve the embrasures.

97. If guns (71, 72) containing $\frac{1}{8}$ of tin only be fired with the medium charge, and the first wad receive five and the second three strokes from two gunners; the thicknesses of metal may be so proportioned that the weight of medium guns may be the same as before expressed (64); and in short guns of cylindrical bores (66, 72, 96, No. 3) they may be diminished, if the charges be lessened or the wads compressed with less force.

98. In short guns and even in medium guns, (6, 7, 8, 9) the trunnions should be placed nearer to the muzzle as they are never intended to fire through embrasures: if this be deemed inexpedient, some method may be devised of fixing the breech to the carriage. Many inventions have been proposed for this purpose, of which the artillerist may conceive an idea from the models in the royal schools. By placing the trunnions nearer to the breech it will preponderate less, and the gun be more easily depressed or elevated.

elevated. The visual ray should pass over the ornaments and intersect the axis of the piece produced not far from the muzzle (94). From the construction of these short guns, there is a very great difference between the diameters of the base-ring and muzzle, which being considered by some artificers as a defect, a projection was made upon the base-ring of some guns cast in the last century, and pierced with holes; which gave the gunner a free and uninterrupted view along the gun, and enabled him to lay it with precision to very distant objects: others have imagined a moveable instrument pierced with holes, the base resting vertically upon the base ring, by means of which the gun could be laid at different elevations as the visual ray passed through the holes along the gun towards the object; other holes were made horizontally to correct the direction in case the preceding one was wrong: but as artificers may supply the want of these instruments in a very simple and easy manner, it is unnecessary to dwell any longer on the subject.

99. The thicknesses of metal in mortars are the same as were used by our ancestors for a long series of years. The theorem $9962 nr^2 = 2rm + m^2 \times q$ will shew that the thickness at the breech in mortars with spherical chambers is sufficient to resist the strongest pressures of the fluid, when the chamber is filled with fine war powder confined by a topmion of wood, and the shell surrounded with earth strongly compressed. The theorem (Philos. Instit.) for the bases of cylinders will serve for mortars with cylindric chambers, but as the modern powder is much stronger than that used in the last century, the thicknesses may be increased $\frac{1}{8}$, and then the mortars will be sufficiently strong for every purpose.

100. In mortars fired with the largest charges, the elastic fluid generated in the chamber is considerably dilated on passing into the chase; the scale of pressures therefore will very suddenly approach the axis of the mortar; whence no damage can ensue if the thicknesses have been properly proportioned. Mortars cast on these proportions, of metal containing $\frac{1}{8}$ of tin, resist the pressure of the fluid, and every other force that tends to destroy them, as the impulsion of the fluid, and the percussion of the shell: but if the chase be not united to the breech by a considerable thickness of metal, it will be broken off, or at least incurvated. If the metal contain $\frac{1}{8}$ of tin, the impression of the shells will be less; but the thickness must be increased.

101. Mortars are moreover liable to an accident that defeats every good purpose expected from the use of them; viz. the bursting of the shell in the mortar, or immediately on quitting it. This may proceed from a defect in the fuse, the negligence of the bombardiers in loading the mortar, or not priming it before the fuse is set fire to, or from a hole in the shell through which the fire from the explosion communicates with the powder. When from either of these causes it bursts in the mortar, it generally renders it unfit for further service. Increasing the thickness of metal in mortars, whatever be the motive, will be always advantageous; provided they are not too unwieldy: since in all fire-arms solidity adds to the justness of execution.

102. The trunnions if equal in diameter to the semi-diameter of the mortar will be sufficiently strong: they should be let into the bed throughout the whole length, or at least the points of support should be near the breech of the mortar; for when they are supported only by the extremities, they are liable to bend and break, as has frequently happened.

103. Mortars are made of different diameters according to the uses for which they are designed; those from 15 to 20 inches, are for throwing stones to retard the progress of the besiegers, and are never fired to a greater distance than 350 yards, as in longer ranges, the stones are too much scattered to do execution; their chambers therefore are in form of a truncated cone, with the greatest base towards the muzzle and contain but little powder. This mortar having no great effort to sustain, may be less reinforced: the thicknesses allotted for stone mortars will answer for every purpose in which it is used, as in throwing fire balls, carcasses, &c.

104. Thirteen inch mortars, with chambers spherical, elliptical, or in form of a pear, are designed for throwing shells to destroy magazines and other military edifices. If it be wished by increasing the range to add to the effects of the shell by the height of the fall, the spherical chamber is the best; but then it is necessary to increase the thicknesses of metal, to insure proper resistance and solidity. In the last century, 20 inch mortars were made with curvilinear chambers to fire from very great distances, that the shells might fall with irresistible force on magazines and other buildings; but their excessive weight has caused them to be disused in land service: even 15 inch mortars are very difficult to work

upon batteries, and the shell is very unweildy; they are principally used at sea in bomb-ketches, for the purpose of bombarding maritime places from great distances.

105. Ten inch mortars are very useful in attack and defence, for dismounting the enemies cannon and demolishing their works and buildings; they are not expensive and easily worked: the best form for their chamber is cylindric; it being of great importance that the firing from them should be very exact, they should be well reinforced to enable them to resist the shock of the shell and increase the solidity. Mortars have been likewise constructed of $5\frac{1}{2}$ and $4\frac{3}{4}$ inches in calibre; they range but a short distance and require the greatest accuracy and precision. It may be inferred from these remarks that mortars cannot be made lighter without considerably diminishing their effects.

C H A P VII.

OF CASTING ARTILLERY.

106. **T**HERE must be a combination of several circumstances to insure success in casting artillery: unless the metal be of good quality and properly proportioned, the guns may be defective, perhaps useless; and though much depends on science and experience, yet chance has frequently no small share in the event. The principal motive for examining and subjecting guns and mortars to various proofs before they are declared fit for service, is the uncertainty under which the most able founders have at all times laboured on this head; and among the several experiments made to ascertain their goodness, there are some which would be highly absurd, were they not intended for the detection of artifice or ignorance.

107. To succeed in casting guns and mortars there must be:

1. A perfect connection between the metallic particles; which depends on the degree of heat and fusion when the metal is run from the furnace into the moulds.
2. An exact mixture of the several metals.
3. A most accurate preparation of the moulds.
4. No vacuity in any part of the bore of the gun, that may render it dangerous to the men that serve it.

108. In disposing the metals in the furnace, the first step is to weigh them separately, in the proportions previously determined and place them near the furnace. When it has been heated for four or five hours, it is cleaned and some cakes of copper put in at the mouth; which being fluxed spread over the surface of the hearth; the rest of the copper is then gradually introduced till the whole be fused; and to facilitate it some tin is thrown in (24). When the metal is thoroughly melted, the scorizæ are scummed off with a ladle: if brads form any part of the composition, the proper portion is put into the furnace and stirred with the ladle, the better to mix it with the copper. When these substances have attained a proper degree of fusion, the tin is thrown in and the fire increased for half an hour and more, till the whole has acquired the degree of heat and liquidity judged necessary; the scorizæ then swim on the surface, and are in part dissipated with a luminous appearance; the remainder is scummed off. The mixture is then well stirred and the furnace opened to let it run into the moulds.

If no brads be used, the proper quantity of tin is put into the furnace after the scorizæ have been drawn away; and when the mixture is sufficiently liquid, it is stirred and the furnace opened.

109. In recasting old guns, mortars, &c. the tenacity and hardness of each piece before it is put into the furnace should be ascertained, in order to find what quantity of copper or tin should be added to make it of a particular quality: some of the new composition should be fused and proved to know whether it is of a proper tenacity and hardness. If it be found that the old metal is unfit for the purpose, it should be absolutely rejected; or only used in casting stone mortars. Being thus assured of the goodness of the new composition, let the furnace be heated; as the metal must necessarily remain for a longer time in fusion, such a calcination may take place as to destroy the proportion between the tin and copper (24); on which account a quantity of tin should be added to make up for what may have been lost: this has always been deemed necessary, and the proportion is fixed at 1 or 2 in the 100, according to the time that the bronze first put into the furnace remains in fusion. But experience and careful observation of the fusion of metals will best enable the founder to decide what quantity of tin should be added: A bright flame denotes that the tin is in abundance; a red

flame that it is in small quantity, and a green flame that it is almost dissipated. Before the furnace is opened the composition should be stirred; and if there be the least reason to be dubious of its quality, a little should be taken out with an iron ladle, and when cold be carefully proved. If the recast metal contained any brass, the zinc will be totally dissipated (23); therefore when brass should form any part of the new composition, a proportion must be added before the furnace is opened, not exceeding (28) half the quantity of tin.

110. The furnace is heated before the copper is put in (108) to give it the necessary degree of heat which it would not otherwise attain; for if it were put in before, the part of the hearth covered by the copper and the copper itself would never be properly hot; therefore not to lessen the degree of heat in the furnace or in the metal already fused, small quantities are put in at a time, that the liquid matter may spread equally over the whole surface. The brass and tin are put in when the copper is thoroughly fused, and just before the furnace is opened, to avoid as much as possible the sublimation of the zinc, and the calcination of the tin (22, 23, 24); they are then well stirred, since the motion produced by the fire is not sufficient to mix them thoroughly.

When old ordnance containing very little tin is to be recast, the founders generally put two or three large guns into the furnace, in such a position that they may cover as little as possible of the base, and a moderate fire is kept up for five hours that the furnace may be well heated before the metal begins to fuse. If on the contrary, the metal to be recast contain much tin, as bell-metal; the founders knowing that the tin accelerates the fusion (24) put a great quantity into the furnace before the fire is lighted, taking care so to arrange the pieces that the flame may penetrate between them before they melt; and the heat is kept moderate till the fusion begins; this in the language of the founders is called *putting them into a bath*.

111. The calcination of copper and tin may be partly repaired by the introduction of phlogistic substances, but it is not judged expedient to have recourse to this method in large furnaces: the founders contenting themselves with dropping, while the melted matter is running into the moulds, some unctuous substances, as fat, suet, &c. to prevent the calcination.

112. The furnace should not be opened (108) till the metal has acquired a proper degree of heat : for if it be too hot when run into the moulds or not hot enough to take the form, the guns will in either case be defective. Tin being a solvent to copper, it would seem that these two metals should form a perfect mixture when in fusion without afterwards separating ; as is the case in the small processes of the chemists and metallurgists : but experience shews that the effects are different in the more extensive operations of the foundry : since in guns the metal is commonly harder at the breech than at the chase or muzzle, for these parts being nearer to the top of the mould contain less tin than the breech does. If from metal of the same quality and liquidity small and large guns be cast ; in the former there will be very little difference between the tenacity and hardness at the breech and the other parts ; but in the latter it will be very sensible from the longer space of time that the melted metal takes to congeal in a large mould than in a small one : Whenever the founders neglect to make a perfect and equal connection between the different metals, there are always particles of tin found unmixed with the copper, particularly in large guns ; some are seen almost pure on the outside of the guns in a long serpentine ridge, others forming small lumps in the copper : the same circumstance occurs in vents that have run, some being irregularly enlarged ; while in others cast at the same time, there is no apparent defect. These irregularities proceed in some guns from cavities contiguous to the vents ; while in other guns no such cavities are visible.

Among the different guns that were examined, there was a 4 pr. that had been practised with, at ALEXANDRIA ; in 60 rounds fired from this piece, the vent was enlarged to three times the original size, and a cavity formed spreading from the vent in a serpentine direction towards the muzzle of about 2 inches in length, $\frac{1}{2}$ in its greatest and $\frac{1}{3}$ in the least breadth : the vent being enlarged by the chissel to introduce a bouch, a stratum of tin was observed beginning at the exterior surface of the piece, and descending vertically to the top of the cylinder ; the chissel penetrated the tin more easily than the copper that surrounded it. This separation is attributed to the property which the copper has of setting before the tin ; whence the latter remaining fluid for a longer space of time insinuates itself by its weight between the interstices

interstices of the copper, already in part congealed, descends towards the bottom, and lodges in any cavity it finds.

113. This circumstance did not escape the observation of our ancestors, and various expedients were devised in the last century for remedying it; some threw a quantity of tin into the trough that conducted the melted matter from the furnace to the mould, when they judged that the mould was about $\frac{2}{3}$ full; others thought to prevent it by the use of brass. Some are said in order suddenly to congeal the metal, to have drawn out the iron cores from the moulds while hot, and to have thrown water into the vacant space; others again were anxious to form very long and weighty heads, that the copper being strongly compressed while setting, the tin might not be able to descend. Experience has proved that this last expedient is the best; since in pieces of large calibre, the difference between the hardness of metal at the breech and muzzle is not very considerable, and hardly sensible in pieces of small calibre.

114. Gun-metal is fusible, not only by a great heat, but even by a moderate one, with the assistance of solvents. It has been already observed that tin is a solvent of copper, of which it accelerates the fusion; but as the quantity of tin cannot be increased without altering the quality of the bronze, this expedient can only be used so far as the proportion of the ingredients will permit. Tartar and nitre are the most powerful solvents; when mixed together in equal quantities, the chemists term the compound a *white flux*; when the quantity of tartar is double that of the nitre, a *black flux*. As these two fluxes, especially the former, are very active, much care and circumspection must be observed in using them, to avoid the damage that the furnace would be exposed to, from the violent agitation they occasion. When gun-metal is made extremely hot, it is often very spongy and porous, particularly towards the muzzle, so that when filled with water, it exudes and oozes through. Tartar is used when from the great rarefaction of the air arising from extraordinary heat, the fire is rendered inactive, and the metal is infusible *per se*. But if fire alone will answer, the founders stir and mix the substances well together before they open the furnace, the melted matter then runs into the moulds; and this method has been found sufficient to render it homogeneous; for, if small quantities be taken out of the furnace with an iron ladle, while the

the metal is running into the moulds, at the beginning, the middle, and end of the process, the several pieces, when cold, will be homogeneous.

115. If an excessive heat, whether produced by fire or a combination of solvents, be attended with bad effects; a deficiency in that respect is not less pernicious: for independent of the imperfect mixture, the metal does not set properly in the moulds; whence proceed the cavities and flaws frequently observable on the outsides of guns after proof: these can neither be attributed to the intrinsic quality of the bronze, nor the want of proportionable thickness, but to the defect of heat and mixture; since the external flaws do not extend and communicate with the bore: from the same cause proceed the asperities visible on the ornaments and bas-reliefs.

The deficiency, in point of heat, does not always arise from too small a quantity of wood being used to heat the furnace, since with the same quantity it takes sometimes 36 or even 48 hours, to effect what at other times 16 or 18 are sufficient to do. This can only be accounted for from a want of elasticity in the atmosphere, which prevents the wood from burning with proper activity; or from the neglect of the workmen in removing the cinders, which partly stops the reverberation of the flame; thus the fire not being so intense, it is longer before the metal acquires the proper degree of fusion.

116. There are some accidents which baffle the utmost caution, as they proceed from variations in the state of the atmosphere. If the melted matter while running into the mould be exposed to a cold wind, it may be suddenly congealed, which will prevent a due tenacity in the particles when solid. After the mould has been heated, if the atmosphere become suddenly loaded with vapour, the mould will imbibe humidity; and the melted metal will extract the moisture, which rushing out and bubbling vehemently, will disturb its setting. On the contrary, when the mould is perfectly dry, repeated experience proves that the metal on running into a hot recipient, sets better, and becomes more tenacious and dense, but less hard than when the recipient is cold.

117. Since cavities proceed from the sponginess of the copper, or from the coldness and moisture of the atmosphere or mould; they are found in all parts of the gun indiscriminately,

minately, and can neither be avoided or discovered before the proof, particularly if the quantity of tin be small: but if it be large, as in bell-metal, these cavities are seldom seen, unless the metal be run into the moulds before it is sufficiently liquid. If the proportion of tin in gun-metal be 16 in the 100, the heads very long and thick, and the furnace not opened till the metal is properly fused and mixed, there will seldom be any cavities large enough to affect the service of the piece.

As no rule has yet been laid down for ascertaining the absolute degree of heat, founders must depend on their own observation; and though they may sometimes be deceived (107) yet a competent share of knowledge derived from experience will enable them to judge with tolerable accuracy when the furnaces are properly heated.

118. From the preceding observations on gun-metal and the method of casting artillery, we may conclude:

1. That the metal must have certain physical qualities to enable the guns to resist the forces that tend to destroy them.
2. That great art is requisite in reducing the metals to a proper degree of liquefaction.

It rests with the officers of artillery appointed to fix the proper proportion for the different natures of guns that are to be cast, to ascertain the physical properties of the gun-metal; it depends on the founders to flux the metals, and form the moulds in so nice and accurate a manner, that the principles laid down by the artillery officers may be punctually adhered to. From a want of attention to these distinctions, it has frequently happened that every thing being left to the *mechanics*, they, either through ignorance of the absolute necessity of having particular properties in the metal or of the means of procuring them, formed the mixture without the least judgment; whence arises the great difference sometimes found in guns cast by the same founders after the same model.

C H A P. VIII.

OF THE VENTS OF GUNS.

119. **T**HE position of the vent contributes also to modify the inflammation and explosion of the charge. (Pl. 3, Fig 8) If in the gun *ABM* the vent *QP* correspond to half *AN* of the charge, it will be the most advantageous position for obtaining the greatest force from the given quantity of powder; but then the motion of the breech, though of the proper weight (84) will be so violent, as to render the firing totally irregular, and of course the fire-arm useless. The vent should be placed at *AC* corresponding to the bottom of the bore, which will obviate the ill consequences attending the former position; and if the bottom of the bore instead of being hemi-spherical be plane, the charge will be brought nearer to the vent, more powder will take fire, and the explosion be more violent, without causing such an irregular motion in the breech.

120. Chambers in guns are liable to great inconveniences from the alteration of their figure, as happened at the experiments with the *Sarcophagus* (36). This gun had at the bottom of the bore a small cylindric chamber *ABCD* (Pl. 3, Fig. 9) of which the diameter *AC* was $1\frac{4}{16}$ inch and the length *AB* 2 inches, the communication *F* to the vent *FG* was distant from *A* $1\frac{4}{16}$: the part *FN* of the vent made in the gun itself was in length $3\frac{7}{16}$, the remainder *GN* was filled with an iron screw *HLMK* $2\frac{2}{16}$ in length, which had been well worked and tempered. After 500 rounds the metal was much corroded at *F*, and round the orifice *AC* of the chamber; and the upper part *PABF* was considerably damaged towards *N*. This increased very much in the next 300 rounds; the clefts extending towards *N* were $1\frac{1}{2}$ inch in length; the pricked line *QQQ* shews the alteration that took place in the figure of the chamber. The part *NG* of the vent formed by the iron screw was regularly enlarged to nearly twice the original diameter: but by the assistance of this bouch the piece might yet have been frequently fired, without apprehending any great increase in the size of the vent;

vent; its position was not at all altered. This single experiment shews the necessity of suppressing the use of small chambers in guns.

121. Several observations and experiments might be adduced to prove that when the bottom of the vent corresponds with the upper part of the bore, it is a long time before it changes its form; and that if the metal be corroded, it is only round the lower orifice.

122. It has been observed (4) that the vents of guns run sooner as the proportion of tin is the greater; and in the second chapter the necessity of having a hard metal to prevent cavities being formed in the bore was insisted on; but this condition can only be obtained by increasing the quantity of tin, and thereby rendering the vent liable to run after a very little firing; and it is well known that when the vent is much enlarged, there must be great irregularity and a considerable diminution of force in the discharge: it is necessary therefore to form the vent of some more resisting metal, which when enlarged may be easily taken out and replaced; the best expedient hitherto devised, is to insert into every gun previous to its being carried on service, a screw bouch which may be replaced at pleasure.

123. From satisfactory experiments made on the resistance of simple and compound metals with a view to determine which is the best for bouching guns, it is in general found that their resistance is in proportion to the difficulty of fusing them in the crucible. The following metals were proved with the machine described in the Treatise on Powder (139) and found to decrease in resistance from the first to the last.

1. Forged iron well worked and welded with the hammer.
2. Iron of the second smelting.
3. Pure copper.
4. German brass.
5. Gun-metal containing $\frac{1}{4}$ of tin.
6. Assayed gold.
7. Assayed silver.
8. Lead.
9. Tin.

Of these metals the three first are least corroded by the action of powder; but forged iron is the only one that can be depended on for making screw bouches (122). Gun-metal

metal containing tin in the ratio of 16 to 17 in the 100 corrodes more easily than assayed gold; but at 4 to 5 in the 100 it resists more than German brass; for which reason, as was before remarked, soft gun-metal was for a long time in great credit. But these resistances are merely relative and can only apply to determined circumstances; for if the quality or quantity of the powder be altered, the wads rammed with more force, or the piece much heated by frequent firing, the metal will be the sooner corroded and the vent enlarged.

124. The first method adopted for repairing the vents of guns that had run, was the application of a bouch: afterward in hopes of totally preventing or at least deferring this accident, they put into the mould a piece of copper or iron at the place where the vent would be: this expedient was soon abandoned, on finding that the liquid metal on coming in contact with a cold body, bubbled and formed cavities contiguous to the vent: and one of the four following methods was universally adopted.

The first consisted in enlarging the vent A B C D (Pl. 3, Fig. 10) when damaged towards the middle F G and filling up the cavity with gun-metal; the metal when cold was perforated to form a new vent.

The second method differed from the first, only in filling the cavity with pure copper.

In the third method, the vent A B C D (Pl. 4, Fig. 11) was enlarged as before, and an iron bouch P applied with the projection Q Q; melted metal was then poured into L M which when cold held the bouch P very firmly; afterward a new vent H K was drilled.

(Pl. 4, Fig 12) The fourth method was to enlarge the vent very considerably in form of a truncated cone A M K E, the sides of which Q R D B L E served as a female screw to receive an iron bouch; in the axis of which was drilled a new vent F G. These different methods of repairing the vents of guns may be applied according to the damage that the piece has sustained, but are not equally good. In the first method the vent may run a second time, if there be too much tin in the metal. By the second, the vent is less liable to corrode; but the copper from its great ductility may spread and lengthen, and being detached from the sides of the cavity, the whole bouch may be blown into the air. The third method is preferable to the two former, since the bouch gives more resistance, and is less liable to the above accidents.

In

In the fourth, it requires more labour to prepare the cavity; but a fresh screw may be inserted when the first is corroded. The old method of using screw bouches was very imperfect; since they were obliged to vary the diameter in each gun in proportion to the degree of corrosion.

125. In order to derive every possible advantage from screw bouches, and render their use more simple, expeditious, and general, the following precautions should be observed.

1. To apply during the time of peace to all guns, particularly to battering cannon, a screw bouch of iron in one of the two methods expressed in figure 12 and 13; they should be formed on the same model for all pieces of the same calibre, that there may be always a quantity in store.

2. The head of each bouch should be so formed that it may be easily screwed and unscrewed; and of such a length, that the bottom may exactly correspond with the upper part of the cylinder.

3. Not to diminish the metal at the breech too much, the diameter of the bouch should be less than $\frac{DQ}{2}$; and to prevent the necessity of frequently replacing it, its diameter should not be less than $\frac{DQ}{4}$.

4. The vent should (119) correspond with the bottom of the bore, which should be a plane figure. If these operations be executed with exactness and precision by skilful workmen, the resistance will be fully sufficient; and there will be no danger of the flames passing among the spirals to damage and corrode them.

126. The resistance of the screw bouch may be easily ascertained: (Pl. 4, Fig. 12) since before it can yield to the action of the powder, it must be driven forcibly out of the female screw and be separated from its spirals; or it must break off and carry away with it the spirals of the other screw, which would leave a vacuum $NBDQ$; or it must break the spirals of both. Now as the tenacity of iron far exceeds that of gun-metal, the spirals of the female screw must first yield to those of the bouch; and if the circumference of a spiral answering to the diameter BD be called $=C$ and its length $DQ=m$, $c m$ will be the section of the fracture; this
section

section multiplied into q = the tenacity of the metal will give $c m q$ for the resistance of the female screw. The formula 9962 $n s$, expresses the pressure of the elastic fluid against a superficies = S . Then if half the diameter $B D = r$, and its circumference

= C , $S = \frac{r c}{2}$ will be the superficies of the circle, against

which the elastic fluid acts in the direction $F G$; then 9962

$n \times \frac{r c}{2}$, will express the force with which the powder acts

against the base of the bouch. For example, if under circumstances the least favourable to the resistance of the bouch,

$r = \frac{m}{4}$, $n = 1200$ (33) and the metal of a less tenacious qua-

lity be heated as much as it can be on service, $m q = 7358758$ (35) the resistance of the bouch. Now supposing $m = 1$; then $4981 n r = 4981 \times 1,200 \times \frac{1}{4} = 1444300$ for the action of the powder against the base of the bouch: thus the resistance of the female screw will be more than five times the force that tends to drive the bouch from its place; an equilibrium between the propelling and resisting powers will be then fully established, if only part of the bouch $Q R = \frac{1}{5}$ of $D Q$ be spirated.

127. When the base of the bouch corresponds with the upper part of the bore, the action of the powder against it is as the pressure: but when the bouch only reaches to $L R$, and leaves the vacuum $D L R B$, then the elastic fluid acts against it with so much the greater force, as $L R$ is distant from the upper part of the bore; and greatly exceeds the pressure that it would exert against the base, were the bouch in the former situation. The reflections in the 2nd chapter on the orbicular cavities formed in the bores of guns cast of soft metal, by the impulsion of the elastic fluid, will convey a just idea of this force.

128. To shorten the operation of making the screws, and at the same time to obtain a resistance superior to the force of the powder, the bouch may be made in the following or any similar manner. (Pl. 4, Fig. 13) Let it be spirated only from P to L ; let $P L$ be about $\frac{1}{4}$ of $F G$ and the remainder $L F$ be in a form of a truncated cone $H K N H$, the diameter $H H$ being less than $B D$, to form a ledge $B H H D$, upon which may be placed a thin circular plate of ductile

ductile metal, as pure copper; so that when P L is strongly screwed down, the plate may spread and fill up the space between P L and H F so exactly, that none of the elastic fluid may be able to penetrate among the spirals. The formula (126) will serve to compare the resistance with the force of the powder, that acts against the base K N of the bouch: $4981 nrc$ expresses the force of the powder, cmq

the resistance of the bouch; put $\frac{KN}{2}$ in the place of r and

the circumference corresponding to the diameter K N in the place of c . If the circumference $= c$ correspond to the diameter B D of the spirals, then in the second formula put the length L P in the room of m ; and since circumferences are proportional to their diameters, these may be substituted and the formulas will be $2460 n \times \overline{KN}^2, BD \times LP \times Q$.

129. The resistance of bouches made on this principle have been found more than sufficient in practice. The experiments made in 1771 prove the goodness of the bouches; (Fig. 9 and 13) their resistance is amply sufficient, and when damaged they may be easily taken out and replaced (127). The bouch (120) was neither moved or corroded in the 800 rounds fired from the *Sarcophagus*; and the same was the result of the experiment (34) with a bouch (Fig. 13). When the bouches were taken out, neither the male nor female screws were in the least altered, nor had the elastic fluid or the water which remained in the gun for 5 hours passed the ledge B D. In the gun called the *Paphos*, which in 1771 was fired in the same manner as the *Invincible* (34) with a bouch (Fig. 13), the same effects were observed. The operation of taking out and replacing the bouches takes up but a few minutes; it may be performed upon the batteries without dismounting the guns.

C H A P. IX.

OF THE EXAMINATION AND PROOF OF NEW GUNS.

130. **I**T was observed in the 7th chapter, that success in casting guns does not entirely depend on the skill and ability of the founders, since it is greatly subject to casualties. The King's service requiring that, beside the precautions taken at the time of casting, the greatest attention be afterwards paid to detect any negligence or error; every gun before it is used should be scrupulously examined and subjected to various proofs, in order to be certain that the founder has adhered to the instructions he received.—The object of these examinations and proofs is to ascertain:

1. Whether the guns are constructed on the proportions given to the founder.

2. Whether before the metal was run into the moulds, the necessary precautions had been taken to avoid all separations between the metallic particles capable of producing an unequal resistance.

3. Whether the tenacity of the metal is proportional to the thicknesses of the piece; and its hardness sufficient to prevent orbicular cavities from being formed on firing very large charges.

131. To know whether a gun be properly constructed, two instruments are used: the first serves to shew whether the piece has been truly bored, and the thicknesses of metal properly distributed; by means of the second, the exact figure of the bore is traced upon the first, whereby the least flaw or deviation from the cylindrical figure is discovered and ascertained. A mirror is afterwards used to discover by the reflection of the solar rays, what cavities, inequalities or other defects there may be; and with the little iron instrument called the *searcher*, their depths and diameters are measured.

132. To know whether there be in any part such a separation of the metallic particles, as to penetrate from the exterior surface to the interior cylinder, the gun is filled with water and placed with the breech downwards to increase its force

force and make it more easily pass between any interstices of the metal; it is further pressed with a high sponge; and in this situation the gun is left for three or four hours. This proof should never be made when the water can freeze.

133. If during these examinations (131, 132) any defects sufficient to make the shot strike against the sides of the gun, or any holes in the charging cylinder or bore be discovered; if the axis be not exactly in the center, the trunnions properly placed or any opening or cavities through which water oozes; in a word, if the piece have any defects that can render it unserviceable or dangerous, or that can tend to prevent the shot from being thrown in a true direction, and no safe remedy can be applied; the gun should be without hesitation rejected.

134. When no such defects are discovered, the other proofs for ascertaining with the greater certainty the nature of the casting and the qualities of the metal may be proceeded to. To this end, a few rounds should be fired in such a manner, that any defects may be discovered as fully as they would be, after a long continued firing with the ordinary charges of powder.

135. To determine the proper quantity of powder for proving guns, it is necessary to advert to the circumstances that modify its force, from the beginning of the inflammation at the bottom of the bore, till the ignited fluid reaches the mouth of the piece; these modifications have been enlarged on in the Treatise on Powder, and may summarily be reduced to the following:

1. The pressure of the elastic fluid in the charging cylinder does not depend on the quantity of powder, provided that it be equally well collected; but on the resistance opposed to its explosion towards the mouth of the piece: and the other ordinates of the scale of pressures increase in proportion to the greater quantity of powder that is fired in the piece.

2. On comparing two equal charges of powder of different qualities to which an equal resistance of shot and wads is opposed, the pressures, excepting the first by which the shot is put in motion, are greater in proportion as the powder is stronger: the difference between the corresponding ordinates proceeds from the greater quantity of fluid produced in equal times, in two powders of different qualities; whence it results, that

that the elasticity of the fluid in the charging cylinder is greater in the strongest powder, though the pressure by which the shot is first put in motion be equal in both charges.

3. The resistance to the explosion of the powder toward the mouth of the piece, is compounded of the weight and friction of the shot and wads: the resistance from friction ceases as soon as the shot and wads are in motion; but the resistance from the weight of the shot exists during the whole length of the piece, and is greater as the elevation at which the gun is laid is higher; this resistance may be calculated in the ratio of the right sines of the angles of elevation.

4. The fluid generated at the bottom of the bore on striking the shot is reflected laterally against the sides of the gun with so much the more force, as the charge occupies a greater space, or as all the powder is more instantaneously inflamed: whence proceed orbicular cavities, whenever the hardness of metal is not sufficient to resist the impulsion.

136. From the preceding remarks we may infer that;

1. The proof charge should never occupy less space in the bore than the largest service charge.

2. The gun should be laid at a higher elevation than when mounted on its carriage.

3. The powder should be stronger than what is generally used, its quantity combined with the greatest resistance of the shot and wads, and proportioned to the largest service charge, in the ratio of the metal when cold, to the metal heated so as to fire powder (35).

4. If a shot made of a soft metal as lead, tin, &c. by any irregular movement proceeding from the strength of the charge strike against the sides of the gun, it should be unable to make the least impression.

137. The defects of a gun loaded in this manner will be as fully discovered in a few rounds as with a great number fired in the common mode; nor will there be the least reason to be apprehensive of bursting the gun, if it has been cast in the manner, and with the proportions already prescribed. When the guns have been thus fired, they should be again subjected to the water proof and re-examined: and if any flaw that may prove detrimental to the service can be discovered (133) they ought to be rejected.

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138. There

138. There may be some defects so slight as not to merit attention; while there are others that must be prejudicial, according to their nature and extent; as the eccentricity of the bore, the number, depth and situation of the flaws or cavities, the wrong position of the vent, or a failure in other points previously concerted with the contractor. As, on the one hand, nothing should induce officers to receive guns that cannot be depended on; so, on the other, they should not be over scrupulous in their examination, lest the founders under pretence of the minute strictness of the scrutiny enhance their price.

139. Iron guns should be subjected to the same proof and examination: but as the hardness of the metal is ascertained, there will be no reason to apprehend any orbicular cavities being formed in the charging cylinder, or any impressions made by the shot in the bore. If properly cast of metal of a good quality, they may be proved with iron shot without fear of damaging or hurting them; the quantity of powder should be determined by the thickness of metal, agreeably to the rules laid down in the 6th chapter.

140. The same precautions and care should be taken in proving and examining mortars: but any little hollows or flaws in the chase may be disregarded, unless from their number and proximity, there be reason to apprehend an essential defect in the interior of the metal.

S E C O N D P A R T .

OF PROJECTILES.

141. **T**H E R E are two general methods of annoying an enemy: with missile weapons; or with pointed and cutting instruments. Under the first head, the ancients made use of the *ballista* and *catapulta*, for throwing large stones and arrows to great distances; and of *slings* and *bows* for throwing them to shorter distances.

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The invention of the powder gave rise to the casting of guns and mortars; which project iron shot and shells of different sizes to very great distances, for the destruction of men, and the demolition of fortifications and buildings. The non-commissioned officers and soldiers of artillery perform the operations requisite for producing these effects. The theoretical part of the profession consists in certain principles and rules, with which the officers ought to be fully acquainted: as from mere practical knowledge they can never hope to be distinguished; nor can their country reap from their exertions the advantages expected from a corps, purposely set apart in all armies for this particular service.

Our ancestors feeling the necessity of regulating their practice by fixed principles, were soon convinced, that, to expertness and adroitness in the mechanical parts, it behoved them to join a just theory; that from a knowledge of causes they might be enabled to account for effects, and conduct their experiments without the confusion and absurdity inevitably attendant on an erroneous system.

If it hath not already been sufficiently proved, that an artillerist should be conversant in physics and mechanics; the second part of this work will clearly demonstrate, that unassisted by science, he never can ensure facility and œconomy in execution, which is the most certain and ready method of obtaining victory, the sole object of military operations.

142. To this end, *each shot should strike the object in the manner that will produce the best effect that circumstances admit of; or in other words, the projectile should produce the greatest effect possible in any particular case.* The officer then, who commands a battery, should examine the calibre, shape and dimensions of the artillery; the qualities and proportions of the powder: the causes that may modify in any considerable degree the initial velocity of the projectile; the resistance of the air to its movement; its nature and form: the quality and size of the objects against which the fire is to be directed; their relative and absolute situation: the position of the enemy's troops; and the nature of the ground. Each of these circumstances merit a particular discussion.

C H A P. I.

OF THE INITIAL VELOCITY OF PROJECTILES.

143. **T**H E initial velocity of shot and shells must be indispensably known, before the problems in projectiles can be solved: but as it may be much diversified by the quantity and quality of the powder, the force used in ramming the wads, the elevation of the guns, and the length of the bore; it is necessary to treat all these circumstances more in detail: the powder will be supposed to be the fine war-powder in a good state of preservation.

1. The largest service charges for heavy guns, are equal to $\frac{1}{2}$ of the weight of the shot in 32 and 16 prs. and to $\frac{3}{4}$ in 8 and 4 prs. These charges are only used on particular occasions; the wads are well rammed, that the powder being closely collected at the bottom of the bore, may all take fire in the piece; and that the inflammation of each grain being as instantaneous as possible, the shot may have the greatest initial velocity.

2. The medium charges are $\frac{3}{8}$ of the weight of the shot in 32 and 16 prs. and $\frac{1}{2}$ of its weight in 8 and 4 prs. These charges are commonly used in sieges, for demolishing works, dismounting the enemies artillery, or enfilading troops; two gunners give five strokes of the rammer to the wad over the powder, and three to that over the shot.

3. The smaller charges are equal to $\frac{1}{4}$; and the least to $\frac{1}{8}$ of the medium charge. These are only used in particular cases, which will be hereafter pointed out; and are always supposed to be wadded in the same manner as the medium charges, in order to compare the initial velocities of shot, impelled by different quantities of powder.

4. As the difference in the diameter and weight of shot causes a great difference in the initial velocity, the shot are supposed to be of the diameter and weight, and the guns of the calibre prescribed by the king's order, and cast agreeably to the proportions laid down in the first part of this work. Shot made, as directed in the
first

first book of artillery, have been found adequate to every purpose; nor can their surface be more polished, or their figures more perfect, without incurring an exorbitant and unnecessary expence.

144. The initial velocities of shot are determined from experiments made with skill and discernment, and conducted with care and circumspection: before we proceed to the method of determining them, it will be necessary to mention the principles adhered to in carrying on the experiments.

1. The piece was always loaded in the same manner, and placed exactly in the same position, lest the result might be erroneous.

2. Since effects are always proportioned to their causes, when any remarkable difference arises in the course of the experiment, it should excite no amazement; as it must proceed from negligence or accident. Some practitioners take the mean result of all experiments, but conclusions drawn from thence must be faulty.

3. In spite of the utmost precaution, there will be sometimes a slight difference, proceeding from the manner of placing or wadding the powder, &c.

If the variations be not very great, a few more rounds may be fired; but the mean result only of those taken that approach nearest to each other: this may then be considered as the absolute result. If, for example, the question be concerning the length of ranges; the mean only of those should be taken, whose differences do not exceed 2 in the 100, and no regard paid to the others. But, should the ranges vary considerably, it will then be necessary to examine carefully every part of the process, to discover the cause of the variations, and be enabled to make fresh experiments in a more exact manner.

145. There are three methods of determining the initial velocity of shot:

1. By measuring their penetrations into a homogeneous butt of a known consistency.

2. By analysing and resolving into its simple movements, the curve described by the projectile on quitting the piece.

3. By deducing it from the thickness of metal of the fire-arm, when it is in equilibrio with the pressures of the elastic fluid, in every point of its length. The

third method is applicable to fuzils and pieces of very small calibre; but not to guns of large calibre, fired with the common charges of powder: because in the latter, the initial velocities are compounded of the impulsion and pressure, as has been explained in the first part.

146. The initial velocities are found very nearly by the first method (145, No. 1.) if the butt be perfectly homogeneous and consistent. To determine its consistence, fire a piece of small calibre, with an iron shot 1 inch in diameter = D : and measure the initial velocity = $u = 1200$ feet, (Treatise on Powder 164, 165). Then the piece being loaded and fired as before, the penetration of this shot into the butt will be 15 inches = S ; and substituting these data in the formula $fS = D U^2$; we shall have $f \times \frac{5}{12} = \frac{1}{12} \times 1200^2$; then $f = 96000$ for the consistence of the butt: let it be written in the formula, which then becomes $96000 S = D U^2$. Place the gun, the velocity of whose shot is sought, very near the butt, and fire some rounds in a horizontal direction, in order to obtain the mean = S of the penetrations of the shot; suppose it = 8 feet, and the diameter D of the shot = 4 inches; then by substituting these data in the

formula, $96000 \times 8 = \frac{4}{12} U^2$; hence $U = \sqrt{\frac{96000 \times 8 \times 12}{4}} =$

1517 feet, the initial velocity sought. In these experiments, the penetrations should be at such a distance from each other, that the loosening of the earth by the first shot, may not facilitate the entrance of the others; the least difference will be then perceptible, since the penetrations of the same shot are as the squares of the initial velocities.

147. To determine the initial velocities, by analysing the curve (145, No. 2); let us take the first part of the curve, where the effect of gravity has not been sensibly altered by the resistance of the air. It is a matter of indifference, whether the space that the shot pass through by the gravitating or impelling power, be first considered; since the latter may be deduced with equal facility from the former, as the former from the latter. Let us in the first place examine the space passed through by the power of gravity.

(Pl. 5, Fig. 14.) Let the gun $A B$, mounted on its carriage, be placed on an even and solid platform, and laid in a horizontal direction $A C$; so that the shot at the first graze may

may touch the earth in the point G of the horizontal line D F : the vertical distance K G between the two planes, expresses the space = S passed through by the gravitating power, and the horizontal line D G = A K expresses the length of the range, or the space = q passed through in the same time by the impelling power. If the known value

K G be substituted in the formula $S = \frac{32 \cdot 18 t^2}{2}$, it will give

with great precision the time $t = \sqrt{\frac{2 K G}{32 \cdot 18}}$, in which the

shot is driven from A to K by the impelling power. Having fired several rounds, and measured the length D G of the ranges, take the mean = q (144, No. 3); and considering this space as uniformly passed through, establish the following proportion; the time = t, is to the space passed

through = q, as one second, is to the space = $\frac{q}{t}$; which the

shot would move through in one second, if there were no resistance from the air; this space is termed the initial velocity.

For example, K G = 4 feet, then $t = \sqrt{\frac{2 \times 4}{32 \cdot 18}} = \frac{1}{2}$

second; and suppose A K = 700 feet, then $\frac{q}{t} = \frac{q}{\sqrt{\frac{2 K G}{32 \cdot 18}}}$

$\frac{700}{\frac{1}{2}} = 1400$ feet, the initial velocity sought. The initial ve-

locity thus found, is not absolutely just, since the shot, from the moment of quitting the piece till it touch the ground at G, has been retarded by the resistance of the air. If from the nature of the ground, where the experiment is made, the vertical line K G be shortened, the initial velocity will be greater, and approach nearer the truth.

148. To determine the length of the movement of impulsion A M, in order to deduce from it the space passed through by gravity; place vertically in M a butt L M N, lay the gun in a horizontal direction, or nearly so, and at M where the line of direction cuts the butt, draw transversely a

L 4 horizontal

horizontal line. Fire some shot into the butt as nearly as possible in the same direction, so that after each round the vertical distance MH between the horizontal line marked on the butt, and the hole H made below it by the shot, may be exactly measured: take the mean $MH=S$ (144,

No. 3) and substitute it in the formula $t = \sqrt{\frac{2MH}{32.18}}$; then

by measuring the distance $DL=AM=q$, it will give the space passed through in the same time by the movement of impulsion; and considering this space, as uniformly passed

through, $\sqrt{\frac{q^2}{\frac{2MH}{32.18}}}$ will be the initial velocity sought

(147). For example, let $AM=200$ feet, $MH=6$ inches,

then $t = \sqrt{\frac{2 \times \frac{1}{2}}{32.18}} = \frac{1}{8}$ of a second, and $\sqrt{\frac{q^2}{\frac{2MH}{32.18}}} =$

$\frac{200}{\frac{1}{8}} = 1200$ the velocity sought. The nearer the piece is

brought to the butt, the shorter will be the time, and of course so much nearer to reality will be the initial velocity.

149. These methods of determining the initial velocity may be applied to guns of all lengths and calibres. The velocities may be compared together when the experiments have been made under a constant state of the atmosphere; but as its frequent changes affect the explosion of the powder, the following rules should be observed:

1. To make the experiments under a mean state of the atmosphere both with respect to heat and moisture; as the inflammation and explosion of the powder are then much more uniform.

2. In order to know if the variation of the atmosphere be the cause of any alteration that may occur, some rounds should be fired from time to time from a gun of smaller calibre of a known initial velocity, as a wall-piece, placed very close to a butt perfectly homogenous, to ascertain whether the penetrations be regular.

3. If the results be constant, it will be a proof that the process has been just in every particular, and that the

the state of the atmosphere has not varied. Any irregularity found in the results from the gun alone, will denote that some necessary precaution has been neglected: but if the results from both pieces are irregular, it will be proper to defer the prosecution of the experiments till another day, when the atmosphere is more settled: in the mean time the utmost attention should be paid to rectify any error in the apparatus, or in the mode of conducting the experiments.

4. If any interval of time be suffered to elapse between the commencement and the prosecution of the experiments, and there be a difference in the initial velocity of the wall-piece, it will be proper to fire some rounds from the gun, in order to compare it with the preceding experiments. For example; if in the morning the initial velocity of a 32 pr. be 1383 feet, and that of the wall-piece 1696 feet; and in the afternoon the initial velocity of a 16 pr. be 1424 feet, while that of the wall-piece be only 1600; a few rounds should be fired from the 32 pr. the initial velocity of which must be necessarily less than it was in the morning; suppose it to be 1315 feet: the following proportion

$$\text{will be formed, } 1315 : 1383 :: 1424 : \frac{1383 \times 1424}{1315} = 1498$$

which would be the initial velocity of the 16 pr. if the atmosphere were in the same state as in the morning. By this mode of operation, experiments made at any interval of time, at different seasons, and under different states of the atmosphere, may be compared together with sufficient accuracy:

150. If under a mean state of the atmosphere, with respect to heat, density, and moisture, these experiments be made with guns of medium length loaded as before (143); it will be found, on firing them in a horizontal direction:

1. That with the largest charges the initial velocities are nearly as follows:

Nature of Guns		Initial Velocities.
	<i>Prs.</i>	<i>Feet.</i>
Shot	32	1517
	16	1618
	8	1696
	4	1720

2. That

2. That with the medium charges they are very nearly as follows ;

Nature of Guns.		Initial Velocities.
<i>Prs.</i>		<i>Fect.</i>
32	—	1350
16	—	1416
8	—	1449
4	—	1467

3. That with the less charges (143) they will be about $\frac{1}{8}$ less than with the medium charge; for instance, a shot from a 32 pr. charged with $7\frac{1}{2}$ lbs. of powder, will be impelled with an initial velocity of about 1180 feet, and a shot from an 8 pr. with $2\frac{1}{2}$ lbs. of powder, with an initial velocity of about 1260 feet.

4. With the least charges (143, No. 3) the initial velocities will be about $\frac{3}{10}$ less than those with the medium charge; for instance, a shot from an 8 pr. charged with 1 lb. 10 oz. of powder, will be impelled with an initial velocity of 1061 feet; and a shot from a 16 pr. with $2\frac{1}{2}$ lbs. of powder, with an initial velocity of 1028 feet. It should be recollected, that with small charges, the least difference in the mode of loading the gun, makes a great alteration in the initial velocities, while with large charges its effects would be scarcely perceptible. The surest mode of keeping all circumstances as nearly equal as possible, is always to ram the wads well.

151. In experiments with three or four guns of the same calibre, but of different lengths, loaded as above (150, No. 2); the following rule will furnish an approximation sufficiently exact to draw from it conclusions applicable to practice. (Pl. 5, Fig. 15,) E B F represents the bore of a gun of any calibre; the medium charge of powder D and the wad S are so placed, that the shot A is distant from B

three diameters of the bore F E: make $FC = \frac{2AF}{3}$ and

from the point C as centre, with the radius C A, describe the arch A K P R, representing the scale of initial velocities, by lines drawn perpendicularly from A F to the arch. To determine the initial velocity of a shot fired, for instance, from a long gun B L (66), loaded in the same manner (150, No.

No. 2); a normal line LQ drawn perpendicularly from the point L in the line AC , will correspond to the relative initial velocity. To have the absolute initial velocity, make the following proportions: the relative velocity FP of a gun of the length BF is to its absolute velocity, as the relative velocity LQ of the gun BL is to its absolute velocity; by the same method the initial velocity of a shot impelled from a gun of any length as BG may be found. The scale AKR would serve for longer guns, but it should not be used (65).

152. Experiments made with a view to determine how much the initial velocities of shot are affected by the difference in the lengths of the guns, fired with different charges of powder, will be found to vary very little, from those computed on the preceding principles.

153. From the theory of the inflammation of the powder in guns of cylindric bores, when all the grains are fired in the piece, the following modifications ought to occur;

1. In diminishing the charges in guns of the same calibre but of different lengths, the initial velocities of shot from the short pieces should correspond more nearly those from the longer ones, as the charges of the latter are diminished; since the shot has its greatest initial velocity, when in the short piece the largest charge is all fired in the gun.

2. The greatest velocity of a shot projected from a short gun, is with the largest charge that is all fired in the gun: it is only in very short guns that this does not hold good. (Treatise on Powder).

154. In computing these initial velocities, the guns have been supposed to be fired horizontally, or nearly so: but the velocities increase as the guns are elevated, which proves that the entire inflammation of the powder is accelerated by the greater resistance opposed to the explosion (Treatise on Powder). If a 32 pr. be fired with the medium charge (150, No. 2) at 20° elevation, the initial velocity will exceed 1350 feet, and increase very much, if fired at 36° .

In the following chapter will be shewn the method of determining the initial velocities of shot fired from guns at high elevations.

C H A P. II.

OF THE CURVE DESCRIBED BY CANNON SHOT.

155. **T**HE charges of powder for common service have been already mentioned (150, No. 1 and 2; the objects against which they are directed should not be very high; and to fire with effect, be less than 1000 yards distant: even then the air's resistance to the shot is very great, though its effects on the gravitating principle be almost insensible. When the line of descent is less than 260 feet, and the time of the shot's flight not more than 4 seconds, the shot's path is a curve of the second kind; so denominated to distinguish it from the curve of the fourth kind, where the movements of impulsion and gravitation are both greatly affected by the resistance of the air. In the Treatise on Powder, it was demonstrated that the air's resistance considerably retarded the movement of leaden bullets; and in the last chapter on hydrostatics, the air's resistance to military projectiles is expressed in pounds. In this chapter we propose to determine the law by which the air retards the movement communicated by the impelling power, in another manner, viz. directly by its forces.

156. To solve this problem, we must find experimentally *the scale of spaces passed through during the time of an impulsive movement, retarded by the medium that the shot flies in:* the initial velocities may be found by the method expressed in the last chapter. Hitherto we have only considered the effects of the alterations in the state of the atmosphere, on the inflammation and explosion of the powder, and consequently on the initial velocities of shot; we will now examine how far they can vary the air's resistance to the shot, and render the former conclusions erroneous.

The barometer will in some degree point out any changes that may take place, and for greater accuracy, two small guns may be fired against a homogenous butt, at any distance not less than 160 yards; to ascertain by the one, if the initial velocities be constant (149); and by the other, if the air's resistance continue the same. An elevated shot should be chosen for these experiments, where, the gun laid horizontally, may be directed to the right or left, that the first grazes
of

of the shot may severally be on planes one below the other. Let these different planes be 4, 16, 36, 64, 100, and 144 feet below the gun's axis; then the time of the shot's flight through the several spaces will be $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3 seconds; thus, the equation of the scale will be more easily found.

Then, with a charge that gives a known initial velocity, fire some rounds towards the place, 4 feet below the plane of the gun, in order to obtain the mean of the horizontal ranges (144, No. 3) which may be called dg (Pl. 5, Fig. 17): turn the gun to the place 16 feet below its plane; fire some rounds, and call the mean rp ; let nb be the mean to the place 36 feet, and Ky to the place 64 feet below the gun. On the directrix aK set off the times $t =$

$$\sqrt{\frac{2S}{32 \cdot 18}} = ad, ar, an, aK, \text{ corresponding to the lines of}$$

descent 4, 16, 36, and 64 feet; and erect from the points d, r, n, K , perpendiculars to the line aK , respectively equal to the means of the ranges already found; the line $agpbby$ passing through the extremities of these perpendiculars, will be the scale of spaces passed through during the times of the retarded movements of impulsion.

157. If no convenient place can be found for this purpose the experiments may be made in another manner: on the side of a hill or mountain as (Pl. 5, Fig. 16) HLA , at the bottom of which is a horizontal plain MZ , chuse the stations A, L, H , of different heights; and from them fire the gun in the horizontal directions AK, LF, HX : then the perpendicular lines GK, PF, ZX will be spaces that the shot fall through by the power of gravity. The longest of these lines should be less than 260 feet, that the resistance of the air may not sensibly affect the gravitating power, and that the difference of the heights may not occasion any alteration in the inflammation of the charge. From each of the points A, L, H , fire some rounds with charges of which the initial velocities are known, in order to obtain the mean of the ranges (144, No. 3); then supposing that from the point A the mean of ranges is $=DG$, from the point $L = KP$, from the point $H = NZ$; mark upon the directrix aK (Pl. 5, Fig. 17.) the times corresponding to the vertical lines GK, PF, ZX ; erect from the points d, r, n , the normal lines dg, rp, nb equal to the means of ranges already found, and

and drawing a line through the points $agpb y$, it will be the scale of spaces in the times of the retarded movements of impulsion.

158. Having constructed this scale (156, 157), the result of the experiments should be examined to see that there be no error, and as it is the scale of a retarded movement, it should have the properties expressed in the treatise on moving bodies: in the first place, the line $agpb y$ should be a curve concave towards the directrix, and the differences pm, bo, Ly between the ordinates, should decrease in a regular progression from a to y ; wherefore, if the scale be a right line, or a curve convex toward the directrix, it is a proof that some errors have been committed in making the experiments, or in taking the results. But if they differ a little in one or two points only, it is immaterial, since small errors are inevitable: when this occurs, the differences should be judiciously corrected. To this end, deduct the second differences from the first: and if the results be still erroneous, take the third differences; in the latter, the least irregularity in carrying on the experiments will considerably disturb the order of progression. To set this matter in a clear point of view, suppose the following to have been the result of the experiments.

Spaces passed through by the Shot from the impulsive motion in corresponding times.

Seconds of Time:	Fet.	Differences.		
		First.	Second.	Third.
1	1302	—	—	—
2	2394	1092	—	—
3	3310	916	176	—
4	4082	772	144	32
5	4730	648	124	20
6	5284	554	94	30

If no error be perceptible in the first; but in the second, the progression does not decrease regularly, and in the third the difference after decreasing from the first term 32 to the second 20, increases from the second term 20 to the third term 30, to correct these errors, let the results be modified as below; then will all the differences decrease in a regular progression and be sufficiently accurate.

Results

Results modified.			Differences.		
Seconds of Time.	Feet.		First.	Second.	Third.
1	1302	—	—	—	—
2	2394	—	1092	—	—
3	3310	—	916	176	—
4	4082	—	772	144	32
5	4736	—	654	118	26
6	5292	—	556	98	20

159. When the scale thus modified has the properties expressed in the preceding paragraph, we should proceed to examine whether the results are just and conclusive.

FIG. 17. For this purpose, if $agpby$ be an equation of this scale, and $ifbe$ the equation of the scale of velocities in corresponding times (Treatise on Moving Bodies), which should be a curve-line convex toward the directrix, whose greatest ordinate ai drawn from a the beginning of the times must be equal to the initial velocity of the shot, the other ordinates will decrease in proportion as the times increase, and the scale $ifbe$ will approach the directrix, and touch it when the shot has entirely lost its impulsive motion. For example, suppose the equation of the curve $agpby$ to be $q^2 + nq = mt$; where q expresses the space passed through by the shot from the impulsive motion, t the time; m and n are two constant quantities which express the initial velocity: if from this equation be deduced the equation

of the velocities in the times, $U = \frac{m}{2\sqrt{\frac{n^2}{4} + mt}}$ will

have all the properties that belong to the retarded motion; whence it may be inferred that the experiments have been properly conducted.

Fig. 17. If on the contrary, the equation for the scale $agpby$ be $p t^2 = q^2$, where p is a constant quantity, and

the scale of the velocities in the times be deduced; $U = \frac{2p t}{3q^2}$,

where $t=0$; the velocity is then equal to 0, which is a manifest absurdity, since it must be equal to the initial velocity of the shot. Again, if $p t - t^2 = q^2$ be the equation for $agpby$

by where p is a constant quantity; and the equation for the scale of velocities in the times be deduced, $U = \frac{p - 2t}{2\sqrt{pt - t^2}}$,

which is an absurdity; since when $t = 0$, the initial velocity is infinite.

160. In fine, if the scale of velocities in the times be conformable to the retarded movement, the scale of the air's resistance to the shot at each instant may be deduced from it; if this scale be a convex curve, and its greatest ordinate at a with a progressive series analogous to the scale of velocities, it will be a certain proof that the result is just; but should the scale of resistances not have the requisite properties, the results must be faulty. From the equation of the

scale of velocities $U = \frac{m}{2\sqrt{\frac{n^2}{4} + mt}}$ may be deduced the

scale of pressures $= p$; then $p = \frac{m^2}{n^2 + 4mt \times \sqrt{\frac{1}{4}n^2 + mt}}$

is an equation that combines all the requisite properties.

161. The resistance of the air to the rapid movements of projectiles depends not only on the actual density of the atmosphere, but on the condensation of the air before the projectile, whenever its velocity exceeds 1300 feet; for a vacuum is then formed behind the shot, which becomes so much the greater as the velocity exceeds 1300 feet.

After repeated experiments and observations on this subject, it appears that when guns are fired with charges that give an initial velocity of about 1300 feet, the formula $q =$

$\frac{crt}{r+t}$ will express the retarded motion of impulsion with suf-

ficient exactness for practice, whenever the extent of the movement is less than 1350 yards: but if the initial velocities be much greater or less than 1300 feet, this formula will not serve. The letter q expresses the line of projection, which in shot impelled horizontally always corresponds to the length of the range; t the initial velocity of the shot, t the time that it takes to pass through the space $= q$; and r a number proportioned to the diameters of the several shot; this number is combined with the actual density of the atmosphere,

mosphere, and its value may be found by experiment. The diameters of the shot are as follows :

Nature of Guns.				Diameter of Shot.
<i>Pr.</i>				<i>Inches.</i>
32	—	—	—	5.760
16	—	—	—	4.566
8	—	—	—	3.653
4	—	—	—	2.881

If from the density of the air, $r=12$ in a 32lb. shot, the value of r for shot of other diameters may be found by analogy ; hence in a 16lb. shot, $r=9.5$; in an 8lb. shot, $r=7.6$; and in a 4lb. shot, $r=6$. If from the density of the air, in a 32lb. shot $r=14$; then in a 16lb. shot $r=11.1$; in an 8lb. shot, $r=8.8$; and in a 4lb. shot $r=7$.

For example, suppose from the density of the atmosphere $r=12$ in a 32lb. shot, of which the initial velocity is 1349 feet = c ; and the value of q , the space passed through with this same velocity in different times, be required : by substituting these data in the formula ; in two seconds of time,

$$q = \frac{1349 \times 12 \times 2}{12 + 2} = 2312 \text{ feet ; and in three seconds, } q =$$

$$\frac{1349 \times 12 \times 3}{12 + 3} = 3237 \text{ feet. If the initial velocity be 1517}$$

feet, in three seconds the line of projection is 3640 feet.

In a 16lb. shot with an initial velocity of 1416 feet, the line of projection in two seconds is $q = \frac{1416 \times 9.5 \times 2}{9.5 + 2} = 2402$

feet ; and in 4 seconds is 3985 feet.

In an 8lb. shot with an initial velocity of 1696 feet, the line of projection in 3 seconds is $= \frac{1696 \times 7.6 \times 3}{7.6 + 3} = 3648$

feet.

In a 4lb. shot, with an initial velocity of 1550 feet, the line of projection in 4 seconds is 3720 feet.

Supposing the atmosphere to become less dense, so that in a 32lb. shot $r=14$; then if the initial velocity be 1433 feet, the line of projection in 4 seconds is 4458 feet.

In a 16lb. shot, with an initial velocity of 1534 feet, the line of projection in 2 seconds is 2599 feet.

In an 8lb. shot, with the initial velocity of 1450 feet, the line of projection in 1 second is 1302 feet.

In a 4lb. shot, with the initial velocity of 1320 feet, the line of projection in 3 seconds is 3612 feet.

162. If from the equation $q = \frac{c r t}{r + t}$ be deduced the scale of velocities V in the times, (159) $V = \frac{c r^2}{r + t^2}$, which will

give the remaining velocities, after the shot has passed through the space q in the time t . For example, suppose from the density of the air $r = 14$ in a 32lb. shot; then if the initial velocity be 1349 feet, the remaining velocity after 4 seconds

will be $V = \frac{1349 \times 14^2}{14 + 4^2} = 816$ feet. A 16lb. shot, with the

velocity of 1416 feet, will have a remaining velocity after 3 seconds of 877 feet.

The remaining velocity of an 8lb. shot, with the initial velocity of 1686 feet, will after 4 seconds be 796 feet. The remaining velocity of a 4lb. shot, with the initial velocity of 1467 feet, will after 2 seconds be 887 feet.

Again, from the state of the atmosphere $r = 12$; then the remaining velocity of a 32lb. shot, with the initial velocity of 1517 feet, will after 2 seconds be 1114 feet: a 16lb. shot, with the initial velocity of 1484 feet, will after 4 seconds be 734 feet: an 8lb. shot, with the initial velocity of 1686 feet, will after 3 seconds be 866 feet; and a 4lb. shot, with the initial velocity of 1600 feet, will after 2 seconds be 900 feet.

163. The problems of the curve of the second kind (155) may be resolved by the formulas $q = \frac{c r t}{r + t}$, $S = \frac{32 \cdot 18 t^2}{2}$.

(Pl. 5. Fig. 16.) Given the initial velocity $= c$ of a 32lb. shot fired from A with the horizontal direction $A K$, to determine by experiment the value of r . Suppose that the shot touch the ground in the point G of the plane $D Z$, as the line of projection $A K = D G = q$, and the line of descent $K G$ are known; by substituting this last value in the formula

$S = \frac{32 \cdot 18 t^2}{2}$, it will give $\sqrt{\frac{2 K G}{32 \cdot 18}} = t$, and by substituting

the

the known values of q , c , t in the formula $q = \frac{ct}{r+t}$, the value of r will be found. For example; let $c = 1517$, and $A K$ be found by experiment $= 2655$, and $K G = 64$ feet; then $t = 2$; and consequently $r = \frac{qt}{ct-q} = \frac{2655 \times 2}{1517 \times 2 - 2655} = 14$. Having thus found the value of r for the 32lb. shot, it may be found for the 16, 8, and 4lbs. from the proportion of the diameters of the shot (161).

164. The value of r being given, to find by experiment the initial velocity of a shot fired in any direction. Suppose in the first place, that when the gun is fired in a horizontal direction $A K$, the first graze of the shot is at G : the line of projection and the line of descent being known, by substituting this last value in the formula $S = \frac{32 \cdot 18 t^2}{2}$ the time

of flight will be found: the substitution of which in the other formula will give the value of c . For example, if an 8lb. shot be fired in the same resisting medium as in the preceding paragraph, $r = 8.8$: and supposing $A K = 3478$ feet, and $K G = 144$ feet, then $t = 3$; and consequently $c =$

$$\frac{q \times r + t}{rt} = \frac{3478 \times 8.8 + 3}{8.8 \times 3} = 1554.$$

Suppose, in the second place, (Pl. 6, Fig. 18) that the gun be fired in a direction $A M$, forming with the horizon the angle $M A R$, whose value is known; and, that the shot strike the ground in H : by measuring the horizontal distance $A R$, the line of projection $A M$ and the line of descent $M H$ will be found. If $M H$ be less than 260 feet, the initial velocity will be greater (154), than if the gun had been fired with the same charge in a horizontal direction. Let $M H = 100$ feet, then $t = 2\frac{1}{2}$: let $A M = 2920$, and the shot be a 4 pr. fired in the same resisting medium as above, $r = 7$; consequently $c = 1585$.

165. To determine the angle of elevation (Pl. 6, Fig. 19) $D A F$ under which a shot with a charge that gives a known initial velocity $= c$ will from the point A strike the object B , above or below the horizontal line $A F$.

Draw the perpendicular line $B D$, and suppose $D A$ to be the direction in which the gun must be fired. Then as the

M 2

angle

angle BAF and the side AB in the right-angled triangle BAF are known, the sides AF , BF may be found; call $AF=m$, $BF=n$. Since the num.

$$S = \frac{32 \cdot 18 t^2}{2}, \text{ and the line of projection } AD = \frac{c r t}{r+t}$$

$$DF = \frac{32 \cdot 18 t^2}{2} - n, \text{ according as the point } B \text{ is above or below } F.$$

As in the rectangled triangle AFD , $\overline{AD}^2 = \overline{AF}^2 + \overline{DF}^2$, by substituting the analytical values we shall have

$$\text{the following equation, } \frac{c^2 r^2 t^2}{r^2 + 2rt + t^2} = m^2 + \frac{1035t^4 + 32 \cdot 18nt^2}{4}$$

+ n^2 : whence may be deduced the value of t . If the point B coincide with the point F and the butt be in the plane of the gun, the value of $n=0$, and may be struck out of the equation: the value of t being thus known, those of BD and AD may be afterwards found, which will give the angle of elevation DAF that was sought.

166. (Pl. 6. Fig. 20.) From the point B to hit the object L situated in the same plane as the gun: the value of t may be found in the following manner with sufficient accuracy for practice; since even when the amplitude of a 32lb. shot is 1348 yards, the difference in the elevation HLB will not be $\frac{1}{2}$ second.

The distance BL between the gun and the object, may

be considered as the line of projection $q = \frac{c r t}{r+t}$, and substituting in this formula, the data q, c, r , the value of t may be found; which being again substituted in the formula $S =$

$$\frac{32 \cdot 18 t^2}{2} \text{ gives the value of } S \text{ for the line of descent } LG:$$

draw the line BG ; then, in the rectangled triangle BLG , the angle GBL will be known: make the angle LBH equal to the angle GBL ; BH will then be the direction in which the gun should be fired to strike the point L . For example, if BL be 560 yards, and a 32 pr. be fired with the medium charge of powder, $c=1350$ feet (150); and from the resistance of the air $r=12$: by substituting these

$$\text{numbers in the first formula, } 1680 = \frac{1350 \times 12 t}{12+t}, \text{ and con-}$$

sequently

sequently $t=1.4$ again substituting this value in the second formula $S = \frac{32.18 \times 1.4^2}{2} = 31$ feet = LG, and finding trigonometrically $\angle GBL = 1^\circ 3'$, the $\angle LBH$ that was sought is also $1^\circ 3'$.

167. From the preceding theory, (Pl. 6, Fig. 20) it will be easy to determine the value of r and the initial velocity = c , when these two quantities are unknown, by firing only two rounds. Fire a gun in any direction BD, provided that the line of descent be less than 260 feet; and, supposing the shot to strike the ground in E, find geometrically the line of projection $BD = q$, and the line of descent $DE = s$; and, by the formula $S = \frac{32.18 t^2}{2}$ find the time: then substitute these

values in the equation $BD = q = \frac{c r t}{r + t}$. If the gun be again fired with the same elevation, and exactly loaded as before, but turned to the right or left, so that the shot may strike another point G, higher or lower than the former one E; having found geometrically the line of projection $BK = q$, and the line of descent KG , find the value of t , and substituting it in the equation $BK = q = \frac{c r t}{r + t}$; these two equations will give the values of c and r .

Suppose, in the first instance, that $BD = 1820$ feet, and $DE = 36$ feet; and, in the second, $BK = 3237$ feet, and $KG = 144$ feet: then substituting these numbers in the first formula, $1820 = \frac{c r \times \frac{3}{2}}{r + \frac{3}{2}}$; and again in the second, $3237 = \frac{c r \times 3}{r + 3}$; from these two equations, $c = 1348$ feet, and $r = 12$.

In firing against the height, RH (Pl. 6, Fig. 18) having fired one round from A, in the direction AM; the gun should be advanced to L, or retired to P; and, from one of these two stations, a second round fired with the same elevation; since whenever it is altered, the initial velocities differ (154).

168. The elevation AD, (Pl. 6, Fig. 21) and the initial velocity = c being given, and the value of r and of the line of descent BD being known, to find the direction

and the quantity KB of compound velocity, with which the shot strikes the point B .

From BD deduce the value of t ; and by the formula $u = 32.18 t$ of the velocities in the times through the movement of gravitation (Treatise on Moving Bodies 283) find the value of u , which set off from B to H : from the point

H draw HK parallel to DA , and by the formula $V = \frac{cr^2}{r+t^2}$

(162) find the remaining velocity $= V$ arising from the movement of impulsion after the time t ; then by setting off its value from H to K ; and drawing the right line BK , it will give the direction, and the quantity of compound velocity which the shot has at the point B . Let $BD = 144$ feet, then $t = 3$, and $u = 32.18 \times 3 = 96 = BH$; and suppose

$c = 1350$ feet and $r = 13$; then $HK = V = \frac{1350 \times 13^2}{13 + 3^2}$

$= 891$ feet; and since the $\angle BHK$ is equal to the $\angle BDA$ which is known, the direction will be found, and also the quantity of compound velocity BK .

169. A combination of the formulas $S = \frac{32.18 t^2}{2}$, $q =$

$\frac{c r t}{r + t}$ (163) will give the equation $S = \frac{32.18}{2} \times$

$\frac{q^2 r^2}{c^2 r^2 - 2 c r q + q^2}$ appertaining to the curve of the second

kind (155), by means of which all the preceding problems may be solved. For example, if the initial velocity be known, and the value of r of a shot of given calibre be required; it will be sufficient to fire a round in a direction AD corresponding to the given velocity; and supposing the shot strikes in B , by finding geometrically the values of the line of projection $AD = q$, and the line of descent $BD = S$, and substituting them in the equation of the curve, it will give the value of r . Again, to find the initial velocity, and the value of r ; it will be necessary to make two experiments with the same charge, and at the same elevation (167); in each of them the values of the lines of direction and descent must be found and substituted in the formula $S =$

$$\frac{32.18}{2}$$

$\frac{32.18}{2} \times \frac{c^2 r^2}{c r - q}$, whence the values of c and r may be

deduced.

The application that will be made in the following chapters of the doctrine here laid down on the unequal movement of impulsion (161) will enable us with a moderate share of discernment, to derive the greatest advantages (141) from the use of artillery.

170. To determine the curve of the fourth kind; when the resistance of the air to the two unequal movements that constitute it is great, and the ranges are long; it is necessary to make a course of experiments, which from the continual variation in the state of the atmosphere, and other circumstances, are very tedious, and require much accuracy and intelligence in those that carry them on. As I had not an opportunity of making all the experiments I deemed satisfactory on this head, I have here only laid down the fundamental principles, that others may be enabled the more easily to prosecute the enquiry. Among the different methods that may be taken to determine the laws of this curve (156), the following appears the best.

Chuse an elevated situation, where the gun may be turned to any side; so that the shot may severally strike points, one below the other, in such a proportion that the lines of descent may be 848, 1696, 3046, 5088 feet. From this spot fire several rounds in a horizontal direction towards the same object, with a charge that gives a known initial velocity, in order to obtain a medium of horizontal ranges and of lines of descent. Persons should be stationed at different parts with second watches, to reckon exactly the time that the shot takes from the instant they see the smoke of the gun, till it touch the ground. Having found the mean of the two movements of impulsion and gravitation, turn the piece towards another object, in order to obtain a different medium, then towards a third and a fourth, with the same precautions as before.

These experiments should be repeated with a gun of a very different calibre, with the same care and attention (156), that the results may not be affected by the variations of the atmosphere. Shot much lighter than the common shot may be made for the occasion, by suspending in the center of the mould a sphere of well-tempered clay, which will be thus

completely enveloped by the melted metal ; the resistance of the air to these projectiles will be much more sensible. If this hollow shot be to a solid one of the same diameter, as the weight of a shell full of powder is to a shell of the same diameter cast solid, the results may be applied to mortars in a much more simple manner.

After the experiments, construct two scales for each gun : one for the space passed through during the time of a retarded movement of impulsion ; the other for the movement unequally accelerated by gravity. The last scale should give a curve convex towards the directrix. The two scales may be analysed in the manner above shewn (158, 159, 160); and if the experiments have been made with care, the equation of each movement will be so expressed as to serve for all the different states of the atmosphere.

171. While the state of the atmosphere remains the same, the results of the experiments (170) will be conclusive, if they have been carried on with proper attention : but the same inference must not be drawn in the former case (157). For if a gun be fired from the different heights A, L, H, (Pl. 5, Fig. 16) and the lines of descent G K, P F, Z X, be very considerable as 848, 1696, 3046, and 5088 feet, the results will be false and inconclusive, even if there be no alteration in the state of the atmosphere ;

1. Because shot fired from different heights are opposed by air of different densities ; the law therefore of the inflammation and explosion of powder is altered, though the quantity be the same : of course the initial velocities will differ.

2. The lines of descent G K, P F, Z X, and the lines A K, F L, H X, which express the movement of impulsion, traverse in an inverse order the air which is of different densities at different heights ; whereas by firing always from the same place H (170), the shot will at the first graze strike the points M, B, E, T, with corresponding lines of descent ; and traverse the air in the natural order ; the lines which express the movement of impulsion will be in the direction H X.

To ascertain the modifications that take place in the inflammation and explosion of powder, and in the resistance of the air to projectiles, owing to alterations in the state of the atmosphere, the following experiments may be made : Let a musquet be fired very close to a butt in the bottom of a valley ;

a valley; and another be fired with an equal quantity of powder of the same quality against the same butt, at the distance of 675 feet: at the same time let another person, at a place 5000 or 6000 feet above the former situation, discharge a bullet from a musquet of the same calibre equally charged, and at the same distances as the former one, against a butt equally homogenous and consistent: the penetrations will be much deeper from the musquet fired near the butt at the foot of the mountain, than from that fired near the butt at the higher situation; but will be much less at the distance of 675 feet, than from the upper one at 675 feet. These effects were so sensible in the campaigns of 1743, 1744, and 1747, in the ALPS, that there were days when the musquets fired at the top of the mountains ranged $\frac{1}{2}$ more than the same musquets at the bottom: sometimes the mountains were enveloped in thick clouds, while the vallies beneath were perfectly clear; at other times the atmosphere in the vallies was loaded with vapour, while those on the heights enjoyed a cloudless serenity: in short, so great and frequent were the alterations, that the experiments of one day bore no analogy to those of the next.

172. To determine in another manner the law of each of the unequal movements that constitute the curve of the fourth kind; let a gun be frequently fired from a horizontal plain P A K, (Pl. 6. Fig. 18.) at the foot of a mountain K I H, with the same elevation K A M, and with a charge that gives a known initial velocity. Fire some rounds from A, so that the medium of the lines of descent may be from 600 to 700 feet: fire again from P, at a greater distance from K the foot of the mountain, that the shot falling in I, the lines that express the movements of impulsion and gravitation, may be longer: remove the guns still farther from K, and fire as before; and, having taken the mean result, retire the gun to a still greater distance from the mountain, so that the shot falling on the plane P L, may give the longest lines of projection and descent possible, under these circumstances; always using a second watch to mark the time of flight of the shot; and, taking every precaution to know whether the state of the atmosphere remain the same. From these results two scales applicable to the uses before expressed (170) may be constructed. Experiments conducted in this manner cannot be very erroneous, but, their results are more complicated than the others, (170) since

since the shot in ascending, passes continually from a dense to a more rarified medium, while the reverie takes place when the shot descends.

C H A P. III.

OF THE EFFECTS OF CANNON SHOT ON WORKS.

173. **T**HE use of heavy artillery (64) is to ruin and demolish permanent fortifications and works.

In the attack of fortresses, 32 prs. are used for battering in breach, when the ramparts are of great solidity ; but, from the great expence attending these heavy guns, and the difficulty of transporting them, 16 prs. serve for dismounting the artillery in the outworks, and beating down the defences. For ricochet and hot-shot firing, 4 and 8 prs. are used, as they require less ammunition, and fewer men to work them.

In the defence of places, against which the besieger can establish any number of batteries he pleases, the proportion of 32 prs. should not exceed a third of the whole number of guns in the garrison ; as 8 prs. will serve for firing against the opening of the trenches, and 16 prs. against the approaches : but, if the situation of the ground be such, that the artillery of the place has a decided superiority over any batteries the besieger can erect ; then, to take full advantage of this circumstance, the number of 32 prs. should be increased : long 4 prs. will keep the enemy in respect around the place, and a few short light pieces (66) may be held in readiness for making sallies.

174. To use fire-arms to the greatest advantage, the effect of each shot should be observed : (141) for this purpose ;

1. The guns and carriages should be constructed with the utmost accuracy.

2. The guns should be served with care and judgment, and placed at a proper distance from the objects intended to be battered.

175. In the former part of this treatise, the principles of the best construction for guns were fully explained : but, as an officer is sometimes obliged to use guns defective in some material point, he ought to consider by what expedient he can

can best remedy the defect: the charge should be lessened, when it proceeds from the want of proper weight in the gun, or of a due thickness of metal in the breech.

The knowledge of an artillerist should be both theoretical and practical: to ascertain the nature of the curve described by a projectile, develope the causes that influence its formation; thence deduce rules applicable to the various cases that occur on service, and be able in the best and most expeditious manner, to repair any accident that may happen, is the part of the theorist, and of the officer. The non-commissioned officers and soldiers are instructed in the part purely practical: they are taught

1. To load the guns in a regular and uniform manner, and to ram the wads when the same charge is used, with equal force; a neglect in this point is the cause of great irregularity, particularly when the guns are depressed.

2. In laying the gun, to remove every obstacle that can tend to derange the firing.

3. Having by two or three rounds ascertained the direction for hitting the object, to continue it without variation.

176. That the gun may be placed at a proper distance from the object (174, No. 2); the shot's path must be considered, and allowance made for every circumstance that can affect the range: the relative size and position of the object must be particularly attended to; for, when it is much higher than the gun, though very distant and narrow, it is more easily hit, than when lower and of greater extent; so that the lower the object is, the nearer the gun must be brought to it. In the attack and defence of places of low profile, the height of the works against which the fire is directed in the first part of the attack, does not exceed 7 feet, as the parapets, the exterior of the embrasures, the heads of saps, &c. The greatest distance at which guns should be fired against such low objects, has been fixed in our military treatises, at 680 yards.

177. After hitting the object, the next point is to consider the degree of force requisite to overcome its resistance: for, if this be superior to the impetus of the shot, no effect will be produced; and, when greatly inferior, it may be sometimes proper to diminish the force of the projectile, in order to produce a greater effect, and avoid spoiling the guns

guns before the siege is over, by firing with large charges. The following considerations may perhaps assist an officer commanding a battery, in forming his judgment on this occasion.

1. The largest charges are only used when a great force is required, and exactness in firing is not absolutely necessary; as battering in breach from the crest of the glacis. But, in firing from great distances to dismount the enemy's guns, batter the trenches, heads of saps, or other low works, the medium charges are sufficient, that the violence of explosion may not produce irregularities (7, 8, 9).

2. The less, and even the least charges will serve for battering towns or villages surrounded with a single wall, unfortified with a rampart of earth; since a shot impinging on a thin wall with great force, makes a hole without shaking the contiguous parts: thus it requires a greater number of rounds with large charges to demolish them, than if the charges were diminished. Should the situation of the ground permit the gun to be laid on an oblique direction at the object, the medium, and even the largest charges may be used: in this case the effects of the shot are in the ratio of the angles of incidence.

178. The force of the direct shock of hard bodies, is calculated from their mass multiplied into their velocity; and the force of the oblique shock, by multiplying the former product by the right sine of the angle of incidence, divided by the whole sine (Treatise on Moving Bodies). If the force $= f$; the weight of the shot $= m$, the velocity with which it impinges $= V$, the right sine of the angle of incidence $= a$;

then $f = m V \times \frac{a}{\text{whole sine}}$ is the general formula in which

the fraction $\frac{a}{\text{whole sine}}$ is equal to unity in the direct shock.

If the value V of the remaining velocity (162) be found, the impetus with which shot of the same or different diameters impelled with different initial velocities, impinge on objects at different distances, may be compared. For instance, let the distance between the gun and the object be expressed by the line of projection, and in a 32 pr. $r = 12$: then

then in the direct shock, the force with which a 32 lb. shot with an initial velocity of 1350 feet, impinges on an object placed very close to it, is to its force at 4056 feet, as 1350 : 759 : and the force with which a 16lb. shot, with an initial velocity of 1416 feet, strikes an object at the distance of 932 feet, is to its force at 3229 feet, as 1226 : 817. On comparing in the same manner shot of different diameters, it appears, that the force with which a 32lb. shot, with an initial velocity of 1350 feet, strikes an object at the distance of 330 feet, is to the force of a 4lb. shot, with an initial velocity of 1467 feet, at the distance of 3520, as $32 \times 1300 : 4 \times 528$; that the force of a 16lb. shot, with an initial velocity of 1416 feet, at the distance of 3886 feet, is to the force of an 8lb. shot, with an initial velocity of 1449 feet, at the distance of 350 feet, as $16 \times 716 : 8 \times 1361$. If under similar circumstances, the shocks be oblique, so that with a 16lb. shot the angle of incidence be 20° , and with an 8lb. shot 75° , the two shocks will be to each other : : $16 \times 716 \times 34202 : 8 \times 1361 \times 96592$.

179. In the preceding paragraph it was supposed, that the compound velocity BK of the shot, when it impinges on an object, was equal to the remaining velocity HK , which is in the ratio of the retarded motion of impulsion : this is the case not only in this particular instance, but in all others that do not admit of geometrical precision. Nevertheless, on ascertaining the greatest difference that can be between these two velocities, in the common service of guns, we shall find it to be too inconsiderable to occasion any material error ; for, if the value of the compound velocity BK be determined (168), the gun having been fired at the highest elevation the carriage will admit of, BK is less than HK in the proportion of about $\frac{1}{4}$ in the 100 ; that is $BK : HK : : 397 : 400$; and if the gun be depressed as much as possible, BK will exceed HK in the proportion of about $\frac{1}{8}$ in the 100 ; that is $BK : HK : : 801 : 800$.

180. Among the several works against which cannon are fired ; there are some which do not yield to the most violent shocks ; and others of very slight resistance. Of the first kind are those cut out of the solid rock, the hardness of which joined to the cohesion is such, that the most violent shocks cause no disunion in the parts. If the weight of the shot = m , the velocity with which it impinges = V and n = the object impinged on ; the whole effect of the shot on this

this work, is a slight tremulous motion in the point of impact, incapable of producing the least separation of the parts: so much does its mass exceed the mass of the shot. There is in this case no method of making a breach but by mining, however tedious or difficult the operation may be.

181. There are three ways in which works that yield to cannon balls (180) may be destroyed:

1. By separating the constituent parts, when the shot cannot penetrate.
2. By penetrating without splitting or shivering them.
3. Or by producing both these effects at the same time.

In the first case, the upper parts being by repetition of the shocks deprived of their base fall down; as in walls built very solidly of hard stones, cemented with mortar: the more speedily to effect this, shot of the largest calibre should be projected with the greatest initial velocity, and the guns placed very near to the object, and fired in *salvos*; that the several shocks being made at the same instant, may be the more efficacious. The 64lb. shot formerly in use, were well adapted to this purpose; as they demolished the wall in a very little time, even with an initial velocity less by $1\frac{1}{2}$ than that of a 32lb. shot; since from the greater quantity of movement, they sooner separate and open works of masonry (Treatise on Moving Bodies, 370, 371, 372). These observations on walls constructed of hard stone and lime, are in some degree applicable to works cut out in soft or friable stone; with this difference that the upper part of the rock being by its nature firmly fixed in the ground, is less shaken than a wall supported by earth, which though an adjunct, is little affected by the shock; whereas, the rock being one body, the shock is communicated to its whole mass; and is so generally diffused, as to be almost insensible. Supposing the two works to be of equal tenacity, that cut out of the rock will suffer less from the shot.

182. Works are destroyed in the second manner (181, No. 2) when the shot penetrating to different depths, disunite the contiguous parts; as in turf, earth, &c. The formula $fS = Dn^2$ (246), serves to determine precisely the penetrations of shots of different diameters, into works of this kind: the penetration of a 32lb. shot, which with an initial velocity of 1517 feet, impinges on a work of this sort, is to that of a 4lb. shot, with the velocity of 1010 feet, as 5.760×1517^2 :

$\times 1517^2 : 2. 881 \times 1010^2$ (161). If a 32lb. shot (146) with an initial velocity of 1517 feet, penetrate a butt of earth to the depth of 20 feet, a 4lb. shot with the velocity of 1010 feet, will under the same circumstances, penetrate only to the depth of $4\frac{1}{2}$ feet; therefore, intrenchments 5 feet thick cannot be pierced by 4lb. shot that impinge with this velocity. The same formula will determine the diameter or velocity that shot ought to have to penetrate a parapet of a given consistence and thickness (146): if the thickness = S be 8.43 feet, and the consistence = F be 37046, by substituting these data in the formula, we shall find that shot which have a velocity of 1012 feet, to pass through this parapet, ought to be 3.653 inches in diameter, which corresponds to an 8lb. shot (161).

183. To determine the relative penetration of shot of different diameters, fired at different distances against a penetrable and homogeneous butt, the remaining velocity = V with which the shot from the distance = q with an initial velocity = c impinges, must be found from the movement of

impulsion: for this purpose the formula $q = \frac{c r t}{r + t}$, (161) will

give the time = t ; and, the value of r being given, the

time may be substituted in the formula $V = \frac{c r^2}{r + t}$, (162).

Having thus found the value of V, the compound velocity with which the shot impinges, may be considered as equal to the remaining velocity (179) without any material error; on this principle, the following table of the relative penetrations of shot of different diameters, impelled from guns loaded with the largest and the medium charges, against a penetrable and homogeneous butt, from four different distances has been calculated; the initial velocities are as before expressed (150) and from the resistance of the air, in a 32lb. shot $r = 12$. By firing one round, the absolute penetration of a shot into a given butt will be determined; and, from the relative penetration it will be easy to ascertain the absolute penetration of other shot, under the same circumstances into the same butt. For example, if a 32lb. shot with the largest charge, fired close to the butt, penetrate to the depth of 22 feet, an 8lb. shot fired with the largest charge, at the distance of 1000 yards, will penetrate only

to

to the depth of 6 feet. If a 16lb. shot with the medium charge, fired at the distance of 340 yards, penetrate 10 feet, a 4lb shot with the medium charge, at the distance of 680 yards, will penetrate only to the depth of $3\frac{1}{4}$ feet.

The relative penetrations of shot, projected from different distances, with given initial velocities.

Nature of Guns.	Weight of Powder.		Diameter of Shot.	Value of r	Initial Velocities.	Relative Penetrations.			
	lbs.	oz.				Inches.	Fect.	Clofe to the Butt.	At 340 yards.
32	13	2	5.760	12	1517	33210	26355	20726	16015
16	6.	9	4.566	9.5	1618	29952	22877	17082	12452
8	4	$14\frac{1}{2}$	3.653	7.6	1696	26000	18696	13069	8837
4	2.	$7\frac{1}{2}$	2.881	6	1720	2128	14122	8902	5290
32	9.	$13\frac{1}{2}$	—	—	1350	26240	20262	15356	11430
16	4	$14\frac{1}{2}$	—	—	1416	22932	16754	11935	8255
8	3.	$4\frac{1}{2}$	—	—	1450	19229	13106	8566	5311
4	1	$10\frac{1}{4}$	—	—	1467	15516	9563	5458	2867

184. To judge of the total effects of shot, it should be observed; that the larger the shot are, the sooner the upper parts are deprived of their base, and fall down. If D^2 expressing the penetration of shot, be multiplied by D^2 a quantity proportional to the base of the cylindrical cavity, made by the shot, $D^3 U^2$ will be expressed by the size of the hole; that is to say, the holes made by the shot are in the compound ratio of the weight of the shot, and the square of its velocity. The effects of a 64lb. shot impinging on a parapet of earth, with a velocity of 1247 feet, are to the effects of a 32lb. shot, with an initial velocity of 1350 feet, as $64 \times 1247^2 : 32 \times 1350^2$ or as 43 : 25 nearly.

Hence it appears, that 64 prs. are in both cases (181) more proper for battering in breach than 32 prs. and the sole reason why they are not used in the attack of places, is the difficulty of transporting and working them.

185. Since

185. Since solid and resisting bodies are demolished by the division of their parts, and those that are less tenacious by the penetration of shot into them (182, 183); bodies partaking of these two physical qualities, are demolished in a compound manner (181, No. 3): of this kind are walls built of brick or similar materials. The effects of shot on walls are much modified by the proportion that the force of percussion bears to the resistance. When two shot of different diameters penetrate to great depths, the holes are in the ratio of $D^3 u^2$ (184): but, if one penetrate to a great depth, and the other but a little way, this proportion will not be just; for, the hole made by the latter, is less than what results from the expression $D^3 u^2$; so that if its force be only sufficient to overcome the resistance, it will bury but a small part of its circumference. Hence it is easy to comprehend, why shot projected from 8 and 4 prs. are sometimes insufficient to beat down walls of this kind; while that they produce all the effects expected from them, when fired against other walls. The direction of the shock, considered relatively to the thickness of the wall, likewise contributes to modify its effects: a shot that with great impetus impinges with a direct shock on a thin wall, passes through, and only makes a hole, without shaking or disuniting the contiguous parts: but, if a wall of the same quality be thick enough to receive all the force of the shot, it, beside making a hole, shakes and loosens the rest of the wall. A single wall is soonest demolished by firing against it directly with small charges, or obliquely with large ones; since the shot not being able to pass through, it receives all its force: the service of artillery in ricochet and hot-firing, is discussed in the subsequent treatise.

C H A P. IV.

OF THE EFFECTS OF CANNON SHOT IN ENGAGEMENTS.

186. **I**N forming a train of artillery for the service of an army in the field, there are several points to be considered: the nature and disposition of the ground; the kind of war that is to be carried on; the intended plan of operations;

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rations;

rations ; the number and quality of the troops that compose the army, and their manner of fighting.

A general commanding an army, should be acquainted with the effects of artillery, that he may know when it can be employed to advantage ; and how far, when judiciously and skilfully served, it can contribute to the attainment of his object (141, 142).

187. In countries where the transport of carriages is attended with no great difficulty, the train of artillery that march with armies, are composed of medium guns, cast of metal containing $\frac{1}{8}$ of tin, and carrying balls of 16, 8, and 4lbs (64). These guns are divided into brigades: the heaviest should not weigh more than 32 cwt. as the bridges constructed by the peasants for their carts and waggons can seldom support a greater weight: beside, if the road be not hard, or have been spoiled by preceding rains, it will be impossible to move heavier guns, even at the opening of the campaign; and, in autumn, when the roads are generally deep, the cattle will be exhausted with the fatigues they have already undergone. Therefore, *the species of artillery should be always adapted to the nature of the country.*

In carrying on offensive operations in a champaign country, the train of artillery should be composed of 8 prs. ; to which may be added a few 16 prs. for occasions of great exertion: there should be a few short light guns (97) to accompany any corps of the army that may be destined by rapid marches to fall on the enemy's convoys or cut off their detachments. In deep hilly countries, short 8 and 4 prs. should be the heaviest guns used: indeed, an exact knowledge of the nature of the country is the best rule for determining the calibre as well as number of the guns.

When the army is to remain on the defensive in a country where the roads are tolerably level and good, and there is no great probability of being obliged to make very long movements, the number of 16 prs. should be greater than would follow an army acting offensively in the same country; but if this defensive system be carried on in a strong country, where the transport of carriages is difficult, and long and rapid marches may be indispensibly necessary; the brigades of artillery should be so constituted as easily to keep up with the army. Any post that the general may wish to occupy and maintain during the campaign should be provided with guns of large calibre (71).

Having

Having already treated of the nature and importance of these posts in the 6th Book of Military Architecture, I leave it to the professors of the academies to explain them fully to the cadets of the royal corps of artillery; that being equally masters of the principles of tactics and fortification, as of their own profession, the service may on every emergency reap the greatest benefit from their knowledge and exertion.

188. These guns are able to bear the largest charges; yet they should not be used but in cases of absolute necessity and when they cannot derange the firing: in all other cases, the charges ought to be proportioned to the initial velocity that the projectile should have to produce the desired effect. For example, the medium charge may be used in enfilading columns of troops; as the shot from its greater velocity will destroy a greater number of men: but if the less charge will impel the shot from front to rear of the column, the medium charge would serve no other purpose than unnecessarily to heat the gun. Against an enemy drawn up three or four deep, the less charges should be used; as the least charges may from some neglect in wadding be uncertain in their execution.

189. From the desire of firing quick in action the greater part of the shot do not take effect; since in working the guns with such precipitation, there will most probably be a want of attention in loading, laying, or some other essential point. The frequency of firing should be regulated by the certainty of doing execution; those who are actuated by any other motive frustrate the designs of the general, and are the cause of all the bad consequences that may ensue: they can neither be justified by the anxious desire that the troops express to see them fire quickly, nor by a chimerical point of honour, which is by some individuals absurdly placed in firing so many rounds in a minute. Whenever the distance is so great or the object so small, that the chance of hitting it is very uncertain and precarious, it would be much better to cease firing and wait till by a nearer approach or by some movement of the enemy, an opportunity offers of doing effectual execution.

190. In engagements, the enemies troops are the objects against which cannon shot are directed; it is therefore highly necessary to know the effects that shot of different diameters, and with different velocities, can produce upon a body of troops, according to the distances at which they engage;

otherwise, the artillerist will in a variety of circumstances be unable to use his gun to the greatest advantage (141).

In firing at infantry, the height above the plane of the ground is about 6 feet, and in firing at cavalry not more than 10 feet; wherefore the distance should never exceed 680 yards, except when the enemy is drawn up so deep, that the shot can hardly fail of taking effect.

The execution of cannon shot in action is estimated from the number of men that are killed, or wounded in such a manner as to be disabled from further immediate service: it is unnecessary to consider the depth of the wounds; as a man struck by a cannon ball is generally incapacitated, at least for the present. The great object of the artillerist "is to endeavour to strike with each shot the greatest number of men possible" (141 142): this depends;

1. On the disposition of the enemy, and the nature of the ground.
2. On the calibre of the guns and the judicious use of round or case shot:
3. On the velocity with which the shot are impelled, and the distance between the battery and the enemy.

191. There are two cases with regard to the nature of the ground (190 No. 1); the first, when the two armies are drawn up on ground nearly on the same plane: the second, when they are on planes differently inclined. When they are both on the same plane, whether horizontal or inclined, the surface exposed to the fire of the cannon is a part of the first line; should this be the head of a column, or the flank of a body of troops ranged in order of battle, the shot by enfilading them will be very destructive. But if the enemy be drawn up three or four deep in front of the gun and within proper distance, case shot will do most execution; since a round shot can in this case, only carry off a file of three or four men, whatever be its diameter or velocity.

192. When the two armies are on different planes, the execution of the artillery must depend on the extent of front and depth of files: on considering the principal cases that can occur in the two general dispositions of an army, viz. drawn up in column, or line; it will appear:

1. That if the enemy be drawn up in column on the slope GF inclined towards F , the head only of the column G (Pl. 6. Fig. 21.) will be exposed to the can-

non

non A : case shot will then be preferable to round shot, if the distance A G admit of it.

2. If the column be on the slope G E inclined towards E or on the height N B M ; it will present to the cannon A an object of great extent, and be from its situation very much exposed : the closer the ranks are, and the deeper the column, the more destructive will be the fire of the artillery.

3. If A B be within range of case shot, its greatest effect will be at N B M, where from the divergence of the shot each may strike a man ; while that in G E much nearer to the gun, the shot not having had time to spread, each man will be struck by two or three, and the execution will of course be less.

4. When the column reaches the horizontal plain P E, it will suffer less than in the former situation : if A and P E be nearly in the same plane, fewer men will be exposed than at A P : the case shot should then be composed of balls of the largest diameter that each of them may kill or wound more than one man ; and then every ball that strikes will enfilade the whole disposition. If P E be lower than A, so that the guns at A must be much depressed ; case shot composed of the smallest balls will be the best ; since from the greater number their effect will be equal to that produced in the former instance by the large balls ; there being in this case no probability of establishing an enfilade.

5. The enemies army drawn up three or four deep upon the height G will be exposed to the same danger, as when in column on the slope G F ; but by retiring a little, G will serve as a parapet, under the cover of which they may securely fire at A.

6. Should the enemy be drawn up three or four deep upon the slope E G, the greatest effect of a round shot will be to carry off a file of men even when the ranks are very close : but if there be a considerable interval between them, case shot, when the distance admits of it, will be most destructive, both in this instance and when the enemy has advanced to the horizontal plain P E.

193. The direction in which guns should be fired depends on the initial velocity of the shot, its diameter, and the distance

stance from the enemy; the formulas $q = \frac{crt}{r+t}$, $S = \frac{32 \cdot 18 t^2}{2}$ (165, 166) will give a solution of the problem.

The opinion of some artillerists, that guns in time of action ought always to be fired horizontally, or at most with $\frac{1}{2}$ degree of elevation, can only be just in particular cases; the following example will evince the necessity of sometimes deviating from this maxim. Let the gun AB (Pl. 5. Fig. 14.) be fired in the horizontal direction AC with the charge that gives an initial velocity of 1416 feet; and from the resistance of the air, $r = 9.5$. Now supposing the gun and the enemy to be in the same horizontal plane; Let KG represent the vertical distance between the two planes AC, DF; KG will then express the space = S passed through by the power of gravity, and by substituting the value of KG in the formula $S = \frac{32 \cdot 18 t^2}{2}$ it will give the time of the shot's

flight before it touch the ground in the plane DF: then by

substituting in the formula $q = \frac{crt}{r+t}$ the known value of t ,

the extent of the range $AK = DG = q$ will be found. For example, if $KG = 5\frac{1}{4}$ feet, the time = t will be 56 parts of a second; and by substituting the values of c, r, t in the formula, $q = 760$ feet. To strike the ground then in the same plane DF at a greater distance, the gun must be elevated in proportion to the increase of distance; should the enemy be at G where the shot touches the ground at the first graze it will only strike his feet; to hit him in the breast the gun must be elevated.

194. The more clearly to explain this theory, and enable others to apply it to the practice on several occasions that occur on service, the following table has been calculated: the gun and butt are supposed to be in the same plane, and from the resistance of the air $r = 12$ in a 32lb. shot; the wads are rammed with equal force and in the manner before expressed, (143, 150); except in the quick firing, when none are used.

Angles of Elevation for firing Guns of different Lengths and Calibres with different Charges of Powder, to project Shot to different Distances.

Nature of Guns.	Weight of Powder.	Initial Velocity.	Distance from the Butt.											
			340 Yards.				680 Yards.				1000 Yards.			
<i>Prs</i>	<i>lbs.</i>	<i>ca.</i>	Line of descent.	Elevation.	Line of descent.	Elevation.	Line of descent.	Elevation.	Line of descent.	Elevation.	Line of descent.	Elevation.		
			<i>Fect. In.</i>	<i>Deg. Min.</i>	<i>Fect. In.</i>	<i>Deg. Min.</i>	<i>Fect. In.</i>	<i>Deg. Min.</i>	<i>Fect. In.</i>	<i>Deg. Min.</i>	<i>Fect. In.</i>	<i>Deg. Min.</i>		
Short guns Of the common length. (66.)	4	8	10	6	10	6	10	6	10	6	10	6		
			9	9	9	9	9	9	9	9	9	9		
			9	8	9	8	9	8	9	8	9	8	9	
			10	—	10	—	10	—	10	—	10	—	10	
	4	8	16	13	—	13	—	13	—	13	—	13	—	
				13	—	13	—	13	—	13	—	13	—	
				13	6	13	6	13	6	13	6	13	6	
				14	6	14	6	14	6	14	6	14	6	
	4	8	16	15	—	15	—	15	—	15	—	15	—	
				15	6	15	6	15	6	15	6	15	6	
				23	6	23	6	23	6	23	6	23	6	
				25	7	25	7	25	7	25	7	25	7	
	4	8	16	57	3	57	3	57	3	57	3	57	3	
				65	7	65	7	65	7	65	7	65	7	
				675	—	675	—	675	—	675	—	675	—	
				675	—	675	—	675	—	675	—	675	—	

without
wads.

195. Many practical inferences may be deduced from this table :

1. Guns of the common length loaded with the medium charge should be elevated half a degree above the horizon to range 340 yards, and $1^{\circ} 20'$ to range 680 yards ; the elevation must be greatly increased to range 1000 yards. The less the calibre of the gun is, the higher must be the elevation.

2. The elevation of short guns fired with the less charges must be greater than of guns of the common length to range the same distance.

3. If a short 4 pr. loaded with the less charge, range 1000 yards, the line of descent is 278 feet ; wherefore the shot's path being a curve of the fourth kind, it will do much less execution in enfilading troops, than shot fired from guns of the common length whose path is a curve of the second kind.

4. The elevation of short guns loaded with the least charge increase in the ratio of the distance : thus the curve described by shot fired from 8 and 4 prs. to the distance of 1000 yards is of the fourth kind ; from the angle of incidence they can be of no service in enfilading, and are very uncertain : the angle of incidence (168°) at the distance of 1000 yards being much larger than the angle of elevation, if the shot fall on soft ground they bury themselves at the first graze.

5. Shot fired from short guns with the least charges and without wads, which range only 680 yards, also describe a curve of the fourth kind ; they are consequently useless in enfilading, and their execution is uncertain.

6. If to these reflections be added the consideration, that in pointing short guns the eye is more easily deceived, from the proximity of the two points of sight, than in longer guns ; and that in the latter the angle of elevation being less, the angle of incidence is less also ; so that the shot on touching the ground rise and from their ricochet are very dangerous : it will be evident that to derive from the use of artillery the greatest possible advantages, *long guns should ever be preferred to short ones of the same calibre.* The good effects resulting from this will be more fully displayed in the sequel.

196. To

196. To form a comparison of the effects that shot of different diameters with different initial velocities produce at different distances on a body of troops; they must be considered as a homogenous butt: then the formula $S = Dv^2$ (183) will give the relative penetrations. The absolute number of men that a shot with a given initial velocity will pass through may be determined by experiment.

The relative penetrations in the following table have been calculated on a supposition that from the resistance of the air $r=12$ in a 32lb. shot, in order to compare together the number in this and the preceding table (183). The calculations are not carried beyond 680 yards, which is considered in field engagements as the greatest distance that shot can range to, with a certainty of doing execution; in extraordinary cases indeed, when the nature of the ground and the position of the enemy are very favourable (192), the range may be extended with tolerable success.

The relative Penetrations of Shot projected from different Distances with given initial Velocities.

Nature of Guns.	Weight of Powder.		Initial Velocity. Feet.	Close to the Butt.	At 340 yards.	At 680 yds.	
	Prs.	lbs. oz.					
Common length.	16	3 10½	1240	17571	11878	8509	
	8	2 7½	1265	14625	9360	5743	
	4	1 3¼	1283	11840	6754	3479	
Short Guns.	8	2 7½	1206	13329	8358	4919	
	4	1 3¼	1222	10784	5933	2944	
	8	1 10¼	978	8746	4874	2450	
	4	— 13½	978	6896	3230	1271	
	8	without wads	10¼	675	4110	1738	427
	4	wads	13½	675	3241	1024	251

197. To reduce into numbers the relative penetrations inscribed in the tables (183, 196), make the following or similar experiment: with a charge that gives a known initial velocity, fire a gun against a butt, and measure the penetration of the shot: then place two horses or other cheap animals close to the same butt, and lay the gun so that the shot after passing through the most solid parts of their bodies may

may enter the butt : on measuring the penetration, it will be found less than the former; and by comparing them together, the number of horses that a shot of a given diameter, with the same initial velocity, could pass through, may be ascertained. On comparing the resistance of a horse's, with that of a man's body, the number of men that the same shot would pass through may be easily calculated. An 8 lb. shot, with an initial velocity of 1450 feet, will pass through 20 horses; and in this table it is presumed on tolerably just grounds, that the same shot would pass through double the number of men, even if it struck the most solid parts of their bodies; the number therefore that may be struck in less resisting parts of the body and disabled must be greater, and may even exceed twice the number of the former. The table has been deduced from the former proportions (183, 196).

Number of Men that can be pierced by Shot projected from different Distances with given Initial Velocities.

Nature of Guns.	Weight of Powder.		Initial Velocities.	Close to the Butt.	At 340 Yards.	At 680 Yards.		
	lbs.	oz.					Feet.	No. Men.
Common Length.	32	13	2	1517	70	55	44	
	16	6	9	1618	63	48	36	
	8	4	14½	1696	55	39	28	
	4	2	7½	1720	45	30	19	
	32	9	13½	1350	55	43	32	
	16	4	14½	1416	48	35	25	
	8	3	4½	1450	40	28	18	
	4	1	10½	1467	33	20	12	
	16	3	10½	1240	36	24	17	
	8	2	7½	1265	31	20	13	
	4	1	3½	1283	25	14	8	
	8	2	7½	1206	28	18	11	
Short Guns.	4	1	3½	1222	23	13	7	
	8	1	10½	978	19	10	5	
	4	—	13½	978	15	7	3	
	8	without wads.	1	10½	675	9	3½	7
	4	—	13½	675	7	2	7	
	4	—	13½	675	7	2	12	

198. Several inferences of great practical utility may be drawn from this table :

1. Guns of large calibre fired at very short distances, with the large or even the medium charges against a corps of troops exposed to be enfiladed, will cause much more slaughter than 8 or 4 prs. especially if short with the least charges.

2. The relative effects of guns of different natures increase in the ratio of the distances; and there is greater difference between the calibres of the guns and the charges of powder.

3. Guns should never be fired without wads, except in particular cases, and when the enemy is very close. Thus when 4 prs. or short guns compose a field train, it is not because they are equal in their effects to longer guns of large calibre, but only because heavier guns cannot be transported with the same facility. When part of an army is to remain on the defensive in a fixed post, the same arguments will evince the propriety of giving the preference to longer guns of large calibre.

199. If the enemy troops be drawn up three or four deep, the effects of an oblique fire will be greater in proportion as the angle of incidence on their front is more acute; since the resistance not being sufficient to turn the shot, it will penetrate in the direction in which it impinges. On the contrary, the effect will be less, the nearer the angle of incidence approaches to a right angle; since it will then only destroy a single file, whatever be its diameter or initial velocity. In this case, if the two armies be within reach of musquet shot, the situation of the artillery-men will be very perilous; for eight paces at least must be left between every two guns, to give the men room to work them; each gun is then exposed to the fire of eight file of musqueteers; or in other words, each artillery-man to the fire of three or four musquets. Thus at a single discharge, all the artillery men may be killed or wounded; while one round from each gun can only carry off a single file of the enemy: when half of the artillery-men are wounded, the gun must cease firing; but the fire of the musquetry will be incessantly kept up, in proportion to the number of men that remain.

200. The fluid generated in a piece of ordnance is so much the more abundant and elastic, as the body it must impel towards the muzzle is heavier (Treatise on Powder).

Whence

Whence it is easy to conceive; that in putting two shots into a gun, the velocity of each must necessarily exceed half of the velocity that one shot with the same charge would acquire; and the quantity of motion of the single shot is less than the sum of the quantities of motion of the two shot: but in ascertaining the effects of the three shot, their force after passing through the men and horses being supposed to be entirely spent, the equation $S = Du^2$ which expresses the effects of one shot must be changed; and to make up the excess, the initial velocity of each of the other two shot must exceed $u\sqrt{\frac{2}{3}}$; and each should strike a separate file. The proportion between the initial velocity acquired by one shot fired singly, and that acquired by each when two shot are fired together with equal charges, can only be determined by experiment, as it changes whenever the charge is altered; but it may be remarked, that in practice the velocity of each of the two shot is less than $u\sqrt{\frac{2}{3}}$: wherefore the expedient of putting two shot into a gun can be only advantageous when the enemy is drawn up in such a manner, that each shot has sufficient velocity to carry off a file. For example, suppose the enemy be drawn up eighteen deep, and each of two shot fired together from an 8 pr. could strike a separate file with an initial velocity of 978 feet, each of them would destroy 18 men (197): under this supposition there would be 36 men destroyed by the two shot; while a shot of the same diameter, fired singly with an initial velocity of 1450 feet, could destroy only 18 men; then its remaining velocity sufficient to destroy 20 more would be useless.

C H A P. V.

OF THE EFFECTS OF CASE OR GRAPE SHOT IN ENGAGEMENTS.

201. **T**HERE are several kinds of shot that come under this head: one is formed of small pieces of iron of different shapes and sizes put into cylinders of tin or pasteboard; the bases of which are closed by two circular pieces of wood.

A second

A second called *case shot*, is composed of small iron balls put into tin cylinders; or regularly disposed in linen bags fastened to a wooden bottom, in the middle of which is a spindle, and wound round with cord or wire; the latter present the appearance of a bunch of grapes, and are called *grape shot*. The first kind is generally used in the defence of places; and fired from the low flanks, where in spite of their divergence they are useful in scouring the ditches and counter-scarps: the resistance of the air, from the irregularity of their figure, renders them in effect more uncertain than spherical shot; but as the objects against which they are fired are always very near, they have force enough to do execution. The second kind is generally designed for field service, as the balls diverge less, and, from their spherical figure encountering less resistance in the air, range farther.

202. In the late wars, our trains of artillery were formed of medium 4 prs. (64): the case-shot for these guns contained 63 or 64 leaden bullets, each weighing $\frac{1}{4}$ of an ounce; the whole weighed nearly as much as a round shot of the same diameter. In order to ascertain their effects, the officers of artillery in 1743 made the following experiments: a 4 pr. was fired against a target of plank 80 feet in length by 10 in height, erected on the same horizontal plane with the gun; so that some of the balls after grazing rose and struck the target: case and grape shot were fired, but no difference in their effects was perceptible. In the first experiments, the charge was 1 lb. 10 oz. of powder, and over the wad, which was well rammed, was placed the case: at the distance of 200 yards, only 3 or 4 balls struck the target. The gun being moved 30 yards nearer, 9 or 10 balls struck it; but the greater part did not go through the planks, which were an inch thick: those that struck were partly melted, and two or three were found in different places sticking together. At the second experiment, the case was placed immediately over the powder and a wad rammed over the whole: at the distance of 170 yards very few of the balls went through the planks, though the report of the explosion was as loud as at the former experiment; others had not force enough to enter, and those that struck were much more liquefied than before; 4 or 5, and at one time 15 were found sticking so closely together as to form a lump of lead. At other experiments, when the case was placed over the

the powder without a wad, the balls at 170 yards struck the target with rather more force, and were not liquefied, though the report at the discharge was more feeble than at the second experiment. At each round, the number of balls that struck the target was between $\frac{1}{8}$ and $\frac{1}{6}$ of the whole; and $\frac{1}{2}$ or $\frac{2}{3}$ of these struck it below a horizontal line drawn 5 feet from the ground. The greatest divergence of the balls at this distance was 60 feet, but frequently not more than 33.

203. Some rounds being fired from the same gun at 170 yards, with $1\frac{1}{4}$ lb. of powder; the number of balls that struck the target was between $\frac{1}{4}$ and $\frac{1}{6}$ of the whole, but their force was less: in these, as in the former experiments, a wad was rammed over the powder; in the second, a wad over the whole; and in the third no wad was used. Two cases being put into a gun and fired together, the number of balls that struck the target was between $\frac{1}{3}$ and $\frac{1}{2}$ of the whole number in the two cases; many of those that touched the target had not force enough to penetrate. The gun being removed to 200 yards and fired again with two cases, about $\frac{1}{10}$ of the balls struck the target, but with much less force.

204. It results from these experiments (202, 203):

1. That case-shot of this nature should never be fired at a greater distance than 200 yards, against objects not exceeding 10 feet in height.

2. A wad should be put between the powder and case; but as sometimes in quick firings this must be dispensed with, the balls will yet have force enough at 200 yards to wound a man.

3. That the greatest possible effect of case shot is when fired against an enemy drawn up in form of a vast amphitheatre between 170 and 200 yards distant, by putting two cases into the piece and using the less charges of powder.

4. That with one case, 6 or 7 men of the front rank may be struck at 170 yards; and still a greater number when two cases are put into the gun: when advanced nearer to the enemy, the balls will pass through the bodies of the men in the front rank and wound those in the rear.

5. That the firing with case shot should commence at 170 yards in order to acquire a superiority over the enemy's musquetry; the effect of platoon firing at that distance

distance is uncertain, while case shot fired with judgment will strike at each round a certain number of men.

At other experiments (202, 203) with case shot composed of iron balls 1 oz. in weight, the whole case weighing as much as the round shot of the same diameter; it resulted that at 200 yards, 3 or 4 balls struck the target, and at 170 yards 8 or 10 struck it; the force of these balls seem to exceed that of the leaden bullets.

205. These conclusions agree with what has been advanced on the same subject, in the practice of artillery and the elements of tactics. It will be shewn in the sequel, that greater advantages may be derived from the use of field pieces than has been hitherto done, in constantly maintaining a decided superiority of fire over infantry drawn up in front of the guns (199) through the use of tin cylinders filled with iron balls weighing more than 1 oz.

To ascertain this, the force and direction with which each ball is impelled, and the proper elevation for the piece should be considered: the two following tables will give a just idea of their force; in the first are set down the relative penetrations calculated (183) on a supposition that the initial velocity is 1450 feet, and that from the resistance of the air to a 32 lb. shot $r=12$, in order to form a comparison between these and the former tables (183, 196): in the second are marked the results of the former experiments (197) and the penetrations inscribed in the first table are reduced to absolute numbers.

• TABLE

Relative penetrations of iron case shot.

TABLE I.

Weight of ball.	Value of r	Clofe to the butt.	At 170 yards.	At 340 yards.	At 510 yards.	At 680 yards.
13	3.8	9614	6553	4283	2655	1538
6 $\frac{1}{2}$	3.	7580	4642	2645	1365	620
3 $\frac{1}{4}$	2.39	6040	3251	1524	604	181
1	1.65	4139	1621	470	74	2

TABLE II.

Number of men that can be pierced in the most solid parts of the body by case shot, of the following weight projected from different distances, with an initial velocity of 1450 feet.

Weight of balls.	Clofe to the butt.	At 170 yards.	At 340 yards.	At 510 yards.	At 680 yards.
ozs.	Men.	Men.	Men.	Men.	Men.
13	20	14	9	6	4
6 $\frac{1}{2}$	16	10	6	3 $\frac{1}{2}$	1
3 $\frac{1}{4}$	13	7	3 $\frac{1}{2}$	1 $\frac{1}{2}$	1 $\frac{1}{2}$
1	9	4	2	1	1
					8614

206. From these premises (190, 191, 192) it may be inferred.

1. That when balls of which case shot are composed weigh 13 oz. each, every ball can pierce a file of 20 men, when fired very clofe; and 4 men at the distance of 680 yards. If each ball weigh 6 $\frac{1}{2}$ oz. it can pierce 16 men when very near; 10 at 170 yards; 3 or 4 at 510 yards; and one only at 680 yards. If each ball weigh 1 oz. it can pierce 4 men at 170 yards; and mortally wound 1 man at 340 yards; the latter is expressed by

by the fraction $\frac{1}{2}$; the same ball at the distance of 680 yards will hardly make a contusion, which is expressed by the fraction $\frac{1}{8212}$.

2. Balls of 1 oz. at 170 yards, those of $3\frac{1}{2}$ oz. at 340 yards, those of $6\frac{1}{2}$ oz. at 510 yards, and those of 13 oz. at 680 yards, produce the same effect; viz. of destroying 4 men; which evinces the propriety of using cylinders filled with large balls for great distances, and with the smaller balls for short distances.

3. On comparing the numbers in the two tables (197, 205), we find that an 8 lb. shot, with an initial velocity of 1450 feet, will pass through a file of 40 men when fired very close to them; 28 at the distance of 340 yards, and 18 at the distance of 680 yards: while a $6\frac{1}{2}$ oz. ball will only destroy 16 men when very near, 6 at the distance of 340 yards, and 1 man at 680 yards; so that with case-shot of this nature, if 5 balls strike 5 separate files, the effects when very near will be $16 \times 5 = 80$ men destroyed, $6 \times 5 = 30$ men at 340 yards, and 5 only at 680 yards. Hence it results, that the effects of case shot fired under similar circumstances, are greater than of round shot of equal diameter, when the distance does not exceed 340 yards; but at 680 yards round shot have a decided advantage.

207. These remarks (205, 206) are applicable to every case that can occur, allowance being made for the difference of the initial velocities; wherefore the effect of the initial velocity on case shot impelled with a given charge of powder should be ascertained. It has been found experimentally, that when the balls are regularly arranged in the tin cylinder in the manner that will be hereafter pointed out, and are equal in weight and diameter to the corresponding round shot, the greater part of them are impelled with the same initial velocity as the round shot, but the remainder with less; provided the charges be equal. This result is constant; hence the effects of case shot fired from different distances with different charges of powder may be determined with sufficient accuracy for practice (205).

208. In firing case shot, the balls are observed at first to take a diverging direction, and for a certain distance to form a kind of a cone; the base of which is towards the object fired at, and the vertex towards the gun.

It is impossible from theory alone to determine the direction

rection that each ball takes after the case is broken; since the contact of the balls and their reciprocal pressures at the discharge and at the commencement of their divergence are unknown: It must then as far as possible be ascertained experimentally.

Experiments made with the greatest attention have given the following results;

1. The conical figure is preserved for a certain distance; after which it is entirely lost.

2. The proportion between the formation of the cone and the point where it begins to lose the regularity of its figure depends on the size of the balls, and their initial velocity: the distance will be less in proportion as the balls are smaller, or their initial velocity less.

3. At equal distances, balls impelled from guns of the common length diverge much less than balls of the same weight and diameter impelled from shorter guns with the same charge. This must be a familiar remark to sportsmen who have used fowling pieces of different lengths.

4. When the balls are ranged in the cylinder in regular order, they diverge much less than when put in carelessly; those of 13, $6\frac{1}{2}$ and $3\frac{1}{4}$ oz. may be regularly disposed in tin cases of the diameter of 16, 8, and 4 prs.; and such only will be in future considered: 1 oz. balls should be disposed in the cylinder in the most convenient manner, and fired at any distance less than 220 yards.

5. From certain distances a greater number of men may be struck by case than by round shot, if the gun be properly laid.

209. The angle that the axis of the gun should form with the horizon is determined (165, 166) on a supposition that the balls in the tin case are impelled in the direction of the axis, which is not always just; as they sometimes quit the case under different angles. The least error in loading or pointing a gun may render a round shot of no effect, but be of little consequence in firing with case shot.

210. In order to shew in one part of view the most interesting particulars in the use of case shot, the following table has been calculated; the initial velocities of a 32 lb. shot are supposed to be 1450 and 1206 feet, and $r=12$ for the resistance of the air, to enable the reader to compare it with the former tables.

Angles

Angles of Elevation at which Guns should be fired with Calc Shot, with the initial Velocities of 1450 and 1206 feet, from the following Distances, supposing the Battery and the Enemy to be in the same Plane.

		Distances between the battery and enemy.											
		170 yards.			340 yards.			510 yards.			680 yards.		
Nature of cate that.	Initial velocity.	Line of elevation.		Line of deflect.		Line of elevation.		Line of deflect.		Line of elevation.		Line of deflect.	
		Ang.	Dist.	Ang.	Dist.	Ang.	Dist.	Ang.	Dist.	Ang.	Dist.	Ang.	Dist.
1450	1450	4	170	4	170	4	170	4	170	4	170	4	170
		4	340	4	340	4	340	4	340	4	340	4	340
		4	510	4	510	4	510	4	510	4	510	4	510
	1206	4	170	4	170	4	170	4	170	4	170	4	170
		4	340	4	340	4	340	4	340	4	340	4	340
		4	510	4	510	4	510	4	510	4	510	4	510

211. From this comparison the following practical inferences may be drawn ;

1. Balls of $3\frac{1}{4}$ oz. that with an initial velocity of 1450 feet range 680 yards, describe a curve of the second kind ; the remaining force at that distance may be expressed by the fraction $\frac{1}{9\frac{1}{2}}$; but it is injudicious to fire a case shot of this nature at such a distance, as their execution is trifling : 1 oz. balls ought never to range 680 yards, as they describe a curve of the fourth kind, and are totally useless in enfilading ; their remaining force may be expressed by the fraction $\frac{1}{36\frac{1}{4}}$ and is hardly sensible.

2. Balls of $3\frac{1}{4}$ oz. that with an initial velocity of 1450 feet range 510 yards, describe a curve of the second kind, and may be of service in enfilading ; but as they can destroy only one or two men, this is the greatest distance at which they should be fired : as to 1 oz. balls, though at 510 yards their curve is of the second kind, yet as the expression of their force is $\frac{1}{7}$, the distance is too great : 340 yards should be their longest range, the expression of each ball is then $\frac{2}{5}$.

3. As a ball of $6\frac{1}{2}$ oz. with an initial velocity of 1450 feet can only destroy one man at 680 yards, it should be considered as the greatest distance ; though from the nature of the curve, it might still be useful in enfilading.

A ball of 13 oz. with the same velocity and at the same distance will destroy a file of 3 or 4 men.

4. When the initial velocity is 1206 feet, the curvature of the lines of descent is greater than when it is 1450 feet ; consequently case shot with the former velocity are less proper for enfilading : they should only be used at short distances, in proportion to the difference between the actual velocity and 1450 feet.

5. A small charge of powder can only have the same effects as a large one, when the enemy is drawn up 3 or 4 deep, and so close that a single ball can carry off a whole file ; the same observation holds good with respect to short guns, since from the initial velocity (151) their range is short.

6. The number of balls that, with velocities equal to or less than those above mentioned, will strike an object of certain dimensions at a given distance, can only

only be determined by experiment. It is not possible to ascertain the particular direction in which the

212. The results of the preceding theory, and the resistance of the air be considered as being at any other determinate value, will never exactly coincide with practice; since the absolute effects of the fire cannot be aligned, but only a proportion established between the greatest and least effects: wherefore it is necessary to use the first three field pieces to the best advantage, having regard to the following particulars.

1. For 16 lbs. there are four kinds of case fire; the first, composed of 16 balls of 33 grs. is never fired with the medium charge above 140 yards against an enemy drawn up 3 or 4 feet: when they are discharged in deeper order, the distance should be less. The second kind is composed of 32 balls of 33 grs. and its greatest range is 320 yards, when the elements are disposed in few ranks: the longest range of the third kind, composed of 64 balls of 33 grs. is 320 yards: the range of the fourth kind, composed of 128 balls of 33 grs. should never exceed 220 yards.

2. There are 3 kinds of case fire for 8 lbs. the first contains 16 balls of 33 grs. and may with the medium charge be fired at the distance of 320 yards: the second contains 32 balls of 33 grs. its range should not exceed 340 yards: the third contains 64 balls of 33 grs. and may range 220 yards.

3. For 4 lbs. there are two kinds of case fire: the first contains 16 balls of 33 grs. and its range with the medium charge should not exceed 320 yards: the second contains 48 balls of 33 grs. and its greatest range should be 220 yards.

4. The number of balls in a 16 lb. case being twice the number of balls of the same diameter in an 8 lb. case, if the two guns be fired from the same distance with the same initial velocity, the effect of the 16 lb. should be double that of the 8 lb. and the effects of an 8 lb. should be double that of a 4 lb. under the same circumstances: guns of large calibre also ranging farther, there will be still a stronger reason for preferring them to guns of smaller calibre, whenever the nature of the ground will of the service admits of it. If case fire be fired from a 16 lb. with an initial velocity less by $\frac{1}{2}$ than the initial velocity

of case shot containing balls of equal diameter fired from an 8 pr. and the distances be equal; the effects of the 16 pr. will in certain cases be greater than the effects of the 8 pr.; for the same reason, the short 8 pr. (66) is sometimes to be preferred to the common 4 pr. as in the instance of the enemy being formed on sloping ground in figure of an amphitheatre, (as happens in mountainous countries) and very near the battery; the 8 pr. case containing double the number of balls that the 4 pr. case does, will do more execution.

5. By increasing the number of balls in the case, the initial velocity, and of course the effect of each is sensibly diminished. When fired against troops disposed in very deep order (200) on an amphitheatre of hills, and very near the battery, the greater the number of balls is, the greater the slaughter will be; and as in this instance, two cases may be put into the gun at the same time, it will be sufficient if the weight of each be equal to that of the round shot.

6. When the enemy is drawn up in very deep order, the medium charge of powder should be preferred to the less, both with round and case shot; the distance at which each nature of shot should be used will be best determined by recurring to the preceding theory (206, No. 3), and the results of former experiments (211 No. 6).

7. If it be necessary in the course of a campaign to place some 32 prs. in a fixed post, five kinds of case shot should be prepared for them: the first with 16 balls of 26 oz. to range 850 yards: the second with 32 balls of 13 oz. the third with 64 balls of $6\frac{1}{2}$ oz. the fourth with 128 balls of $3\frac{1}{4}$ oz. the fifth with 384 balls of 1 oz. the four last may be fired under the restrictions already laid down. The two former may be of excellent service in the defence of places at the opening of the trenches; but as the balls spread very much, they should be used with caution, lest they hurt the detachments of the garrison posted in the advanced works.

213. Balls of hammered iron are the best for case-shot; but, if from motives of œconomy they be made of cast iron, the metal should be of a hard and tenacious quality, or they will break to pieces at the explosion: the number that break increase in proportion to the augmentation of the charge. Each shot therefore before it is put into the case, should be placed

placed upon an anvil, and receive a smart blow from a heavy hammer; if they stand this proof, they are fit for service. The cylinder of tin should be of the same diameter as the corresponding round shot; one end is closed by a wooden cylinder $1\frac{1}{4}$ or $1\frac{1}{2}$ inch thick, on which the first row of balls is regularly placed, putting into the interstices small pieces of wood to keep them firm: the balls of the second row are placed over the interstices of the first, and each row is fixed with chips or something of that kind to prevent their moving, when the ammunition waggons pass over rough and stony roads; which might break the cylinder or deform it, so that it would not enter the gun. All the rows of balls being thus disposed, the top of the cylinder is closed by a cylindrical piece of wood $\frac{1}{2}$ an inch thick, nailed to the tin, and marked so as to be easily distinguished from the base; and on the top is marked the diameter of the balls contained in the case, that the artillery men may make no mistake in the nature of the case-shot, or in the manner of placing it in the gun.

If mastic be used instead of chips, to fix the balls in the case, its tenacity will increase the force of the powder and the balls will diverge less. The best mastic for this purpose is made of melted pitch and powdered marble: but the quantity should be proportioned to the force of the charge; for if it be of such tenacity that the case reaches the object before it breaks, or breaks very close to it; all the advantage arising from the proper divergence of the balls would be lost: the effect of these projectiles being evidently as much diminished by too little as by too great divergence (190).

214. To derive from artillery in field engagements the fullest advantages (212), the following rules should be adhered to:

1. Brigades of the heaviest guns in the army should be posted at the points whence it is proposed to make the greatest efforts against the enemy, or where the briskest attack on their part may be expected: and the guns of smaller calibre placed so as to favour the principal attacks and distract the enemy's attention.

2. In posting brigades of artillery in a defensive situation, a parapet, ditch, hedge, pallisadoe, chevaux de frize, or other obstacle, should be placed before them, to keep the enemy in check; in case they advance with fixed bayonets.

3. There should be to each brigade a reserve of artillery

lety men covered by an epaulment or the ammunition waggons, to replace without loss of time any that may be killed or wounded. If it be judged expedient to draw up an army in two lines, that the troops of the second line may in case of necessity be brought forwards to replace those in the first; with equal reason should the number of artillery-men be sufficient to keep up the fire from the cannon with proper vivacity during the whole engagement, in spite of any loss that may be sustained.

C H A P. VI.

THE EFFECTS OF THE HOWITZER AND SPR. COMPARED.

215. **I**N the last century, guns from 6 to 7 feet in length were used to project stones, case shot, &c. from besieged places: the shortness of these guns and the largeness of their calibre generally adapted to a shot of 24 lbs. gave rise to the idea of the howitzer; the proportions of which vary among different nations, according to the several uses for which they are intended. The longest howitzers I ever saw were 6 diameters of the muzzle in length of bore, with a cylindrical chamber capable of containing 1 lb. 10 oz. of powder: the bore of the shortest was 4 diameters of the muzzle in length, with a cylindric chamber containing 1 lb. of powder. The long ones were used in the imperial army which Prince Eugene of Savoy commanded against the Turks, and the shells fired from them are said to have caused great destruction and dismay among the Ottoman cavalry. On the other hand, the predilection for this species of ordnance was much abated at the battle of *Gustalla*, fought on the 19th of September 1734; where our cavalry of the left wing was neither disordered nor hurt by the shower of shells fired by the enemy, but made several charges with great effect. As the Ottoman cavalry generally charge in an irregular, desultory manner, they present a much larger object than our cavalry drawn up two or three deep with close files; being therefore very much exposed, the explosion of the shells will be more destructive among them, than in the regular movements and dispositions practised by us. Whatever may be the reason of this difference, we will only consider the physical effects of projectiles

tiles impelled from a howitzer 6 diameters of the muzzle in length of bore, and compare them with those of the 8 pr. (183), in order to ascertain the disorder that each of these pieces can severally produce among a body of troops: leaving it to others to discuss the moral effects resulting from the use of howitzer shells, which have by many authors been supposed to be very great: a disquisition totally foreign to our purpose, as the absolute consequences can neither be calculated nor depended on; for it has happened more than once, that troops, which had at the beginning of an engagement been thrown into disorder by the fire of artillery, have at length recovered themselves so far as to despise the former object of their fear, on finding that their apprehensions had greatly magnified the effects of these seemingly terrific machines.

216. *A shell is fired from a howitzer with a view of destroying the enemy both by its shock, and explosion on bursting:* its greatest effects are when, having enfiladed a body of troops and being quite spent in striking men or other objects, it bursts in the midst of those that remain. To convey a just idea of the comparison we propose drawing; let the howitzer be equal in length of bore to an 8 pr. of common length, and let them both be loaded with $3\frac{1}{4}$ lb. of powder: the elastic fluid on quitting the chamber of the howitzer dilates towards the chase, and exerts against the shell less pressure, than the same quantity of fluid generated in the gun exerts against the shot; consequently its initial velocity is less. As a howitzer 6 diameters of the muzzle in length of bore is only half as long as an 8 pr. and as the largest charge for throwing a shell 16 lbs. in weight is 1 lb. 10 oz. of powder (215), this projectile must have a much less initial velocity than an 8 lb. shot impelled by $3\frac{1}{4}$ lbs of powder, with the wads well rammed. The initial velocity and the specific gravity of the shell being less than those of the shot, the air's resistance will be greater; and consequently its penetrations into the same butt will be less.

217. There are two methods of ascertaining the effects of howitzer shells: the first is, by firing against a butt at different elevations and distances, and comparing the penetrations of the shell with those of a shot fired from an 8 pr. The result will express the proportion between the effects of the two projectiles, though the hole made by the howitzer shell will be much larger than that made by the shot: but the velocity

velocity with which the shell impinges on the butt and its specific gravity being less than those of the shot, the penetrations, provided the butt be of a proper consistence, will be less than would result from the formula $f \propto D u^2$ (182).

The second method, is to find the initial velocity of the shell fired at different elevations (167.)

As the difference between the elevations and the corresponding velocities will be greater in the shell than in the shot; it will be necessary, after having ascertained the initial velocity and the value of r = the resistance of the air, to find the remaining velocity = V and substitute its value in the formula $D u^2$, in order to obtain the penetrations of the shell supposing it to be solid: but as its weight is less than the specific gravity of a sphere of solid iron of the same diameter, the expression $D u^2$ must be diminished in the ratio of its actual weight to its weight when solid; which will then nearly give the absolute penetration to be compared with that of the shot.

218. These experiments having been made with a $5\frac{1}{2}$ inch howitzer and $r = 12$ for the resistance of the air to a 32 lb. shot, the remaining velocities of the shell fired with proper elevation to strike the butt at the different distances are inserted in the following table, and also the corresponding relative penetrations, supposing the shell to be solid and the butt easily penetrable.

The velocity with which the shell impinges.		Relative penetrations.
	Yards.	Feet.
Shell fired close to the butt		472
At the distance of 340	340	364
At the distance of 680	680	286
		$5\frac{1}{2} \times 472^2$
		$5\frac{1}{2} \times 364^2$
		$5\frac{1}{2} \times 286^2$

The weight of the howitzer shell being to a solid sphere of iron of the same diameter as 7 to 10, the above penetrations will be reduced to $\frac{7}{10}$ and will be as follows:

	Yards.	Relative penetrations.
Shell fired close to the butt		2359
At the distance of 340	340	1404
At the distance of 680	680	869

On

On comparing these penetrations with those of the 8 lb. shot (183) the number of men in file that the shell can pass through from the different distances will be found in round numbers.

	Yards.	Number of men destroyed by a shell.	
Fired close to them	—	—	5
At the distance of	340	—	3
At the distance of	680	—	2

219. To derive from the howitzer shell the fullest effects, it should burst in the midst of a body of troops, and its power of movement be quite exhausted in passing through the obstacles it meets with before it bursts.

To determine the effects of the splinters, let some howitzer shells burst in the midst of a number of dead animals and their effects be carefully observed. The result in general will prove that the splinters of a shell will not pass through the thickest parts of a man's body; and if it burst in the midst of a number of men, not more than four of those nearest to it will be wounded: by adding to the possible effects of the shock (218) those of the splinters, we shall ascertain how many men can be killed or wounded by a howitzer shell.

Number of men killed or wounded.

	Yards.	By the shock alone.	By the shock and splinters.
Fired close to them	—	5	—
At the distance of	340	3	—
At the distance of	680	2	—

The number of men wounded and killed will be greater, if the least resisting parts of the body be struck, as was remarked in the case of cannon shot.

220. On comparing the effects of a shell and howitzer shot it is apparent that in respect to the effects alone, the only common 8 lbs. shot is more destructive than the howitzer, and has the only advantage over them, as when the shell bursts at 680 yards. A howitzer shell fired against the front of an army will seldom range the ranks, and even then it is mere chance, if it burst in the midst of a man, that he should not thus happen, or should be by accident struck again.

a stone, or the fuze be extinguished by falling into soft ground, its effects will by no means equal the effects of the shot.

221. The remarks on the penetrations of shells compared to shot will precisely apply to the length of their respective ricochets. That the first graze of the shell and shot may be at the same distance, the howitzer must be more elevated than the gun; the shell consequently will not so easily reach its destination, the angle of incidence being less acute its force will be more deadened by the fall, and its ricochet shorter and fewer.

222. To ascertain the effects of a howitzer loaded with case shot equal in weight to the shell, it suffices to remark that the initial velocity of each ball is equal to the initial velocity of the shell (207): which being found by experiment, and a round of case shot fired at the same angle of elevation, the penetrations of the balls may be easily determined (205). Suppose the balls be projected from different distances, then on comparing the relative penetrations with those in the preceding table (205), or with others produced by velocities less than 1450 feet, it will give the ratio between the effects of case shot fired from a howitzer and a gun. The initial velocity of a shell fired horizontally or nearly so, is about 474 feet; the following will be the penetrations of the case shot.

Weight of balls.	Very near the butt.	At the distance of
oz.		170 yards.
6½	—	803
3½	—	640
1	—	444
		138
		59
		6

On comparing this with the former table (205), the penetrations of balls projected from a howitzer placed close to the butt, are to those of balls of equal diameter impelled from of a gun with an initial velocity of 1450 feet; as 803:7580; or as 10:94 nearly: and at the distance of 170 yards, as 138:4624; or as 1:33 nearly.

223. But as the howitzer contains three times as many balls of the same diameter as the 8 pr. and 6 times as many as the 4 pr. this difference should be likewise estimated. To this end, the relative situation of the troops against which they are fired must be considered.

Suppose a howitzer and an 8 pr. to be on the same plane with

with the enemy and equally distant from them; the number of men in the first rank struck by the case shot from the howitzer and by that from the gun will be in the ratio of the bases of the two cones, that is less than 3 : 1; each man struck by the howitzer, will be touched by more balls than one: but when the enemy is drawn up in very deep order, the case shot from the gun will make more havock, as from the greater velocity, it will pierce a whole file; and the greater the distance, the more will its effects exceed those of the howitzer, on account of its greater remaining velocity = V . To make the comparison clearer, suppose circumstances the most advantageous to the howitzer; viz. that at 170 yards, it strikes triple the number of men; under this supposition, its greatest effects will be to those of the gun as $3 \times 138 : 4642 :: 1 : 11$.

224. Again, if the enemy be drawn up on a rising ground in form of an amphitheatre, and so near that each ball may strike one man; the effects of the howitzer will be to the 8 pr. as 8 : 1 and to the 4 pr. as 6 : 1: but if three rounds of case shot be put at once into the 8 pr. it will regain its superiority, the number of balls being then equal, and the initial velocity of those projected from the gun, being greater by $\frac{1450}{3}$ (200) than of those projected from the howitzer; they will range farther and do more execution: the 8 pr. is therefore to be preferred. It was shewn in the former part of this work, that there is no danger of the gun bursting, if 3 cases be fired at the same time; and this has been fully confirmed by experience. On comparing a howitzer 6 diameters of the muzzle in length of bore, and a common 4 pr. charged with 1 lb. 10 oz. of powder; the latter, except when the enemy is very near and drawn up on an amphitheatre of hills, will be more destructive than the former. If the length of the howitzer be curtailed, the difference will be still greater.

225. In constructing howitzers, that from the great size of the chambers may project shells with a greater initial velocity and from the increased diameter contain larger shells, the preceding reflections should be had in view: the carriage and the wheels, for instance, should be made strong enough to resist the greatest efforts of a large quantity of powder. But when the shell is projected with twice the initial velocity supposed in the course of this comparison, the howitzer will yet be inferior to the 8 pr.

226. There

226. There are particular cases however, where the howitzer may be very useful; as in the attack of posts where the enemy is perfectly covered from cannon shot: the shells from the curve line that they describe may then be of excellent service; or, in the attack of towns or villages, where large quantities of straw, hay, faggots, or other combustible materials are deposited. Some pieces of port fire composition may be put into the shell, which on bursting will communicate the flame to every thing around: by these means, towns and magazines may be easily set on fire.

227. The howitzer may in the following cases be useful in the attack and defence of places.

1. In a fortified town, when the casemates or caponieres are too narrow to admit guns of the common length; howitzers are then preferable to short guns of cylindric bore, as the explosion of guns of large calibre soon destroy the embrasures.

2. To prevent as much as possible the inconveniences arising from the smoke in casemates and caponieres, and yet be able to project case shot with the greatest initial velocity; the howitzers may be lengthened if there be sufficient room; this will in some measure bring back the *pierrier* guns formerly in use.

3. In the attack of places, some howitzers may be planted on the batteries designed to fire à ricochet, to enfilade the covert way and its branches: essential service will be derived from this mode of using them; since beside the destruction they may cause among the besieged, they soon silence the fire of the infantry, and cover the workmen in carrying on the approaches.

C H A P VII.

OF SHELLS PROJECTED FROM MORTARS.

228. **T**HIRTEEN and 10 inch mortars are much used in sieges: 15 inch mortars are now generally disused; as from their great weight when properly reinforced, and the size of their chambers, they were very difficult to work on the batteries: when the thicknesses of metal are diminished and the chambers reduced in size, their ranges are so much shortened, that the shells do not fall with more force than those

those projected from 13 inch mortars; they are moreover very cumbersome and heavy.

229. The principal advantages to be derived from shells may be reduced to the three following;

1. In sieges, to dismount the enemy's artillery and bombard cities.
2. To set fire to and overthrow works, and produce havock and disorder among troops.
3. To break through the vaulted roofs of barracks, magazines, casemates, caponieres and other military edifices, that have not been constructed with sufficient strength to resist the shock.

Ten inch mortars are generally adequate to these purposes; hence on principles of œconomy, 13 inch mortars are seldom used, unless the distance be too great for the smaller mortars: their figure being the same, their longest ranges are nearly in the ratio of 4:5. Of shells of the same construction, the largest are undoubtedly the best for setting fire to buildings, especially when some pieces of port fire composition are put into them: the splinters are more destructive to works and buildings than to men, and the harsher the quality of metal of which the shell is cast, the greater number of pieces it will burst into.

Shells made of a very tenacious iron are best adapted for penetrating the vaulted roofs of barracks, magazines, &c. that on coming in contact with a hard body, they may not break before they explode: by diminishing the interior cavity of the shell, the force of the shock and its resistance to the explosion are much increased.

230. Our ancestors, in establishing the proportions of shells, conceived that the thickest part should be opposite to the fuse; that from its superior weight, it might always come first to the ground, and in striking against hard bodies be less liable to break. Hence they supposed also, that the shell, though buried in the earth, would always burst, since the fuse would remain uppermost; but experience has proved that these effects do not always take place, owing to the rotatory motion of the shell; the force of which overcoming the preponderance of the heavy part or bottom, makes it fall on every side indiscriminately; and when it enters a close compact soil which stops any communication between the fuse and the external air, the fire is soon smothered and extinguished. When the fuse is not driven far enough into the

the shell, it frequently happens that the shell beginning to turn before it quits the mortar, the head of the fuse strikes against the muzzle, and breaks off; thus, if the fire has not penetrated beyond the eye of the shell, it may reach the object but will not burst.

231. The difference in the form and size of the chambers, the various purposes for which they are used, and the different qualities and modifications of powder render it necessary to alter the charges and elevations of mortars.

In the largest mortars, the initial velocity of a shell increases in proportion to the charge; hence to obtain the greatest initial velocity, the chamber should be filled with the strongest powder, a tampion of wood placed immediately over it, and both the tampion and shell surrounded with sifted earth well rammed; that from the increase of resistance, the inflammation of the powder may be more instantaneous, and the fluid more abundant and elastic. An increase of elevation also adds to the initial velocity, even with equal charges; since from the greater resistance opposed to the explosion in this position of the mortar, the fluid generated in the chamber acquires, before the shell begins to move, greater density.

The same effects do not take place in musquets, though fired at different elevations (Treatise on Powder).

To prove that the initial velocity of a shell is modified by the elevation; fire the same mortar with two equal charges, but at different elevations; for instance, at 70° and 20° : the shell will range much farther at 70° than at 20° ; though, from the theory of projectiles, fired *in vacuo*, the ranges should be equal; and fired in the open air, the second should be the longest. By varying the charge of powder in the same mortar, it has been found, that there is a particular elevation which with each charge gives a longer range than can be obtained from the same charge at any other elevation; wherefore mortars should not be fixed in their beds at a certain elevation, as from the theory of projectiles many have imagined should be the case. The elevations that give the longest ranges, differ very sensibly in two mortars of different calibres, but of similar proportions, charged with a quantity of powder proportionate to the weight of their respective shells, and the size of their chambers.

232. It is evident, therefore, that a knowledge of the various circumstances that conduce to the effectual use of mortars

mortars, must be founded on theory, and derived from science (142, 231); consequently the generality of bombardiers are very ill-qualified for this service: but from the small number of officers, there being frequently a necessity during a siege, of leaving the direction of mortar batteries to the bombardiers, a particular form of instruction has been expressly made out for their use, calculated for unscientific men, that they may be enabled to do their duty with propriety and effect. For this purpose the use of shells is reduced to two principal cases; (229) the first consists in dismounting the enemy's artillery, destroying buildings, setting fire to and overturning works, and causing disorder among troops: the second, in breaking through casemates that have not been properly constructed.

233. It is sufficient in the first case (232) that the shells be projected with justness, without much regard to the force of the shock; this may be attained by observing the following instructions, which are within the comprehension of every man. The bombardiers should practise with 13 and 10 inch mortars of the common construction; afterwards with some of the same calibre, but with chambers of different dimensions, in order to convince them that a difference in the size of the chamber considerably affects the length of the range.

1. They should know the elevation that gives the longest range, when the chambers are filled; and also the best elevation and charge for firing from the batteries constructed in the first and second parallels, when the besieged town and the batteries are in the same plane.

2. They should be made to observe that a difference in the form of the chambers in mortars of the same calibre, induces a necessity of altering the elevation, and also affects the range; and that with the same mortar, the ranges diminish in proportion as the elevation is greater or less than that which gives the longest range.

3. They should be taught always to load the mortar in the same manner, when the same charge is used; since to negligence or mistake in this particular, may be attributed many of the varieties that occur in the lengths of ranges: and that with the same charge, the error that may tend to shorten the range, will not add much to the deflection of the shell.

4. As a difference in the quality of the powder, in the moisture and temperature of the atmosphere, considerably affects the ranges, they should be taught to make allowance for these circumstances, by elevating or depressing the mortars; by increasing or decreasing the charge.

5. They should fire at a butt with the degree of elevation that gives the longest range, and increase or diminish the charge till they strike the object: this will convince them that less irregularity ensues from altering the charge, than from altering the elevation; for the more the elevation deviates from that which gives the longest range, generally between 40° and 50° , the more irregular are the ranges.

6. When the object is to fire at troops or entrenchments, it is better to lay the mortars at small elevations, that the shells may not bury themselves.

7. When the plane of the mortar battery is below the plane of the object, it is much easier to project the shells with justness, than when they are both on the same, or the mortar on the higher plane.

234. The second case (232) viz. to break through casemated buildings, requires much theoretical knowledge in the officer charged with the execution of this piece of service, in order to determine the situation of the mortar, its proper charge and elevation; that the shell may impinge on the object with the greatest possible force. Suppose a shell projected from the point A, in the direction AP (Pl. 6, Fig. 22) has described a curve AFNB L of the fourth kind; in order to determine the force that the projectile has in each point of this curve, the direction and quantity of compound velocity at each point must be found. For this purpose it is necessary to have a scale of the spaces passed through in times of unequal movement (170, 172) from whence may be deduced the scale of corresponding velocities: then, to ascertain the direction and quantity of compound velocity at the point B, in the perpendicular line BP, make BE equal to the corresponding velocity at this point, of a movement BP unequally accelerated by gravity; draw EH parallel to AP, and equal to the velocity which at the same point B corresponds to the retarded movement of impulsion AP; then the right line HB will express the direction and quantity

tity of compound velocity, which the shell has at the point B (168).

235. From the construction (234) it appears;

1. That if the point F represent the vertex of a curve, FC will express the horizontal direction which the shell has at that point, and the quantity of compound velocity, which is less than the shell can have in any other point of the curve.

2. That the compound velocity at the point N increases in proportion to the distance of N from F: that the direction of the compound velocity forms a very acute angle with the horizon, when the point N is very near to F, is less acute in proportion as N is farther distant from F, and becomes a right angle when the shell has lost its movement of impulsion; which in practice is always greatly below the plane AB: the velocity of the projectile is then reduced to the unequally accelerated movement of gravity.

3. That the angle formed by the direction of the shell with the horizon, approaches nearer to a right angle, in proportion as the angle PAB is less acute: on the contrary, when the mortar is fired at a very small elevation, the angle formed by the direction of the shell and the horizon, can only become a right angle, in a point L far distant from the horizontal line BA.

236. The formula $mV \times \frac{a}{\text{whole sine}} = f$ (178) serves to express the force of the shock of a shell against a plane, of which the inclination is given; the application of this formula will be rendered more familiar by the following remarks:

1. The force of the shell N increases, in proportion to its distance from the vertex F of the curve; since its compound velocity also increases (235, No. 2): the force of the shell at the point B being expressed by $mV = m \times BH$ is greater than its force at the point F, because BH is greater than CF.

2. If the shell at the vertex F strike at right angles a vertical plane, it will impinge with all the force expressed by $mV = m \times CF$; since in this case, the quantity

a being equal to the whole sine, the expression $\frac{a}{\text{whole sine}}$

represents unity: on the contrary, if the shell at the point F meet a horizontal plane, $a=0$; in this case, there will be no shock, and the shell will roll upon the plane.

3. If the shell strike the point B in the plane Z γ inclined to the horizon with a direct shock, its force will be to the force of a shock on the horizontal plane B Q, as the whole sine is to the right sine $=a$ of the angle of incidence H B Q: wherefore, if the shell instead of striking the horizontal plane B Q, strike the inclined plane I O, the force of the shock will be less; and will be in the proportion of the right sine of the angle of incidence H B I to the sine of the angle H B Q.

4. If two shells be projected from two mortars of different calibres, but of similar proportions, fired with the largest quantity of powder, and with the same degree of elevation; the largest shell will have the most force in the corresponding points of the curves, owing to its superior weight, and greater compound velocity (229); since it describes a larger curve.

5. If two shells of different diameters, fired as above, in corresponding points of their curves strike two objects in differently inclined planes, the shock of the least shell may exceed that of the largest; because the angle of incidence of the latter may be most acute.

237. To strike with a direct shock, and with great force, a superficies whose position is given (234); it is necessary:

1. To place the mortar so that the axis produced may cut the vertical plane of the object; and that the curve described by the shell, be at right angles to it at the point of impact.

2. To use the largest quantity of powder that the chamber of the mortar can contain.

3. To observe the relative position and figure of the given superficies, whether flat, or convex like the roof of a casemate; whether horizontal or inclined.

4. Thence to determine the distance that the mortar should be placed from the object and its proper elevation.

238. It is observed, that the curve described by shells does not always cut the vertical plane of the object, in the direction of the axis of the mortar, but deflects from it so as to describe a double curve. The solid sphere of bronze projected

projected from the *eprouvette-mortar*, when it reaches the vertex of the curve, deflects either to the right or left, though it be very dense, and its surface very smooth. The deflection of shells, whose specific gravity is less, and centre of gravity distant from the centre of the figure, and which from the ears and the head of the fuse present an uneven surface to the air is greater: the fuse, from the rotation of the shell round its axis, describes a kind of *piccoloide*.

This deflection does not much diminish the force of the shock on a flat, but on a convex superficies its effects are very considerable; for, however small the deflection may be to the right or left, the angle of incidence instead of being right, becomes very acute. This circumstance merits a more particular examination:

239. Suppose in the first place, that the superficies B to be impinged be flat and horizontal like the ramparts of fortresses, (Pl. 6, Fig. 22) under which are casemated barracks or magazines, covered with thick layers of earth well rammed: in order to break through these casemates, the mortar should be placed in Q very near to the point B, and laid at a very high elevation, as 75° or 85° , that the angle of incidence may be nearly a right angle. If the distance from B to Q be short, and the plane of the mortar much higher than B, the compound velocity of the shell will be greater, since the angle of incidence approaches nearer to a right angle, and the force of the shock will be greatly increased: the reverse will happen if the mortar be much lower than the object; insomuch, that if the shell on reaching the vertex of its curve, meet a horizontal plane, it will roll upon it without penetrating (236). This first supposition is the most favourable to the effect of shells, the vertical plane cutting the plane of the object at right angles; and the given superficies being generally of great extent, the mortar may be placed so, that the shell will always fall on it, in spite of any trifling irregularity in the length of the range.

240. Suppose in the second place, that the plane to be impinged, be $\gamma B Z$, inclined to the horizon AB ; the mortar must then be removed so much the farther from B towards A, as the angle $AB\gamma$ is the greater; the axis of the mortar produced should pass through a vertical plane, supposed to cut YZ at right angles. The distance between the mortar and object, and the proper elevation for giving a

direct shock, must be determined from a knowledge of the two unequal movements that form the curve (170, 172); and the initial velocity produced at a certain elevation, known by previously firing a few rounds to ascertain the quality of the powder. But if the law of the two unequal movements cannot be obtained, the officer must have recourse to the treatise on curves, and their greatest amplitudes; in order to determine the distance AB, and the angle of elevation, taking notice that in general these inclined planes form with the horizon angles from 30° to 45° , and that the initial velocity of the shell increases in proportion to the greater elevation of the mortar: by properly combining these circumstances, he may, without removing the mortar a great way from the object, procure an oblique shock of greater force than the direct shock that could be obtained at a greater distance with a less initial velocity; since the greater the distance the less will be the elevation, and the less, of course, the initial velocity. Under this second supposition, deflections to the right or left do not much diminish the force of the shock, but a very small error in the amplitude is sufficient to prevent the shell from impinging on the object; since these planes, in the direction of the mortar, are of no great extent, and from their inclination, the shocks would become so oblique, that the end proposed could by no means be attained (236, No. 3).

241. Suppose in the third place, that the superficies be convex, as the roof of a casemate turned with a circular arch: the mortar should be placed as near to it as possible, that from the higher elevation, the shell may have a greater velocity; and in the direction of the keys of the arches, that notwithstanding any small variation in the amplitude, they may still be of service: the least deflection will be sufficient to render the shock, which should be direct, very oblique. Again, if the superficies be convex, in form of a dome, the slightest error in the direction or range will greatly diminish the force of the shock; since this superficies declines on every side from the perpendicular: wherefore, it is of all others the most difficult object to strike with a direct shock.

242. When the officer has determined the best situation for directing the mortars against the objects he proposes to bombard; he will inform the bombardiers of the proper elevation and quantity of powder, and point out every particular that can conduce to the better execution of the service:

vice : the bombardiers having been already trained at the school of practice (233) will be enabled to execute with precision and efficacy the order they receive.

243. In bombarding military edifices, the shells may fall on solid works of masonry, built upon arches, or on soft substances, as earth, &c. with which arches are frequently covered, to secure them from shells. When they fall on solid works of masonry, they tend by their shocks to penetrate and split the casemates, and by their explosion to overturn the counterforts, and shatter the walls.

Arches constructed on the principles laid down in the first and second books of Military Architecture, are capable of resisting the most violent shocks from 13 inch shells : their resistance increases when they are constructed of the best materials, in a climate favourable to their acquiring great tenacity ; and when they are contiguous to solid and immoveable bodies.

In buildings totally detached from others, or built on eminences, the counterforts should be so proportioned, as not only to resist the pressure of the vaulted roofs, but every shock to which they may be exposed from shells.

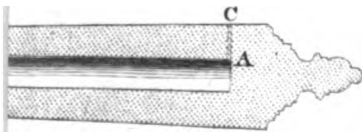
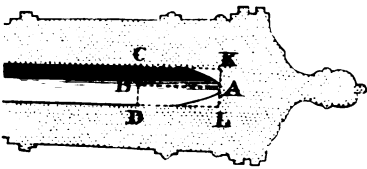
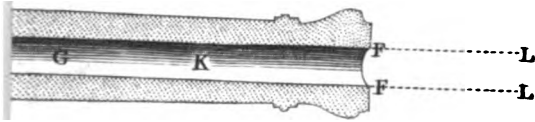
244 All the effect of a shell falling upon a solid work of masonry built on arches, is reduced, if the arch be well turned and made of choice materials, to a small excavation in the place where it falls : it even often happens that the shell breaks before it bursts, particularly when cast of brittle iron. But if the arch be not firmly supported, the counterforts not sufficiently solid ; or in insulated buildings not well proportioned to resist the shock, and the unnecessary thickness which masons generally give to the arches, under the idea of rendering them impenetrable ; the substances in too small a mass, as in detached powder magazines ; or the stone of of so elastic a nature, as considerably to increase the shock ; (Treatise on Moving Bodies) in all these cases the shells will produce the desired effects. A shell on penetrating a brick arch, makes a hole nearly circular, if the bricks be of a good quality : but if from the negligence or ignorance of the workmen, the materials be bad or badly worked up ; or if owing to the climate, they have not acquired a sufficient degree of tenacity, the shell, beside making a hole, will split and shatter the building.

245. Shells falling on arches covered with earth or other soft materials (243) bury themselves without doing any material

cial injury, if the earth has been properly prepared (Military Architecture). Arches of this kind will sustain no damage from 10 inch shells, nor will the building be much shattered if the counterforts are of proper dimensions: the only danger is that the explosion of the shell may carry off a part of the circumjacent earth; so that by a number of shells falling on the same spot, the top of the arch may be entirely uncovered, and, in the event, pierced through. Those that wish to enter more particularly into the construction of military edifices, to enable them to resist the force of shot or shells, may refer to the fifth book of Military Architecture, where the subject has been fully discussed.



Plate 1.st



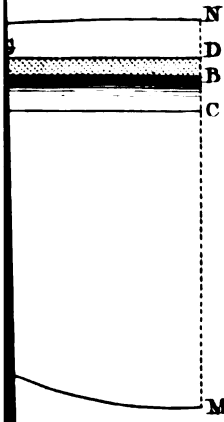
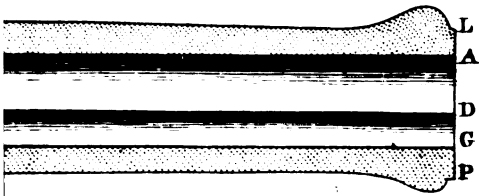
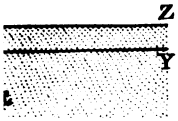
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Plate 2.^d

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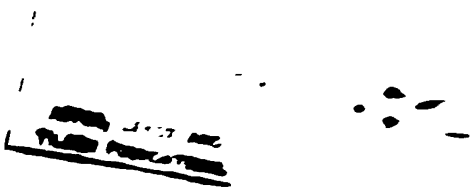
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Fig 11.

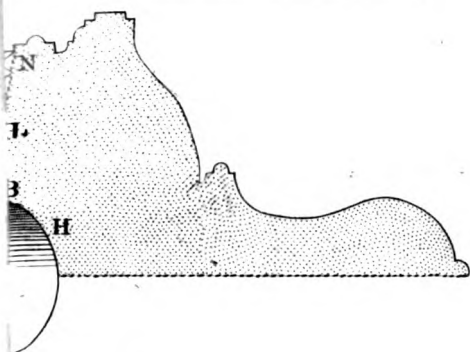
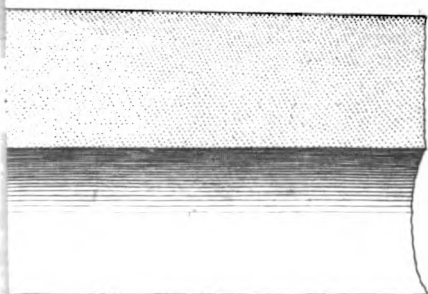
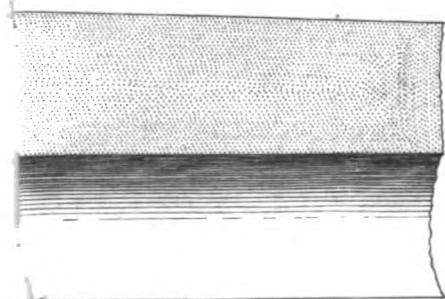


Fig 13.



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A
T R E A T I S E
O N T H E
S E R V I C E O F A R T I L L E R Y
I N
T I M E O F W A R .

1. **I**N all well constituted governments, the arsenals and places of strength are furnished in time of peace with artillery, ammunition and stores of all kinds, sufficient to check the sudden incursions of any of the neighbouring powers; without incurring any unnecessary expence, or purchasing any articles that are of a perishable nature. Hence, as the peace establishment of troops is small, and the magazines are unprovided with many things indispensably requisite for the service in time of war; whenever there is reason to apprehend its approach, new levies are made, provisions and ammunition purchased, the magazines filled, the fortifications repaired and mounted with cannon, carriages for transporting stores and baggage provided, and a corps of officers, non-commissioned officers, and drivers formed for taking care of the horses belonging to the field-trains of artillery.

The proportion of each is regulated by the nature of the country, and the kind of war that may be expected; whether offensive or defensive; in the capacity of principals, or auxiliaries; whether the scene of operations be in an open
champaign

champaign country, or in one intersected by rivers and canals, or divided by impenetrable forests, extensive morasses, or lofty mountains.

2. The stores to be deposited in the magazines during peace, consist principally of those articles that are difficult to procure in time of war, or that require much time to manufacture and prepare; as arms and iron work of all kinds, shot, shells, and every thing that must be brought from foreign countries: deferring the collection of those that can be procured at home, or are liable to be damaged by keeping, as wood, linen, &c. till the eve of the declaration of war.

3. Taking it for granted then, that the arsenals and places of strength are abundantly provided with every thing requisite for carrying on a war of any continuance; that the royal corps of artillery is sufficiently numerous; and that the non-commissioned officers and soldiers are fully acquainted with the instructions compiled for their use in 1770; I propose in this work, to enlarge upon the principal duties of the superior and subaltern officers, that the cadets having thereby an opportunity of knowing the duties attached to each particular station, may be enabled to ascertain what may be expected from them on every emergency.

4. The object of an artillery-officer, in the time of war, *is to derive the greatest possible advantage from the use of cannon, mortars, fire-works and mines.* The knowledge requisite for attaining this may be considered as two-fold: the one has respect to the planning of enterprizes, in which artillery is employed; the other is solely confined to the executive part.

5. In the planning of every enterprize there are six points to be previously considered. The first is its nature and object: is a fortress for example, to be attacked or defended? to consider, whether the attack can be best carried on by regular approaches, by assault or blockade; and in a case of defence, whether the greatest efforts of the garrison should be exerted at the beginning, or reserved for the latter end of the siege; whether the ground will admit of countermines being used with effect; or whether the fortifications be of such a construction, as to enable the garrison to dispute the ground inch by inch with the besiegers.

6. In the second place, an officer should be well grounded in the principles of fortification and tactics, as well as in the theory of artillery; and should be master of the practice in every

every part. There are certain particulars that ought to be ascertained, before an officer can safely give his opinion : in the case, for instance, of his being consulted about forming a field train of artillery ; he must, before he is competent to decide, be acquainted with the nature of the country, the plan of operations and the strength of the army ; that the quantity of artillery may be adequate to every object proposed by the commander in chief, without being so numerous as to embarrass or retard the movements of the troops.

7. In the third place, he should adapt every thing so judiciously to the nature of the service, that they may all concur with precision to the attainment of the object in view, without unnecessary trouble or expence.

8. Having decided on the means to be employed ; the fourth consideration is, how to employ them to the best advantage ; or the enterprize may at last prove abortive : for victory depends not more on the number of troops, than on the disposition that is made of them ; and a train of artillery sufficient for the reduction of a fortress may become inadequate to the purpose, through injudicious management.

9. Under the fifth head, are classed the dispositions for carrying any project into execution (5) ; they are as it were the soul of the enterprize ; for by them all the various parts of the system are put into motion and made to concur to the same point ; whereas a want of concert might render all the previous measures ineffectual and be productive of nothing but confusion. A certain number of persons are made acquainted with the leading steps that have been taken to ensure its success, and the plan laid down for carrying it into execution in a given time.

10. And lastly, to render the event successful, all accidents capable of deranging the plan should be carefully guarded against. In this, respect must be had both to the object itself and to every collateral incident. If it be intended, for example, to dispatch a convoy of artillery by land ; a sufficient number of pioneers and carpenters should be sent forward to mend the roads, and repair the old or make new bridges, that the march of the convoy may not be impeded by the breaking down or upsetting of any of the carriages. Is a post to be surprized ? the different bodies of troops destined for this service should be provided with trusty guides, perfectly acquainted with the country ; and every precaution taken by the officers commanding the several divisions

visions to prevent desertion, lest the enemy be apprized of the design.

11. The plan being thus digested, the execution follows: and first, the officer charged with the construction of the first battery at a siege will determine from observation, whether by direct firing, he should endeavour to dismount the enemy's artillery, and beat down the defences; by ricochet firing, enfilade the works and harass the besieged; or by firing with red-hot shot set fire to the buildings.

He will, in the second place, reconnoitre the ground, that the battery may be erected on the most advantageous spot.

He, will in the third place, ascertain what number of men, and what quantity of tools and materials are wanted for its construction.

Fourthly, he will consider the means of employing every thing to the greatest advantage, that the battery may be constructed in the best manner, and in the shortest space of time possible.

Fifthly, he will divide the workmen into different parties, directing these to throw up the earth in digging the ditch, in order to form the battery; those to piquet down the fascines: some to ram the earth; and others to bring the materials from the grand magazine.

Lastly, he will take every precaution to guard against mistakes in throwing up the works, or cutting the embrasures during the night; and to prevent the several detachments from missing their way, or interrupting each other in transporting the ammunition, &c. to the battery. The subaltern and non-commissioned officers will inspect the conduct of the workmen, and take care that they do their duty.

12. The circumstances that arise in the execution of an enterprize frequently induce a necessity of deviating from former systems, and sometimes even of varying the whole disposition to the great embarrassment of young officers: they should therefore be practised in the solution of different problems best calculated for exercising their inventions, and obliging them to have recourse to their own minds for resources in cases of novelty and difficulty, but which yet require instant determination and execution. Such is the path trod by all military men that aspire to eminence in their profession; and such is the road by which officers have arrived at distinction and renown.

The

The division of this work is into three parts: the first treats of the service of artillery in the attack; the second, in the defence of fortified towns; and the third comprehends the various other branches of artillery service in the field.

F I R S T P A R T.

OF THE SERVICE OF ARTILLERY IN THE ATTACK OF FORTIFIED TOWNS.

13. **W**HENEVER a town fortified according to rule is intended to be taken by siege, the object of the besieger is to make a breach; which may be effected by the means of heavy artillery, or of mines: and the execution, in either case, rests with the royal corps of artillery.

C H A P. I.

OF THE FIRST DISPOSITIONS TO BE MADE FOR BESIEGING A PLACE IN FORM.

14. **T**HE first duty of an artillery officer, when it is resolved to lay regular siege to any place, is to make out a state of the guns, mortars, ammunition, machines, and carriages of all kinds requisite for that purpose. To be enabled to make a proper proportion of stores, the commanding officer of artillery must be master of certain data (6); that is to say, the commander in chief, or the general officer charged with the direction of the siege, should communicate to him a plan of the fortifications and environs of the place, accompanied with such profiles and remarks, as may enable him to ascertain what fronts are most attackable; with the advantages and disadvantages attending each attack; both

both with respect to the works and countermines, the nature of the soil where the trenches must be opened, and the several heights and hollows in the vicinity of the town. He should likewise be informed of the enemy's force; viz. whether the town be protected by an intrenched camp, or left solely to the exertions of the garrison: if it be amply provided with artillery, provisions, stores and casemates; if the garrison be sufficiently numerous; and whether composed of veteran troops or new levies; if the governor be in high estimation for his military talents: if the town be populous, and whether the inhabitants are well affected to the garrison, and of a martial or pacific disposition. The commanding officer of artillery should be likewise acquainted with the nature of the country, through which the stores, &c. must be transported; as the dispositions that serve for transport by land will by no means answer for water carriage.

15. But if it be impossible to collect sufficient intelligence to regulate the quantity of artillery and stores, the proportion must be formed on the general principles of attack. On his arrival in camp, the engineers should impart to him the observations they have been able to make on the place and its environs; and the commander in chief should communicate whatever intelligence he may have received from his correspondence within the town; the original state of ordnance and stores may be then varied and adapted to circumstances, that the siege may be carried on with proper vigour. The roads that the last convoy must take to reach the camp should be covered from the enemy, till all the stores are safely arrived.

16. If the officer intrusted with making out the state of ordnance and stores be sufficiently acquainted with the place and its environs, he should ascertain (according to the fundamental maxim of all besiegers) against which front the attack can be made, the *least exposed and with the greatest expedition*: and examine whether the siege can be best carried on by regular approaches; by taking advantage of any defect in the situation, to break ground close to the works; or by blockade: and whether the former and latter parts of the direct attack will be similar. By the aid of this investigation, the quantity and quality of stores wanted for a siege may be determined with the greatest accuracy; but it will be
better

better to increase the proportion, if the escorts be large ; and to diminish it, when few troops can be spared for this service.

17. The primary consideration towards deciding the number and calibre of the pieces of ordnance, is *to keep up constantly a fire superior to that of the place.*

The following are the particular rules for the observation of this maxim, in the first part of the direct attack ;

1. The proportion of 32 prs. for firing at the principal defences of the place, and covering the approaches to the crest of the glacis, ought to exceed by a third at least, the number that the garrison can bring to bear on the attack, from the body of the place, or any of the outworks, capable of making a long resistance.

2. The proportion of 16 prs. for dismounting the enemy's artillery in the ravelins, and other advanced works that may retard the progress of the besiegers, should exceed by a fourth at least, the number of guns in those works.

3. The ricochet firing is from 8 and 4 prs. the number for enfilading any works should never be less than three.

4. Each of the works attacked should be enfiladed by at least three 10 inch mortars, when the object is to dismount the enemy's artillery ; and, by perpetually annoying them, oblige them to abandon their works. But if the bastions be casemated, the mortars should be 13 inches in bore, and the number increased.

5. As the ricochet firing may be stopped for fear of incommoding the workmen in completing the third parallel, two or three royal mortars should be planted in the second parallel, against each face of the covered way, to harass the garrison during the cessation of the ricochet-firing.

6. Some stone mortars may likewise be placed in the finished parts of the third parallel, for firing into the covered way.

18. Having determined the nature and number of the ordnance requisite for the first part of the attack, the quantity necessary for the second is then resolved on ; making use, for this purpose, of the guns planted in the first erected batteries, which cease firing when a lodgment is effected on the crest of the glacis.

19. This

19. This artillery (17, 18) is only designed for firing against the front of the attack; but if there be any objects within the town exposed to the fire of the besiegers, the ordnance must be proportionably increased. If the barracks and the magazines, for instance, can be cannonaded, a proportion of 32 prs. should be destined for this service; 16 prs. will be sufficient for beating down the houses, &c. and 8 prs. for projecting red-hot shot to set fire to buildings. When the barracks and magazines are covered from cannon-shot, but not secured from shells, the number of 13 inch mortars for breaking through the casemates should be increased: in case the troops or stores are lodged in the common edifices of the city, 10 inch mortars will suffice for the bombardment.

20. The number of rounds fired from each gun and mortar against the front of the attack; is estimated at 60 rounds a day. From the damage that may be done to the batteries by the fire of the place, the accidents that will inevitably happen, and the occasional suspension of the firing, this calculation is seldom exceeded; it may therefore be considered as the expenditure of every gun or mortar mounted on the batteries, from the day they are opened till the end of the siege.

21. The calculation for the guns intended for firing against barracks and magazines, (19) is from 250 to 300 rounds a gun for each 32 pr. when the distance is short, and the line of direction nearly perpendicular to the objects: but for longer distances, and very oblique directions, the number of rounds must be regulated by the situation of the place, and it's environs; on the principles laid down in the third book of Military Architecture, and the Philosophical Institutions, with regard to the effect of cannon-shot on walls. Large shells are the best for penetrating casemates; to produce the full effect, the mortars should be laid between 35° and 45° , and the shells projected with the greatest initial velocity should fall perpendicularly to the plane of the object.

22. The number of gun-carriages and mortar-beds, as well as spare articles of every kind, is proportioned to the duration of the siege: we generally compute three carriages for every two guns, and two beds for each mortar, when the siege is expected to last about a month; the proportion is increased for longer sieges.

The

The number of beds for each mortar is likewise increased, when the chambers are to be filled with powder; as the shocks are then very violent, and soon render them unserviceable.

The quantity of tools for the pioneers, and for making fascines and gabions, are regulated by the works that are intended to be thrown up; whether lines of circumvallation, or only approaches and batteries on the front of the attack.

The quantity of powder is computed from the number of rounds (20), and the proportion for each charge; this is in general estimated at $\frac{1}{3}$ of the weight of the shot for large guns, and half of the weight of the shot for guns of smaller calibre. The common charge for 13 inch mortars, including that of the shell, is $12\frac{1}{2}$ lbs. of powder; $6\frac{1}{2}$ lbs. for the 10 inch mortar, and $3\frac{1}{2}$ lbs. for royal mortars; the charge for the stone mortar is 4 lbs. of powder, and for hand grenades, $3\frac{1}{4}$ oz.

23. When artillery, stores, &c. are transported by land, oxen, horses, and sometimes mules, are used for drawing them. The weight that two oxen will draw on tolerably level ground, is about 9 cwt. two horses or mules will draw about $7\frac{1}{4}$ cwt.: in hilly countries, the weight should be diminished by a fifth.

The weight in cannon being more concentrated than in common carriages, five pair of oxen are harnessed to a 16 pr. mounted on it's carriage, weighing $36\frac{1}{2}$ cwt.; whereas, four pair would suffice, if the weight were divided into four equal parts. In mountainous countries, the ammunition, tools, &c. are carried on beasts of burthen: a common mule will carry a weight of $2\frac{1}{4}$ cwt. and a full load for one of the strongest, is $2\frac{1}{4}$ cwt. but every article that exceeds $1\frac{1}{2}$ cwt. should be put into carriages. It is much more expeditious and æconomical to make use of boats, if there be any rivers or navigable canals in the country, that the convoys are to pass through: to determine the number, the size of the boats must be known, and the soundings of the rivers; as the freight of each must be proportioned to the depth of water.

24. To exemplify the above maxims, let us suppose;

1. A fortified town NN (Pl. 1), is to be besieged in form: that the nature of the soil is favourable for carrying on the approaches, and constructing the batteries; and that the adjacent country is level, and

Q

neither

neither particularly advantageous nor disadvantageous to the besieger.

2. That the works are reveted; the revetements of the common thickness; the height of the body of the place about 40 feet; and of the counterscarp, about 20 feet; the profiles just, and the works mutually flanking each other; no countermines, but casemates and magazines covered from cannon-shot; and an ample provision of stores of all kinds.

3. That from 16 to 18 guns may be mounted on the faces A, B, of the bastions in the front A B that is attacked; and the same number upon the four faces C, D, E, F, of the ravelins.

4. That the garrison is sufficiently numerous, composed of veteran troops, and commanded by experienced and gallant officers.

25. The first step towards making out the proportion of artillery for laying siege to the supposed fortress, (Pl. 1) is to draw a plan of the attack; and then determine the number and nature of the pieces of ordnance, on the principles before laid down: the following will be the result;

Twenty-four 32 prs. for the royal battery G.

Twenty-four 16 prs. for the batteries H, K.

Twelve 8 prs. for the ricochet batteries M, O.

Twelve mortars; four of 13 inches, and eight of 10 inches, to be distributed in the batteries L, N.

Twelve royal mortars to be placed in the second parallel, for covering the sappers in the third parallel, when the ricochet firing ceases.

Six stone-mortars to be placed at Q, in the third parallel, to annoy the besieged in the covered way.

26. Upon the same principles may be computed the quantity of artillery necessary for the second part of the direct attack: it will be nearly as follows;

(Pl. 2.) Five 32 prs. for battering in breach the ravelin P from A.

Four 32 prs. for silencing from the battery B, the guns on the bastion Q which covers the ravelin P.

Eight 32 prs. viz. five for battering in breach the bastion from C, and three to be planted in the battery O.

Six 32 prs. for firing from D against the upper and lower flank R.

Three

Three stone-mortars to fire from the battery E against the ravelin P.

Three stone-mortars to fire from the battery F against the flank R, which covers the breach N in the bastion Q.

Eight 13 and 10 inch mortars to fire from the battery G against the flank R; on a supposition that its fire is superior to the counter battery D.

Eight royal mortars to harrass from the battery K the troops that defend the ravelin P.

Eight mortars of different calibres, to harrass from the battery H the troops that defend the bastion Q; and prevent them from throwing up intrenchments.

According to this calculation, the artillery used in the first part of the attack, will be amply sufficient for the second.

27. The number of rounds for each piece is determined by the duration of the siege. In the case in question, the greatest number of days that the batteries will be open, will be nearly as follows;

(Pl. 1.) The batteries G, H, K, L, M, N O, twelve days,
The royal mortars in the second parallel, eight days.

The stone mortars at Q in the third parallel, six days.

(Pl. 2.) All the batteries constructed for the second part of the attack, eight days.

28. The following is a proportion of stores for carrying on a regular siege, under these circumstances (24): the whole is supposed to be supplied from one depôt, and transported to the scene of action, in carriages drawn by oxen along level and well made roads. This state will also serve as a rule for ranging each article, in the class to which it properly belongs.

State of Artillery, Ammunition, and Stores of all kinds, for laying regular Siege to a fortified Town N N.

<i>No. and Nature of Ordnance.</i>	<i>No. and Nature of Gun-carriages.</i>	<i>No. of Pairs of Oxen.</i>	<i>No. of Carts.</i>
24 Heavy 32 prs. carried on 24 block waggons, with draught chains for 8 pairs of oxen to each .....	.....	192	—
24 Heavy 16 prs. mounted on travelling carriages with limbers and draught chains for 5 pairs of oxen to each .....	.....	120	—
12 8 prs. mounted on travelling carriages, with limbers and two pairs of oxen to each .....	.....	24	—
60 Guns.	36 Carriages for 32 prs. with limbers and side arms at 2 pairs of oxen each	72	—
	12 Spare carriages, with limbers for 16 prs. and 36 sets of side arms	12	—
	6 Spare carriages with limbers, and 18 sets of side arms for 8 prs	6	—
	54 Carriages.		
6 Stone mortars	Carried upon 7 block carriages with draught chains, for 5 pairs of oxen each .....	.....	35
4 13 inch ditto			
8 10 inch ditto			
	Carried over	461	—
			12 Royal

<i>No. and Nature of Ordnance.</i>		Brought over	<i>Pairs of Oxen.</i>	<i>Carts.</i>
			461	—
12	Royal ditto, carried in } 2 common carts, with } 2 pair of oxen each }	.....	4	2
30	Mortars 6c Mortar-beds at 2 to each mortar		22	22
60 Sets of side arms for the mortars			1	1
Spare Articles.				
4	Block waggons, at 2 pairs of oxen each		8	—
24	Wheels shod with iron for 32 and 16 } pr. carriages }		12	12
12	Wheels shod with iron for 8 pr. and } block ditto }			
100	Axle-trees for carriages of all sorts		10	10
200	Sponge-staves for guns		4	4
100	Sheep-skins for sponges		1	1
Shot, Shells, and Grenades.				
28800	Shot for 32 prs. at 1200 rounds a gun, } and 40 to each cart }		720	720
17280	Shot for 16 prs. at 720 rounds a gun, } and 80 to each cart }		216	216
7200	Shot for 8 prs. at 600 rounds, and 160 } to each cart }		45	45
2400	Cafe-shot, half for 32 prs. the other for } 16 prs. }		45	45
4800	13 inch shells, at 1200 rounds for each } mortar, and 7 shells to each cart }		686	686
9600	10 inch shells, at 1200 rounds for each } mortar, and 15 shells to each cart }		640	640
11520	Royal shells, at 840 rounds for each mor- } tar, and 40 shells to each cart }		288	288
12000	Hand grenades, at 500 to each cart		24	24
Carried over			3187	2716

		<i>Pairs of Oxen.</i>	<i>Carts.</i>
		Brought over 3187	2716
Shot, Shells, and Grenades continued.			
5500	Fuzes for 13 inch mortars	} Packed up in sand bags }	12 12
11000	Ditto for 10 inch ditto ...		
13000	Ditto for royal ditto		
15000	Ditto for hand grenades ..		
4000	Bottoms of wood for the stone mortars ...	16	16
4000	Baskets for ditto	40	40
Machines and Cordage.			
600	Hand-spikes	10	10
400	Coins	8	8
10	Long levers with horses	3	3
8	Gins complete	4	4
2	Capstans with ropes }	} 2 2	
6	Hand jacks		
6	Ropes for guns, 25 fathoms each	} 12 12	
4	Ropes for gins, 15 fathoms each		
20	Double slings		
100	Ropes for tying the ammunition upon the waggons, 8 fathoms each		
100	Drag ropes, 10 fathoms each	4	4
26	Cwt. of cordage for tying and packing ...	4	4
Ammunition.			
5922	Whole barrels of corned powder, viz.	647	647
2635	<small>ewt. grs. lbs.</small> 1 12 For 28800 rounds from 32 prs. } at 10½ lbs. }	} 790 2 24	} For 17280 rounds from 16 prs. } at 5½ lbs. }
790	2 24 For 17280 rounds from 16 prs. } at 5½ lbs. }		
105	1 20 For 7200 rounds à ricochet, at } 1 lb. 10 oz. 4 dr. }	} 527 0 16	} For 4800 rounds for the 13 inch } mortars, at 12 lbs. 4 ozs. 12 drs. } including the charge for the shell }
527	0 16 For 4800 rounds for the 13 inch } mortars, at 12 lbs. 4 ozs. 12 drs. } including the charge for the shell }		
		Carried over 3945	3474

Ammunition

			Brought over		Pairs of Oxen.	Carts.
Ammunition continued.			3945	3474		
cwt	qrs.	lbs.				
562	1	4	For 9600 rounds for the 10 inch mortars, at 6 lbs. 8 oz. 14 drs.			
337	1	9	For 11520 rounds for the royal mortars, at 3 lbs. 4 oz. 7 drs.			
146	1	20	For 4000 rounds for stone mortars, at 4 lbs. 1 oz. 9 drs.			
21	3	24	For 12000 hand grenades, at 3 oz. 4 drs.			
512	2	0	For the infantry, at $\frac{1}{8}$ of an oz. for each musquet cartridge			
282	3	1	To supply the waste and losses, being in the proportion of $\frac{1}{10}$ of the whole			
91	0	0	Of match	10	10	
1830	0	0	Of musquet balls including 91 cwt. of pistol bullets	200	200	
150000	Flints			4	4	
660	Oil-cloths for covering the powder and match					
Various Articles.						
2000	Oak planks for the platforms			200	200	
1000	Sleepers for ditto			50	50	
1000	Fir planks for the frame of the gallery of descent into the ditch			70	70	
500	Beams for ditto			30	30	
40000	Sandbags			16	16	
5000	Ballast baskets			35	35	
150	Cuirasses with casques for the sappers			6	6	
91	Cwt. of grease for the axle-trees and the laboratory			10	10	
Carried over				4576	4105	

	Pairs of Oxen.	Carth.
Brought over	4576	4105
Iron-work and Nails.		
54 Cwt. of iron of forts for the wheels and axletrees of gun carriages	6	6
36 cwt. — Of forge iron in bars and rods	4	4
9 cwt. — Of steel		
29 cwt. — Of nails for wheels		
54 cwt. — Of nails for platforms	10	10
5 cwt. — Of nails of 40 to the lb.		
3 cwt. — Of iron wire		
Articles for the Laboratory.		
36 cwt. — Of mealed powder	4	4
36 cwt. — Of refined saltpetre	4	4
18 cwt. — Of flowered sulphur	2	2
45 cwt. — Of tar	5	5
45 cwt. — Of pitch	5	5
4 cwt. — Of packthread		
3 qrs. 8 oz. Of common thread		
3 cwt. — Of flax		
3 qrs. Of fine tow		
4 cwt. — Of glue		
3 qrs. — Of yellow wax		
2 cwt. 2 qrs. Of wax candles		
1246 Yds. of barras		
1246 Yds. of linen and cotton cloth	6	6
10 Reams of fine writing paper		
10 Ditto of common paper		
40 Oil-cloths for covering the above articles		
Carried over	4624	4153

	Pairs of Oxen.	Carts.		
Brought over	4624	4153		
Instruments for the Laboratory and work-shops.				
3 Mealing tables with trestles	2	2		
40 Wooden troughs for mixing fuse composition	}	}		
20 Heavy mallets for fixing fuses				
40 Setters for driving ditto			2	2
60 Drifts for ditto				
30 Ladles for ditto				
24 Small brushes for glue				
24 Tin funnels of different sizes for loading shells and grenades				
50 Rasps with handles				
50 Drawing knives				
6 Sieves of hair or fine silk				
6 Hand saws				
12 Pair of scissars of sorts				
30 Augers and gimblets				
6 Handcrews				
12 Gouges				
4 Pair of pincers				
150 Tin measures of different sizes	3	3		
150 Can-hooks for shells				
100 Quadrants				
1000 Pricking wires				
100 Lanterns of sorts				
60 Wire sieves				
1 Bench for carpenters				
6 Buckets				
10 Pails				
2 Large melting pots with iron trivets				
2 Small ditto				
6 Small axes				
12 Hand bills				
Steels, flints matches and tinder boxes				
Carried over	4631	4160		

Intrenching

	Pairs of Oxen.	Carts.
Brought over	4631	4160
Intrenching Tools.		
5000 Pick-axes of kinds	} 100	100
10000 Mattocks with helves, supposing there are no lines of circumvallation to construct		
600 Spades with helves	5	5
300 Axes of forts	} 25	25
1000 Hand bills		
Tools for forty Miners.		
20 Iron mallets	} 3	3
200 Jumpers and gads		
20 Hammers with heads and points		
20 Cutting hammers		
40 Trowels		
20 Small spades for cutting		
2 Searchers in several pieces		
Tools for thirty Carpenters.		
10 Cross cut saws	} 4	4
20 Common ditto		
30 Broad axes		
20 Hammers		
10 Sledge ditto		
150 Chisels and gouges of forts		
300 Augers and gimblets		
6 Hand vices		
10 Iron crows		
6 Planes		
10 Pairs of pincers		
Carried over	4768	4297

Tools

	Pairs of Oxen.	Carts.
Brought over	4768	4297
Tools for ten Blacksmiths		
2 Forges complete, with anvils and stocks	2	2
20 Pairs of forge tongs of different sizes	}	}
8 Nail borers		
15 Hammers		
8 Sledge ditto		
40 Files of forts		
2 Benches with beak irons and vices	3	3
2 Presses	}	}
Spare carts and oxen with each convoy .....			87	48
Total	4860	4350

The miners tools contained in this inventory, are for working under ground, and piercing the wall of the counterscarp; but if the soil be rocky or very hard, there must be a greater proportion of iron picks and steel gads; and the following articles should be added: iron jumpers case-hardened at the points; small iron scrapers for clearing the holes; needles for charging them; common iron crows of different sizes; picks pointed with steel; cutting mallets with steel edges; and mallets with case-hardened points.

29. Should it be intended to attack two fronts at once; the quantity of guns, mortars, ammunition and tools of all kinds must be increased in proportion to the extent and seriousness of the second attack.

If only one front be attacked, and the works difficult to beat down; as when constructed of hard turf, 900 or 1000 cwt. of powder must be added to the quantity in the inventory: since after having made openings in the revetement with cannon shot, the miners must be introduced for the purpose of making practicable breaches; and the number of rounds allotted for the mortars in the second parallel must be augmented by about $\frac{1}{3}$, that the garrison may be continually harrassed till the operations of the miners are completed. If the works be of common earth with one stage of countermines; the above-mentioned quantity of powder must be allowed for the mines and mortars, and a third added to the quantity intended for the direct firings from the first batteries,

ries, that a constant firing may be kept up against the defences of the place, while the miners are busied in exploring the countermines: with two stages of countermines, the number of rounds for the mortars must be doubled, and at least four times the quantity of powder provided for the attack of the countermines, together with planks and joists for the shafts and galleries. When there are no out-works on the front attacked, the artillery and stores designed (28) for the attack of the ravelin may be omitted. If the profiles of the out-works are too narrow to admit of cannon, the 16 prs may be left out of the inventory: as the fire from the 10 inch mortars will in this case be sufficient against the ravelin.

30. These observations have reference only to the place itself: but there are others to be made on the nature of the adjacent country, and the choice of carriages for the transport of stores. If the fortress be situated among mountains, where it is difficult or perhaps impossible to use wheel-carriages, a greater number of capstans with ropes and pulleys, both single and double, must be provided, that every necessary article may be brought forward by men. If the soil be so rocky as not to furnish a sufficient quantity of earth for the construction of the batteries, a proper number of sacks filled with earth and wool must be transported to the spot.

If the town be surrounded with rivers or broad canals, some wooden or leather boats with their apparatus should be provided, together with a large quantity of trestles and every other thing requisite for constructing bridges, for the passage of the artillery and stores, and for keeping the communication open between the several parts of the attack. If the stores be transported in boats or waggons, the oil-cloths for covering the powder, match, and other combustibles, should be much larger than when they are carried on beasts of burthen: when the latter expedient is adopted, strong nets must be provided for holding the shot and shells; the weight put into each package should never exceed $1\frac{1}{2}$ cwt.

31. When the whole or a part of the stores for the siege is drawn from any fortified town, it ought to be as far distant as possible from the theatre of war: should it of necessity be a frontier town, the commanding officer of artillery ought to signify it to the persons at the head of his department, that the stores he has taken away may be instantly replaced; lest from some accident, the system of the war be suddenly

suddenly changed, and the enemy take advantage of the unprovided state of the town to attack it.

Guns that are not perfectly good will answer very well for ricochet firing and for battering in breach : when there are any such, therefore, in the town from whence the stores are drawn, they should be included in the inventory, and after the siege be condemned and sent to the foundry : likewise any powder, carriages, cordage, sand-bags, or other stores that have been kept too long in the magazines ; since a commanding officer of artillery may by skilful and judicious arrangements employ them very usefully, without detriment to the service, yet greatly to the interest of his sovereign, by saving the money that the purchase of new articles would cost.

Finally, if there be reason after the trenches are opened to apprehend that the obstinacy of the garrison may so far protract the siege, as to render the supply of ammunition inadequate to the reduction of the place, the commanding officer of artillery should give timely intelligence to the persons charged with supplying his department, that the operations may not be retarded or suspended.

32. The following return shews the least number of officers, non-commissioned officers and privates for the service of the artillery at a siege under the presupposed circumstances (28).

A commanding officer	
Second in command	
Major	
An adjutant and assistant	
Captains	12
Subalterns	36
Serjeants and corporals	92
Bombardiers and gunners	700
	<hr/>
	840
Sappers	80
Miners	40
Artificers for laying platforms and } bridges	} 40
	<hr/>
Total	1000

Beside these, a detachment from the line must assist the bombardiers and gunners in constructing the batteries, and working

working the artillery; and a few steady intelligent men picked out for carrying on the sap. With one stage of countermines, the number of miners must be increased to 80, and with two to 160. The infantry must furnish some fit men for working under ground, and building the frames of the shafts, branches and galleries.

C H A P. II.

O F C O N V O Y S.

33. **T**HE transport of artillery and stores is either by land, or water: in the former case, a rendezvous is appointed for all the carriages, and the roads are put in repair; in the latter, the boats are collected at the place most commodious for embarkation.

So soon as the commanding officer of artillery has received orders from the general to forward the guns, stores, &c. contained in the inventory previously concerted between them; he dispatches an experienced officer to the camp, the moment he hears that the place is invested, to choose a proper place for the park; and when the convoy marches by land, he detaches one or two subaltern officers to examine the condition of the roads and bridges, that they may be repaired, or rebuilt if necessary: in the mean time, the stores are loaded and every thing prepared for departure.

34. The roads should be broad and straight, for the sake of shortening the line of march, and avoiding the delay that sometimes happens in narrow roads to a whole convoy from the breaking down or oversetting of a carriage, particularly of a heavy gun. In a mountainous country, where the roads are steep, narrow and winding; they should if possible be widened and mended: if that cannot be effected, new ones must be made sufficiently broad and straight. A steep road is less inconvenient than a winding one; the difficulty in the first case being surmounted by dividing the stores into a number of carriages; but in the second, from the short turns, the guns must frequently be dragged on sleighs by the soldiers with the assistance of ropes and tackles, with great labour and much loss of time.

35. Bridges, for the passage of heavy artillery, are made either with beams, trestles, or boats. Should there be a
necessity

necessity for passing without delay a deep ditch less than 20 feet in breadth, six or seven beams may be taken from the nearest houses or villages: when there are none within reach, some trees measuring 4 or 5 feet in girth should be instantly felled, and when stripped of the branches laid across the ditch, at about ten inches distant from each other; and upon them a layer of boughs, or any wood that can be more easily procured, 12 or 14 feet in length, and 4 or 5 inches in thickness; and the surface made smooth with a coat of earth or turf. If no trees large enough for this purpose can be found, or the ditch is more than 20 feet wide, a firm and substantial bridge may be made by placing a trestle in the middle of the ditch, and resting the ends of the trees upon it; or in lieu of the trestle, a thick piece of timber supported at each side by two beams fixed in the banks; this cross piece will be strong enough to support the ends of the trees resting on it.

36. Bridges on trestles can only be laid over canals, or rivers that are not subject to floods; as in case of a large swell they would be in danger of being carried away. The trestles are generally made on the spot of well-seasoned timber that squares from 8 to ten inches. Their height above the surface of the water should be at least 3 feet, and the cross piece that forms the head 12 or 14 feet long: the distance between every two trestles is 14 or 16 feet; and when the bottom of the canal or river is not rocky or gravelly, their feet are nailed upon square wooden frames, to prevent their sinking. Six pieces of timber, 7 or 8 inches square, called *baulks*, are laid on the trestles, and the ends nailed down; the whole breadth from outside to outside of the baulks is from 10 to 12 feet, and over them are two layers of planks or cheffes $1\frac{1}{2}$ inch in thickness, and 12 or 14 feet in length. When the timber is green, the thickness should be increased by $\frac{1}{2}$; and, in lieu of planks, any wood that is 4 or 5 inches thick may be nailed on, and covered with turf or earth as before-mentioned (35).

37. If the river be subject to freshes or very deep, the bridge is made of boats fastened together two and two by six well-seasoned baulks from 6 to 8 inches square, and of such a length, that the ends rest on the outer gunnel of each boat, after leaving an interval of eight feet between every two boats; they are nailed down to the gunnels of the boats, and covered with planks two inches thick and 14 feet

feet long ; a second layer of planks $1\frac{1}{2}$ inch thick, and 10 feet long is laid transversely. The pairs of boats thus fastened together are placed at 8 feet distant from each other, joined by baulks 6 or 8 inches square and 10 feet long, nailed down to the gunnels, and covered with cheffes as before. To every two boats there is an anchor, and a cable from each to hold them against the stream ; and when from its great rapidity this is found insufficient, a sheer-line from each boat is made fast to the banks of the river. Rails 4 feet high are placed along each side of the bridge for the safety of passengers.

If the river be navigable an opening is occasionally made in the bridge, by placing the center pair of boats almost contiguous to those on each side, and joining them by baulks that are not nailed down ; thus, they may be easily removed to give a passage to any boats or vessels passing up or down.

To render the bridge more secure against swells, large stakes are driven into the bed of the river, at the places where the anchors lay, and the boats are fastened to them with strong cables. And when there is any reason to apprehend that the enemy have a design of sending down with the current, boats filled with combustibles to set fire to the bridge, a strong iron chain should be stretched across the river, and supported by stakes at about $1\frac{1}{2}$ foot above the surface of the water.

38. When the bridges are made, and the roads repaired, the train of artillery, &c. sets off, divided into several convoys : for if the whole moved at once, the line of march would be nearly 17 miles ; since each pair of oxen takes up at least 10 feet, and each carriage about the same. The distribution should be made into four parts ; this will enable the officers to pay more attention, will render the march less troublesome and tedious, and they will be more amply supplied with provisions and forage on the road.

In the first convoy should be sent the intrenching tools of all sorts, that the troops may proceed to throw up lines and open the trenches, together with every article belonging to the laboratory, and a certain proportion of shells and powder ; that the laboratory may be instantly established, and the necessary preparations made for the ensuing siege.

The second convoy should be composed of the guns intended for the royal battery, the mortars for the second parallel,

parallel, and about 200 rounds of ammunition for each gun; together with the sleepers and planks for the platforms.

In the third convoy should be forwarded the guns and stores that will be soonest wanted; and the fourth should include every other article contained in the inventory. A store keeper and deputy should accompany each convoy: a commissary of artillery and some clerks of stores should be likewise sent to take account of all issues. The stores in each convoy ought to be classed under the proper head, that every thing may be kept distinct, and without confusion: at the head of the line of artillery, should be a waggon carrying a gin and hand jack, with proper ropes and tackles, in case any of the guns are overset; the guns should follow next on the block carriages, and then their carriages, stores, &c. in the order laid down in the inventory.

The drivers are divided into companies from 40 to 60 each, under the direction of a conductor, who has the charge of the carts, and is responsible that the drivers are attentive to their duty.

39 The detachment from the royal regiment of artillery, intended for the service of the siege, is also divided in as many detachments as there are convoys, and the command of each is given to the eldest officer; who previous to the march, gives the necessary directions to his subalterns. When there are guns in the convoy, he posts the most experienced non-commissioned officers and gunners on the flanks, to direct the drivers in the turnings and hollows of the roads, that the carriages may not be overset through their unskilfulness or negligence; a subaltern officer superintends this particular duty: another subaltern and a party is detached to the powder; and the remainder is divided into three parts; of which one forms the vanguard, the second the rear-guard, and the third is distributed in a single file from front to rear, to prevent the line of march from being broken. A non-commissioned officer and some privates should be sent forward, to extinguish all fires in the houses on the side of the road. If the number of artillery-men be inadequate to these duties, the commanding officer should apply for a detachment of infantry. Matters being thus adjusted, the drummers at break of day beat the *general*; and an hour afterwards the *assembly*, when the drivers harness their oxen; and at the third signal, the convoy moves in the order before-mentioned. At the

first signal, the quarter-master with the camp-colour-men and a waggon-master, goes forward to the place where it is intended to halt, in order to prepare quarters and forage, and choose a spot for parking the artillery; it ought to contain all the carriages drawn up in a square, leaving between each file a space sufficient for harnessing and unharnessing the oxen. The park is formed as fast as the carriages arrive; and guards posted for the safety of the powder and stores, and to prevent the desertion of the drivers. The forage is distributed in such proportions, that the cattle may be able to continue their route at the appointed time. The guards furnish rounds and patrols during the night, and allow no person to approach the park, unless sent by the commanding officer. The same order of march is resumed the next and following days, till the convoy reaches its destination; never moving more than 14 miles a day, especially with oxen. To prevent confusion, the drivers are obliged to keep the same place during the whole march; and for the sake of punishing irregularity, each carriage is numbered, and the driver wears a ticket in his hat.

40. When part of the stores are carried on beasts of burthen (23), in making up the several convoys, they should be kept totally distinct from the carriages; and the officer who goes forward to mark out the park, should pitch on one or two houses for lodging the stores, where they may be ranged in their several classes, and the powder and other articles effectually sheltered from rain. If no shelter can be found, some mules laden with planks and sleepers should march at the head of the convoy, to make platforms for keeping the articles that may be damaged by wet, from touching the ground; and oil-cloths with which every mule ought to be provided, should be laid over the whole.

41. When the artillery and its appurtenances are to be transported in boats, some skids should be laid under the guns and mortars, and small floors made of planks for supporting the shot, shells, match, &c. always leaving a clear space in the middle of the boat for bailing.

The stores are transported in waggons from the magazines to the place of embarkation, which should be spacious enough to admit of many men being employed at the same time, without confusion or danger of mixing the stores of different species together.

When

When there is a sufficient number of boats, the whole should set off at once, and form but one convoy; but when from the scarcity of boats, several trips must be made, the preceding directions for land-carriage should be attended to, and a detachment of artillery sent with each convoy, reinforced, if necessary, by a party of infantry: a particular guard composed solely of artillery-men, should be put on board the powder-boats, which in the evenings should be moored at a distance from the others. The place of debarkation having been pointed out by the commander in chief, to the officer who was sent forward to the camp (33) the carriages which that officer has provided are ready to receive the guns and stores when the boats arrive, and transport them to the park. The landing-place ought to be spacious and commodious, and a working party of infantry without arms should assist in unloading the boats.

42. It is taken for granted, that the country, through which the convoy is to pass, is entirely clear of the enemy's troops; so that the guard will only have to prevent emissaries or marauders from pillaging or privately setting fire to the stores, or endeavouring in any other method to destroy them or impede the march.

But if the country be infested with flying parties of the enemy, it will be necessary to take other precautions with regard to the march and halts of the convoys; according as the danger seems more or less pressing. The train of carriages, &c. should be drawn up if possible in some secure place, as a walled town. In case of parking in the open country, a strong spot should be pitched on, and the accessible points fortified with pallisades or abbatis.

43. The necessary dispositions to be made in marching through a suspected country, may be reduced to the following cases: when there is apprehension from flying parties only, detachments to check their incursions are posted in the towns and places contiguous to the route of the convoy, and a sufficient escort marches with it for its protection.

When the convoy is exposed to be attacked by a considerable body of troops, there are three methods of covering it: the first, by marching a corps superior in number to the enemy, between them and the convoy, till it reaches the camp; this supposes but one convoy: if there be several, this corps must advance to the enemy, follow their motions,

and keep them in check, till the whole have passed. When the line of march can be covered by a large river, this route should be preferred, though it may be the longest. The third method is when the escort that marches with the convoy is strong enough to repel any attack of the enemy: the artillery should in this case contribute towards its own defence; it is necessary therefore to enlarge a little on this head.

44. In open champaign countries, the van and rear guards consist of cavalry; the infantry, which is the main part of the escort, forms the centre. But in a strong country intersected by rivers or canals, by forests, morasses, ravines, or defiles, the number of infantry is increased, and the cavalry diminished, by substituting in their place dragoons, who occasionally act as cavalry or infantry. If the route lie through a mountainous country, the escort is composed solely of infantry.

The command of a numerous escort is generally given to a general officer, who makes the following disposition previous to the march, that every person may know their posts in case of attack: a few hours before the convoy sets out, he sends detachments to reconnoitre the country, and divides his troops into four parts; the first forms the vanguard, the second the rear-guard, and the third, which is the largest, and consists solely of infantry, is reserved for the centre: the fourth part is distributed in small detachments along the flanks, to seize posts and occupy cross roads, &c. till relieved by the rear-guard. When the road is 25 feet wide, the carriages move two a breast, to shorten the line of march, and be the more ready to repel an attack.

Previous to crossing a bridge, or entering a defile, the country on the other side should be reconnoitred for fear of an ambuscade, and the carriages drawn up in several lines close to the bridge, that the escort may be as much as possible collected together: on moving forward, the former order of the march is resumed. If during the march an order be given to prepare for action, the officer of artillery will instantly form the carriages into an oval or oblong figure, presenting the longest side to the enemy, with the heads of the horses or oxen turned toward the centre, that there may be no possibility of their running away: the infantry may be sometimes compelled to retire behind the line of carriages, the powder waggons therefore for fear of accidents

accident should be placed in the centre. But when from the nature of the ground, it is impossible to form in this manner, the carriages should be drawn up in two or more lines, that the infantry may retire behind them, always placing the powder waggons at a distance. The guns mounted on travelling carriages should be placed in situations, where from the nature of the ground, and the dispositions of the enemy, their fire may have the greatest effect. When the convoy consists of beasts of burthen, they should be drawn up close to each other, and in one line, that the infantry may form behind them as a parapet, direct their fire against the enemy.

Strict orders should be given to the drivers under the severest penalties not to unharness before they are ordered; which can only be, when the escort is obliged to abandon the convoy: the artillery-men should in that case, before they retire, privately dispose some fire that it may communicate to, and blow up the powder and stores, so soon as the escort is out of danger.

C H A P. III.

OF THE PARK OF ARTILLERY.

45. **T**HE park of artillery should be established in a secure place out of the reach of cannon-shot from the town, and as near as possible to the front attacked: it should be so spacious that the different stores may be separately classed, and loaded or unloaded without delay or confusion. With these requisites it is indifferent whether its figure be regular or not.

The carpenters, miners, and smiths shops are fixed in the houses contiguous to the park; when there are no convenient houses, sheds are made of planks covered with oil-cloths. A large house at a proper distance from the park is chosen for the laboratory; and some detached buildings surrounded with walls and hedges for lodging the powder.

46. The waggons should be unloaded as fast as they arrive at the park, and sent back; reserving a proper number for transporting the guns and stores to the batteries.

The guns are drawn up in one or two lines; the 32 prs. mounted on their carriages; and the whole furnished with side-arms, coins, hand-spikes, and limbers, to be ready for service. The mortars are left upon the block waggons; and the shot of different diameters separated from each other. The intrenching tools are deposited at the park; the artificer's tools sent to the respective work shops; and the laboratory stores to the laboratory; the powder is lodged in the buildings allotted for it; a space is left for the waggons that are to remain; and the tents of the artillery-men are pitched where they can best guard the park.

During the night a patrol goes constantly round the park and laboratory, to keep off pillagers or scouts of the enemy, and guard against fire; suffering no stranger or idle person to approach. A strong guard is stationed over the powder magazine, allowing none to come near it but those who are known to have business. All these guards should be furnished by the infantry, that the artillery-men may not be diverted from other necessary duties.

47. Things being thus disposed, the artificers are set to work; the carpenters to prepare timber for constructing bridges over the ditches, and laying the platforms of the batteries: the miners to make ready the frames for the descent into the ditch, and the attack of the countermines; and the smiths to repair any of the iron work that may have been damaged.

The senior officer of the bombardiers superintends the laboratory. All the combustible articles are lodged, the compositions mixed, and the fuses driven in the rooms least exposed to accident; and the shells and grenades are loaded under a shed separated from the other buildings. Three or four small furnaces are erected in convenient places for melting the pitch and glue.

The working hours are regulated, and the greatest honesty and sobriety recommended. The floors of the rooms where the fuses are driven, and the compositions mixed, are covered with oil-cloths: all iron tools are forbid to be used; no person is suffered to bring in fire of any kind, nor are any of the people employed at the furnaces allowed to enter the house: the loaded shells are put by themselves. The bombardiers should reject all split or rotten fuses, lest the shells burst immediately on being fired; they should be careful not to make them too thin, lest they split in driving;

driving; and to cut them of a proper length: for, when they touch the bottom of the shell, the head being too long, may strike against the mortar when fired, and break off, so that the shell will not burst. The shells should be examined before they are loaded, and those rejected that do not stand the water proof.

The fascines should not exceed 10 feet in length; those of 20 feet are only used when the works are intended to stand a long time; as they are more solid than works made with shorter ones.

C H A P. IV.

OF THE CONSTRUCTION OF THE FIRST BATTERIES.

48. **T**HE object of the besieger, in the construction of his first batteries, is to dismount the cannon in the front attacked, destroy the embrasures, and harrass the garrison so much in the several points of defence, that they may be obliged to abandon them, or at least slacken their fire; that the approaches may be carried on with more expedition and less danger: 32 and 16 prs. are used for this purpose; the batteries are constructed with embrasures, and situated so as to fire *directly* against the works: the edifices in the town are likewise cannonaded from these batteries (19). The besieged are perpetually harrassed along the front attacked, with shot and shells fired *à ricochet*; the batteries for this purpose are made without embrasures, on the faces of the attacked works produced; whence they are enfiladed with great precision and effect.

49. There are three kinds of batteries with embrasures; sunk, level, or raised on cavaliers: the first require fewer workmen, and are soonest made, wherefore they are always preferred when the ground permits: those on cavaliers are never erected but through necessity, their construction being very tedious and laborious.

(Pl. 1.) If the ground at the points G, H, K, be some feet higher than at P, Q, the batteries erected at G, H, K, may be sunk. If G, H, K, and P, Q, be on the same level, the batteries may be likewise level; and when the ground at P, Q is higher than at G, H, K, so that the sap cannot be carried on without the sappers being endangered by the

fire from the batteries G, H, K, then they must be raised on cavaliers. Mortars and ricochet batteries should be always sunk; they may be made in the approaches, which will save time; and they will be less exposed to any attempts of the enemy. The mortar batteries, L, N, Q, and the ricochet batteries M, O, are sunk in the parallels. Batteries for red-hot shot may also be sunk in some part of the trenches. It having been demonstrated in the treatise on projectiles, that the path of a projectile is always a curved line, whatever be its initial velocity, or length of range, it is evident that the direct fire mentioned above, can only be relatively reputed such in practice: for, to express in few words the difference between two lines of projection, one of which is *direct*, or, more accurately speaking, the curvature of which is but small, and of the other, large; if we suppose the besieged to be covered by the parapets from the former, they will be exposed to the latter.

50. The object of the first batteries being to dismount the artillery that may impede the progress of the sap (17, 48); the fire from them should be nearly perpendicular to the faces of the works attacked, and at a proper distance; that is to say, from 400 to 550 yards from the covered way: when at a greater distance, the shot will often be of no effect; and when nearer, they will be too much exposed to the musquetry of the place. Upon this principle, it sometimes happens that two batteries are joined together, and present a salient or re-entering angle towards the place; and at other times are entirely separate: this difference proceeds solely from the distance between the battery and place, and the relative situation of the works.

(Pl. 1.) In this case, there are but three batteries with embrasures, viz. G, H, K; each of which has two faces presenting a salient angle towards the place.

If these batteries were erected at the points R nearer to the place, the faces would be separated, and there would be six single batteries R: again, if they were erected at S, farther distant than G, H, K, there would be three batteries, each presenting a re-entering angle towards the place; and if carried farther back as to T, there would again be six single batteries.

If, instead of varying the distances of the batteries from the place, we suppose a difference in the relative position of the works, the batteries in order that their fire may be perpendicular

perpendicular to the faces of the works, must be erected more to the right or left, which will occasion similar changes in their figure and situation.

Some artillerists having observed that the batteries S, T establish a cross fire, concluded that they were preferable to batteries G, H, K, the fire from which does not cross; but to destroy so erroneous an opinion, it is sufficient to recollect that a cross fire is only advantageous when the point of intersection falls on the object to be battered, when being thus taken in front and flank, the effect is greater. The lines of direction G A, L A, are precisely of this kind, as they batter in front, and enfilade at the same time the face A; whereas in the cross fire X A, X B, though the lines of direction intersect each other at the point Y, yet their effect upon the faces A, B, is the same as if they did not intersect each other, and were drawn from the battery G.

By help of the directions given in this and the first chapter, it will be easy in every case to determine the number, situation, direction, and kind of batteries most proper for battering the works, demolishing the buildings, breaking through casemates not constructed with sufficient solidity, and cannonading with red-hot shot; it only remains then to point out the method of construction.

51. In regular sieges, batteries are constructed with fascines and pickets to give them the requisite solidity.

So soon as the engineers have carried on the approaches to the places where the first batteries are to be erected, the commanding officer of artillery makes a disposition of his officers: he detaches a captain to each of the most considerable batteries as G, H, K, and puts under his direction a competent number of subalterns, non-commissioned officers and gunners; he then accompanies the eldest of the captains to the spot where the battery is to be erected, and traces it out with pickets, leaving an interval of 20 feet between every two guns; he does the same at the other batteries in succession. The captain of the first traced battery returns to the magazine, where all the artillery men and parties of the line that are to work at the construction of the batteries during the night, assemble before sunset. The adjutant of artillery makes the distribution of pioneers, in proportion to the extent and kind of battery, allotting 14 or 16 men to every 20 feet in length, when the battery is to be with embrasures, and sunk; and 20, or 25 when it is to be raised, the exact number of men being determined by

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the distance from the park. At sunset, the captain takes the major part of the subalterns, and a few men to carry fascines, pickets, and mallets, and marks out the battery; making his detachment observe the roads and turnings, that the men who bring up the stores may not mistake the way; which frequently happens when this precaution is neglected, particularly if the road does not run along the trenches of communication, but across fields and meadows. While the captain is thus employed, the subalterns and a part of the non-commissioned officers return to the park: the pioneers are by this time divided into squads, and provided with shovels and pick-axes alternately; they then load themselves with fascines and pickets, and each squad with an officer in front, and a non-commissioned officer in rear, proceeds with all expedition to the battery; a serjeant marching on the flank to make the men keep their files, and prevent the line from being broken, or any unnecessary delay. When the squads arrive at the battery, their work is pointed out; one or two being reserved to transport the rest of the materials from the park to the battery.

52. In sunk batteries, the interior face is traced parallel to the exterior at 20 feet distant; and on both faces, pickets are planted at every 20 feet to mark the centre and direction of each embrasure. On the interior face, 12 inches are set off to the right, and as many to the left of each picket; and on the exterior face $4\frac{1}{2}$ feet to the right, and as many to the left, which gives the form of the merlon. A trench is then dug on the interior face $2\frac{1}{2}$ feet deep, and lined with fascines picketed to the ground: to give the battery greater solidity, a stratum or layer of long pickets is placed with the heads resting on the upper fascines; these heads which are about 6 inches in diameter form part of the interior revetement: the remainder of the merlon is traced with fascines picketed to the ground.

The ditch is then enlarged towards the country, and the earth thrown into the merlons: in proportion as they are raised, other fascines are placed, and a layer of long pickets laid between every two rows of fascines along the sides of the embrasures, and between every three rows along the interior and exterior faces; the slope on both faces is a fourth part of the height. In general, the merlons are not raised above three feet the first night. At day break the workmen are relieved by a fresh working party, and the ground levelled, that the carpenters may lay the platforms. At sunset a fresh party completes

completes the battery, constructs the powder magazines, and mounts the guns on the platforms as fast as they arrive, that the battery may be ready to open at break of day. While the batteries are erecting, a part of the line make two trenches of communication between the flanks of the battery and the nearest parallel; this detachment is likewise relieved every 12 hours.

53. In level batteries, the figure is first marked out with fascines picketed to the ground, and not less than 20 feet allowed for its thickness when the soil is firm and tenacious, and 25 feet when it is light or sandy; leaving a berm 5 or 6 feet wide on the exterior side. The workmen then begin to dig the ditch, throwing up the earth to raise the battery; upon the second fascine, on the exterior face is placed a layer of long pickets, and on the interior face another row of fascines, which gives the height of the cell of the embrasure. The ditch instead of being widened should be deepened as much as possible the first night, that the pioneers may the next day work under cover. The battery is seldom raised above $2\frac{1}{2}$ feet high the first night: the merlons are traced in the manner before directed. At break of day this working party is relieved by another consisting of half their number; they enlarge the ditch all the day, throwing up the earth to form the battery or merlons, if traced. When the embrasures have not been marked out, the senior officer plants the pickets at sun-set for determining their direction, and completes the tracing of the merlons at the arrival of the fresh working party, which should be as numerous as in the preceding night; for the sake of dispatch, a proportion of work is allotted to each man, that the battery may if possible be finished that night, which however rarely happens when the nights are short. During this night also the platforms are laid, and some guns brought to the battery, if they be covered from the enemy's fire during the next day. The following day and night are employed in constructing the powder magazines, completing the batteries, and preparing every thing for opening them on the third morning at sun rise. During the first night also, the communications between the flanks of the batteries; and the nearest parallel are made, that in case of a fall from the town, every part of the trenches may be mutually supported.

54. In constructing batteries on cavaliers, the first step is to raise the ground to the same height as the intermediate ground

ground between the battery and the place. Too many pioneers cannot be employed in this work during the night; but during the day so many only as can be covered from the enemy's fire; and to expedite the work, the soil nearest at hand is used. The breadth at top should be at least 45 feet, and the slope two thirds of the height. A berm of 5 feet is left towards the place, and the dimensions of the battery are the same as before directed (53). In the rear of the battery a proper slope is made for the drawing up the cannon, and adjoining to it is constructed the powder magazine.

The battery for school-practice on the other side of the river Po will convey a just idea of this species of battery, and be at the same time a convincing proof that works which require so much time and labour, should never be undertaken at a siege, without an absolute necessity.

It has been advanced by some authors, that the first batteries should always be erected on cavaliers, even if the ground be on the same plane with the place, that greater part of the ramparts may be thereby discovered: but if we reflect how high the cavalier must be raised before a single foot of the revetement can be seen, it will appear that such a trifling advantage by no means compensates for the loss of time and labour; besides, as the first batteries are intended to dismount the artillery of the place, and destroy the defences, this end will be fully answered when the besieger from them can see his objects without endangering the lives of the sappers, or interrupting their progress.

55. So soon as the second parallel is completed, the first ricochet and mortar batteries are constructed at the points whence the faces of the covered way, and the attacked works can be enfiladed with most effect (17). These batteries should be completed in twenty-four hours; wherefore, 14 or 16 pioneers are allotted to every 20 feet; the parapet is faced with fascines, and the trench enlarged as much as may be necessary: passages of communication are made round the rear, to prevent any embarrassment; and the powder magazine is constructed in the space between this communication and the battery. When the ricochet batteries can be incommoded by a plunging fire from the cannon of the ramparts, embrasures should be made from 6 to 8 feet wide, sloping inwards: by this expedient the guns will be concealed, and may be placed closer to the parapets. When the sappers begin the third parallel, the
fire

fire from the ricochet batteries ceases; some royal mortars are then placed in the second parallel to annoy the troops in the covered way; and for the same purpose, some stone mortars are brought into the third parallel, so soon as any part of it be finished. The batteries for these pieces need not be faced with fascines, unless the soil be sandy; it being sufficient if they resist the shock of the discharge.

56. The guns and mortars are drawn to the batteries during the night, along the roads least exposed to the enemy's fire: proper bridges having been previously laid over the trenches for their passage: the horses should be changed where the ground is level, and any that are killed or wounded immediately unharnessed.

If the road be exposed to the fire of the enemy's musquetry, two or three guns only should be brought forward at a time, to avoid the confusion that arises when any of the horses or drivers take fright. In mountainous situations, where the musquetry of the place has a great command, new roads for the cannon should if possible be made less steep and exposed. In steep and winding roads that cannot be made practicable for horses, the guns must be dragged by men: when this must be performed under the fire of the place, strict silence and regularity should be observed, and the whole halt and move forwards at once, by signal from the commanding officer.

C H A P. V.

OF THE DAILY SERVICE OF THE FIRST BATTERIES.

57. **T**HE batteries being compleated, the general of the trenches for the day gives an order for them to open; and immediately each battery directs its fire against its particular object.

The ricochet and mortar firing is continued, but the direct firing ceases during the night. By using moderate charges, loading the guns with care, and pointing them with accuracy, the service will be carried on with precision and effect: for when the guns in the first batteries are fired with the charges that produce the longest ranges, the object

is frequently missed from the violent shock that the carriage sustains, a great quantity of ammunition is uselessly expended, and the guns are often rendered unserviceable, before the conclusion of the siege.

58. In making the distribution of artillery-men, the following is the proportion to be relieved every 24 hours; *viz.* eight men to a 32 pr. six to a 16 pr. 13 inch or stone mortar; four to an 8 pr. and 10 inch mortar; and two to a royal mortar. An officer and non-commissioned officer are attached to every 4 or 6 pieces; and when a battery contains a greater number, it is commanded by a captain.

59. The object of the direct firing is to dismount the artillery and ruin the defences, that the garrison may be unable to work their guns when the besieger has established himself with his musquetry in the second or third parallels. The firing from any battery should never be diverted from the particular object against which it is intended to any other, as such desultory operations are generally inefficacious towards the reduction of the place. The common rate of firing from batteries at a siege is at most 9 rounds an hour from each gun.

In ricochet firing, the guns are elevated between 8° and 12° ; and fired with very small charges, just sufficient to throw the shot over the parapet or into the covered-way; that it may afterwards make several bounds: the proper charge having been ascertained, is put into flannel cartridges; that the powder being always collected together in the same manner the inflammation may be uniform; and since the firing is to be continued day and night, the coins and platforms should be marked that the elevation and direction may remain the same.

In batteries for throwing red-hot shot, a large iron grate is fixed behind the battery; the shot are laid in it and a strong fire kindled: the proper charge for throwing the shot into the place with an elevation from 8° to 12° is put into the gun with a wad and turf over it; then the gun being pointed and primed, a gunner sponges it out with a wet sponge, and with a pair of pincers puts the red-hot shot into the gun, and another gunner instantly sets fire to the priming with a match. These batteries likewise fire night and day; but as the guns are soon heated, the firing ceases at proper intervals to allow them time to cool.

60. The mortars intended to enfilade the works in order to dismount

dismount the artillery and harass the besieged, should be laid at small elevations, that the shells may not bury themselves: and when from the small extent of the work to be entailed, this method would produce no effect; the charges should be diminished and the elevation fixed between 35° and 45° , being that, as has been already observed, which is least liable to irregularity. Mortars designed for breaking through casemates should be fired at the highest elevation and with the largest charges, that the shells may produce the greatest effect, supposing they fall on a horizontal plane: but if it be inclined, the charge must be so combined with the elevation as to cause the greatest possible shock. The solution of this problem may be found in the essay on projectiles. Sceldom more than 5 rounds from each mortar can be fired within the hour, from the very great attention necessary in loading and laying them. The school practice will shew the service of stone mortars at sieges; the showers of stones projected from them produce great effect when fired at an elevation between 40° and 50° , and with a range not exceeding 270 yards.

61. In case of a general sally of the garrison, the officers will direct as heavy a fire as possible from the batteries against them, bring some of the guns to the flanks of the battery to cover the adjoining parallel; and use round or case-shot according to circumstances. There are frequently some field pieces placed on the flanks of the places of arms for checking sorties. If, in spite of these dispositions, the guard of the trenches is overpowered, and the enemy are on the point of getting possession of the batteries; the artillery men should discharge all the guns, and carry the side-arms into the parallel in the rear, lest the enemy turn the guns upon them. But these enterprizes cannot be of long duration, for as soon as the besiegers advance in force, the garrison will be compelled to retire; the artillery-men should then instantly return to their batteries; and in the first place examine the magazines to see that the enemy have not concealed any fire in them; they should then recommence their fire against the troops of the sortie, and when the action is over repair any damage that may have been done to the battery.

62. The commanding officer of artillery will visit the batteries every morning to see that the fire be well directed, and examine the effects of the preceding day: he will then go and make his report to the commander in chief of every thing within his department, and submit to him his ideas on the

the future conduct of the siege: he will visit the batteries again in the afternoon, taking with him a staff officer; to take notes of what ammunition will be wanting for the current service of the following day, and what case-shot and flannel cartridges, to enable the batteries to keep up a very close fire in case of sallies: he will also examine whether the magazines of the centre and flanks of the second parallel be provided with cartridges and flints for the infantry. On his return to the park, he will direct the articles that are to be sent to each battery to be separately prepared; and delivered over to the non-commissioned officers and privates detached in the evening to receive and conduct them at close of day, along the roads that lead most directly from the park to their respective batteries.

C H A P. VI.

OF THE SECOND AND THIRD BATTERIES.

63. **I**T being the object of the second batteries to make practicable breaches in the works, they should be combined two and two together in such a manner, that while one batters in breach the other may play on the defences that cover the breach. The second mortar-batteries will be properly disposed, if while one bombards the work that the besieger intends to give the assault to, and prevents the garrison from throwing up intrenchments within it, or at least retards their construction; the other directs its fire against the works that defend the breach: so that the garrison may from the continual shower of shells be compelled to abandon the defences; or, if they persist in remaining, be exposed to great loss.

64. When the trenches are advanced under the fire of the first batteries far enough to establish the batteries in breach, the artillery-men will construct them on the points whence their fire may the most speedily and effectually render the breaches practicable.

If the profiles of the works be advantageous for defence, and there be no commanding points, the batteries in breach and the collateral batteries must be erected on the crest of the glacis; but if there be a rising ground, whence at least half of the circuit of the place can be seen, and any points nearer

to but lower than the works, whence they can be battered with effect, as in the case of the place being built on an eminence and much exposed; then the batteries in breach should be erected on these points and collateral batteries established to destroy the defences.

Each battery should be erected opposite to that part of the fortification which it is intended to batter; and the breach will sooner be rendered practicable, if some guns can be brought to bear upon it obliquely. The service of the mortars will be most exact, when their batteries are perpendicular to the faces produced of the works that are to be bombarded; those for the stone-mortars should be established in the most advanced lodgements, taking care that the stones from their spreading can do no injury to the besiegers.

65. The third batteries are constructed on the outworks of the place: when there are two lines of cut-works, the besieger after reducing the first, must erect a fourth set of batteries in the outworks most contiguous to the body of the place; he will also be under the necessity of doing this, whenever the body of the place is constructed on a *system of demolition*, or with double bastions: he must determine on the spot from actual observation, whether there be any readier or surer method of reducing them than by opening breaches.

66. In the second plate these directions (63, 64) are exemplified: the battery in breach A is opposite to the part M M of the face of the ravelin in which a breach is to be made, and some guns might if necessary be placed at I to bear on it obliquely; the collateral battery B is directly opposite to the part Q that flanks the face M M. The battery in breach C is opposite to the part N N of the face of the bastion in which a breach is to be made, and if the ground at C does not admit of a sufficient number of guns, two or three may be planted on the face O of the place of arms, or on the lodgement made by the sappers within it; these two batteries will be supported by the collateral battery D opposed to the flank R.

The face M M of the ravelin and the flank R are enfiladed from the mortar battery G; and some stone-mortars are placed at F and E, to project stones into the flank R and the ravelin P, and interrupt the communication between the ravelin and the body of the place. The mortar battery K enfilades the ravelin and its communication, and contributes to annoy the flank R, and the part Q that covers the breach

S

M M;

M M: finally, the mortar battery H enfilades the face N Q, as well as the interior of the bastion.

If there be a cavalier, tenaille or fausse-braic, so as to make R a double flank, the number of mortars should be increased.

All the dispositions here laid down for attacking the body of a place, are equal applicable to the attack of a more extended front, whether covered with horn or crown-works.

67. With counter-guards before the bastions and ravelins, the batteries in breach should be constructed in such a manner that after the counter-guards are reduced, the guns may bear on the works they covered, in case the profiles of the counter-guards are too narrow to admit of the third batteries being erected on them. Thus, batteries should be erected at A, B (Pl. 3.) to open a breach at CC corresponding to the part KK of the face of the ravelin; and other batteries at D, E to open a breach at FF corresponding to the part LL of the face of the bastion. The collateral batteries should be erected agreeable to the preceding maxims; one at G to bear upon the flanking part I; and another at H to bear upon M. When the besieger after getting possession of the counter-guards, finds himself under the necessity of constructing a battery at N to ruin the defences O of the breach KK and another at P to ruin the defences Q of the breach LL, and the counter-guards are so narrow that the guns cannot be brought up through the breaches CC, FF to the respective batteries N, F; he must construct four others on the crest of the glacis; viz. one at R to make a breach at N where the guns may be got up, and a collateral battery at S to ruin the defences T; a third at V to make a breach at P in order to get up the guns; and a collateral battery at X to ruin the defences at Z. Under this supposition, the number of guns for batteries on the crest of the glacis, will far exceed the number requisite for the first batteries; which must be allowed for in making up the proportion of stores (28).

The rules given for the mortar batteries will be equally applicable to this as the preceding case (64), and will give the same position Y.

68. The batteries constructed on the crest of the glacis are always sunk, since the lodgements made there form a parapet. It should never be less than 20 feet thick; and for greater solidity the interior part should be faced with fascines. The distance between every two guns is 20 feet, independent

of the traverses of which there should be several to prevent the batteries being enfiladed. The interior width of the embrasures should not exceed 20 inches, that the gunners may be sheltered as much as possible from the musquetry of the place; without this precaution the service will be much retarded.

If the place be so situated that it can be battered in breach from any of the adjacent points, batteries should be erected on them without regarding the lodgments on the glacis; these batteries may be either sunk or raised according to the nature of the ground.

The artillery-men being very much exposed to the enemy's musquetry during the construction of the second batteries, the general of the trenches should order a number of marksmen to be stationed at proper places behind sand-bags or gabions, to keep up a continual fire on the parts whence the artillery-men are most annoyed. While the batteries are erecting, the commanding officer of artillery gives the necessary orders for moving the guns towards them, causing proper bridges to be laid over the trenches for this purpose.

If there be a dry ditch in the way, a slope may be made for getting the guns across; but if wet, a bridge must be thrown over. When the approach to the batteries is tolerably level, the guns may be drawn up by horses one at a time, to prevent the confusion that generally ensues when a gun is dismounted or a driver killed: when the approach is narrow and steep, the guns must be dragged by men.

69. The batteries for making breaches should fire day and night, directing their fire against the foot of the wall; and afterwards against the counterforts: since the earth soon crumbles down, when the counterforts that support the wall are beat down. A wall not very thick and solid is soonest demolished with small charges and an oblique direction; on the contrary, the charges that give the greatest initial velocities should be used against walls of great thickness, provided there be no danger of the guns becoming unserviceable before the conclusion of the siege. It will be likewise proper to fire *salvoes*, i. e. to discharge all the guns together; as beside the holes made by the shot, the adjoining parts are more violently shattered, even in the most solid revetements. The collateral batteries seldom fire during the night, their primary object being to dismount the artillery of the place, and enlarge the embrasures so as to render it dangerous for the besieged to

work their guns. When this service is effectually performed, their fire is directed against the other parts of the parapet to destroy all shelter for the enemy, and the whole is seconded by a brisk fire of musquetry from the besiegers, that the artillery-men being covered may fire with greater justness and precision. The second mortar-batteries will fire day and night according to the former directions (63, 64).

70. The third batteries are constructed in the lodgments made in the outworks, and the same precautions taken as during the construction and service of the second batteries to cover the artillery-men from the fire of the place.

When there are no outworks but ravelins, and the enemy seem determined to defend the breach in the bastion to the last extremity, some guns should be brought, into the lodgment made in the gorge of the ravelin, to bear on the breach; or a mortar-battery constructed, to fire incessantly into the bastion, to prevent the garrison from throwing up intrenchments to protract the siege. Should the curtain be covered by a tenaille or other works, a battery must be constructed in the ravelin to fire against it.

When the bastions are double, or constructed on a system of demolition, and a lodgment is completed in the exterior bastion between the summit of the breach and the second bastion; the besieger must erect a third battery to demolish the interior work, when it can by this method be effected in less time than by mining.

FIG. III. Should the profiles of the counter-guards admit of it, the third batteries may be constructed at C C, F F, to open the breaches at K K, L L; and the collateral ones at N, P to ruin the defences: in this case, it may perhaps be necessary to erect the fourth battery in the ravelin or bastion. But with narrow profiles, the parts C C, F F, must be battered from A, B, D, E, till they are so completely beat down that K K, L L, can be battered in breach from A, B, D, E.

The besieger having made himself master of a horn or crown-work should erect the third batteries on the terre-plein, the interior slope, or the gorge, as may best answer his purpose; the mortar-batteries may be placed in the ditch before the front of the work.

The greatest difficulty met with in completing the third and fourth batteries, particularly when constructed on the counter-

counter-guards is in getting up the 32 prs. which from the narrowness and steepness is a very troublesome and tedious operation, since they must be dragged by men.

C H A P. VII.

OF THE ATTACK OF COUNTERMINES.

71. **H**ITHERTO the besieger has been supposed to construct his batteries on the glacis and the other parts of the outworks, without any molestation from the countermines of the besieged: but if the place be well countermined and under the direction of skilful officers, the establishment of the batteries will be a very arduous undertaking; since in this subterraneous war the advantage lies on the side of the besieged. That the second and third batteries may be erected in proper situations, and the subsequent operations of the siege not retarded by the springing of the countermines, one of the first objects of the besieger is to render them of no effect; either by filling them with water by means of a canal made for that purpose; by rendering the air unfit for respiration, by throwing into them various compositions that emit an insupportable stench and smoke of a fetid and poisonous nature; by making a few fougasses to cut off the communications between them and the body of the place; by over-setting on the principle of compression, the galleries and branches intended to blow up the batteries; or finally, by seizing possession of the countermines along the front of the attack and preventing the besieged from entering into them. But the besieger not having it always in his option to adopt the most convenient method, even when provided with an exact plan of the countermines; and being, when he has no plan, under the necessity of feeling his way with extreme caution and at great hazard; here follows a general idea of each mode of attack, that the besieger may judge which is best suited to the particular exigency.

72. When the level of the countermines is lower than the ditch, so that a stream of water may be made to flow into them, this expedient will be the most easy and effectual. To this end, the pioneers are employed in digging a proper canal; while the miners divided into squads are searching

for the principal galleries, either by sinking shafts or making slopes in the glacis; and the instant they have discovered one, they make an opening to turn the water of the canal into it.

73. If the countermines cannot be inundated, the readiest and least dangerous way is to attack them at the entrance, which is known to be in the saliant and re-entering angles of the covered way, and destroy them: the besieged will be then prevented from penetrating into those under the glacis. To this end, the sappers must effect a lodgment between the saliant angles of the covered way and the places of arms: when these lodgments are effected, the squads of miners must as expeditiously as possible sink shafts a little lower than the countermines, from 40 to 60 feet distant from each other, and carry on two branches parallel to the counterscarp and a return at the extremity of each to form the chambers; which must be well loaded, that the adjoining galleries and branches may be entirely overfet by the explosion. If, in the course of this work, they meet with a gallery, they must immediately break into it, and throw in quantities of fetid compositions to make it impossible for the besieged to re-enter, that that they may finish their mines without molestation; they should be sprung as soon as completed.

When the besieged destroy any of the shafts by springing a countermine, others should be immediately sunk at such a distance from the former, as not to pass through any of the earth shaken by the explosion; since the labour of the miners in working among loose earth is endless, for the sides crumble down as fast as the excavation is made.

Supposing these shafts to be completed and the chambers charged, other shafts may be sunk in the lodgments on the crest of the glacis, particularly on the capitals of the works, for the purpose of more easily exploring the enemy's galleries under the glacis and entering them, when the communication between them and the body of the place is cut off by springing the mines under the covered way; and when by means of these shafts a gallery is discovered, a party of armed miners should examine whether there be a possibility of the besieged returning into it. If it be possible, they should penetrate beyond the points corresponding to the attack, and throw in some fetid combustibles, taking care to retire time enough to save themselves from suffocation; and then

then destroy the communication with tools, and afterwards with a chamber, which will effectually deprive the besieged of all access.

When there are two stages of countermines, and the miners in penetrating into the upper one, find the ventilators belonging to the lower stage; they should throw in such quantities of fetid combustibles as will render it impossible for the besieged to remain in them, taking the precaution to close the ventilators, that they may not be incommoded by the smell and smoke, which in these subterraneous operations are extremely pernicious.

74. It has hitherto been suppose that the ground around the place is nearly level: but when the fortress is built on a tongue of land, so that the front of the attack be terminated on each side by a deep ravine, the miners may then drive a shaft below the countermines, and those parts of the outworks on which the batteries are to be erected; and make some chambers for blowing up the works, or at least destroying the countermines: or, if the place be situated on an eminence, and the slope of the glacis such that the miners can drive a shaft below the countermines and penetrate under the points where the second batteries are to be erected, advantage should be taken of these circumstances.

It should in general be understood, that whenever any subterraneous work of great extent is carrying on, a gallery must be made to give a free circulation of air; but in limited operations, a branch which is sooner made will answer every purpose.

74. If the besieged make no attempt to destroy the shafts in the covered way (73), it is a sign either that they are ignorant of their duty, or are seized with dismay; wherefore, if the miners meet with any of their galleries instead of enpoisoning them, they should enter them and advance towards the doors that lead into the ditch; and supported by a second detachment proceed into the large gallery on each side, till they have passed beyond the front of the attack, and destroyed the gallery in every part by which the besieged can re-enter the countermines: when there are two stages, they should endeavour to descend into the lower one, and approach the doors that lead immediately to the body of the place; this gallery should also be destroyed with the greatest expedition. Having thus taken possession of the counter-

mines, they should make fougasses to render all endeavours of the garrison to regain possession of them abortive.

76. The discussion of this subject has been hitherto confined to shafts, galleries, branches, and chambers made in firm and solid ground; but in a loose sandy soil, the excavation requires the addition of frames and planks, to support the earth along the whole of the subterraneous work: and as these operations must be performed as expeditiously as possible that the besieged may have the less time to destroy them by countermining, the squads of miners should be relieved every six hours; since in that time each man will have had his turn of the most laborious part of the work. Shafts are generally made square, and the dimensions of the smallest are $4\frac{1}{2}$ feet. The galleries are 6 feet high, and about $3\frac{1}{2}$ feet wide. The branches $4\frac{1}{2}$ feet high and 3 feet wide; a return is made at the extremity of each branch for the chamber which is of a cubical form, and in it is placed a wooden box of the same figure to contain the proper quantity of powder; the spaces between the sides of the chamber and the box are filled up with clay or dung. The saucisson is laid in a pitched wooden trough; and the branch and adjoining shaft or gallery filled with bags of earth or sand, and the angles barred with strong oaken planks, supported by cross beams, that the line of least resistance may be on the side against which the mine is intended to act.

77. The quantity of powder for charging mines, intended only to shake the ground without making any excavation, depends on the quality and tenacity of the soil, and on the line of least resistance: but it being sometimes out of the power of the besieger to make proper experiments for ascertaining the tenacity; the following table will serve as a rule for the quantity to be used, in a soil of such tenacity as to need no frames to support it, in order to shake the ground from the bottom of the chamber to the surface, without displacing it; supposing the powder to be of a strong quality and well preserved.

Table

Table of the Quantity of Powder, for charging Mines under different Lines of least Resistance.

Lines of least Resistance.	Interior side of the Chamber.		Quantity of Powder for charging the Chamber.		
	Feet.	Feet. Inches.	Cwt.	qrs.	lbs.
10	—	1 2	0	3	18½
13½	—	1 7	2	0	1½
16⅔	—	2 1	3	3	10½
20	—	2 4	6	2	10
23⅔	—	2 9	10	2	13
26⅔	—	3 2	15	2	27
30⅔	—	3 6	22	2	1½
33⅔	—	3 11	30	1	16
36⅔	—	4 4	41	0	0
40	—	4 9	53	1	22
43⅔	—	5 1	67	3	17½
46⅔	—	5 6	84	2	27½
49⅔	—	5 11	104	1	9

78. In the use of this table, it ought to be observed that the object of the besieger being to destroy the countermine effectually, his mines should be fully charged; wherefore the quantity marked in the table should be generally increased by a half: thus, if the line of each resistance be 23 feet, the quantity of powder for the charge according to the table is 10½ cwt., to which add 5½ cwt. or the half; then 15½ cwt. will be the charge required, to be contained in a cubical box of about 3 feet 2 inches on the interior side. If the tenacity of the soil be greater, the charge must be increased to double the quantity in the table; thus the line of least resistance being 26 feet, by doubling the quantity 15½ cwt. marked in the table, 31 cwt. will be the charge required to be contained in a box 3 feet 11 inches on the interior side. In loose sandy soils, the same rule must be observed; as the elastic fluid escaping more easily, acts with less force.

79. By whatever method the besieger succeeds in rendering the countermine useless, he should instantly proceed to the construction of the second batteries; and for greater security, keep some miners stationed in the galleries that he has taken possession of, to listen if the besieged make any efforts to re-enter.

80. The

80. The countermines under the outworks or ditch, must be attacked before the third batteries can be erected.

If the profile of the attacked work be narrow, as that of a counter-guard, for example; two or three holes, distant from each other about 50 or 60 feet, should be made near the foot of the revetment by the battering guns; sloping even for that purpose, if necessary, the embrasures and the top of the counterescarp: the wall being thus pierced and the descent and passage across the ditch completed by the sappers, the miners should be introduced into each hole, to drive a shaft into the terreplein, equal in length to the height of the wall; and having made branches to the right and left, they should make a chamber at the extremity of each, to destroy the surrounding countermines. If they meet with a branch or gallery, they should endeavour to chase the besieged from it by throwing in fetid combustibles; and in the mean time prepare and charge a chamber or two to destroy these countermines and shake down the casemates: while one party of miners is thus employed, another should explore the communications leading to the countermines under the glacis from the attacked outworks, in order to drive the besieged from thence by force or other means.

These operations are carried on under cover of an incessant fire of musquetry from all the lodgements that bear upon the ditch, to check the besieged in any attempt to destroy the epaulment, or disturb the miners.

81. If the attacked work be very spacious and the besieger under the necessity of erecting batteries at the gorge; after having destroyed the countermines under the breach (80), he must effect a lodgment in the gorge by assault; and then by sinking shafts endeavour to cut off the communications between the countermines and the body of the place: for this purpose the direction given (73) for the attack of the countermines under the glacis may be successfully applied. While this is going forward, he should endeavour by means of the shafts sunk upon the capital, or of the countermines he has got possession of, to penetrate into the galleries under the gorge of the work, and totally expel the besieged, ascertaining by these means the security of his batteries.

82. From these premises it may be inferred;

1. That to attack a place with two stages of countermines, there must be a large corps of miners and
great

great consumption of powder; and even then the progress of the besieger will be slow, if the garrison exert themselves.

2. That it is necessary to have an exact plan of the countermines; otherwise much time may be lost in exploring them, or they may be so badly disposed as not to merit the trouble of counteracting their effects.

C H A P. VIII.

OF THE SURRENDER OF THE PLACE.

83. **T**HE artillery will continue firing after the charge is beat, till ordered to cease by the general of the trenches for the day, or till answered by the besiegers; and every thing will be kept in readiness for renewing it at a moment's warning.

While the terms of capitulation are settling, no person is to be suffered to reconnoitre the batteries and approaches. When the capitulation is signed, and one of the gates of the place taken possession of by some picquets of grenadiers, the commanding officer of artillery, by order of the commander in chief, will send the senior officer to receive the artillery; and the senior officer of miners, accompanied by one belonging to the garrison, to examine the countermines. In the mean time the batteries are provided with stores, &c. till the place be entirely evacuated.

84. A few hours before the garrison marches out a detachment of artillery will be sent to receive the keys of the magazines, and take an account of all arms, ammunition and stores; and all places where any articles may have been concealed or deposited: to be the more exact, the officer commanding this detachment should demand a copy of the inventory of stores previous to the siege, and an account of the expenditure while it lasted.

Every article that is liable to be stolen should be locked up in the magazines, and a sufficient number of centinels and guards posted for their protection.

After the evacuation, an inventory of stores must be made out; the guns, &c. drawn back from the batteries to the park, and every thing prepared for marching: the guns
should

should be examined, and their condition reported. The commander in chief will direct whether the town is to be put into a posture of defence, or the works dismantled: in the former case, the commanding officer of artillery will go round the place accompanied by the officer destined to be left in the command of the artillery, and order the necessary quantity of stores to be completed from the park: if it is to be dismantled and the works demolished, he will leave the proper quantity of powder, wood and tools, for undermining and blowing up the works, and cause all the artillery and the remainder of the stores to be transported to the places assigned by the commander in chief.

C H A P. IX.

OF IRREGULAR SIEGES AND BLOCKADES.

85. **SIEGES** are termed irregular, when any of the operations requisite for besieging a place in form are dispensed with. From this definition, it is evident that there are different kinds of irregular sieges, which vary according to circumstances. If in the vicinity of a place there be any deep ditches, ravines, or rising grounds, that may save the besieger the trouble of breaking ground at a distance, and carrying on regular approaches; or whence he can directly batter in breach the magistral line, and annoy the garrison in their points of defence; or under cover of which a lodgment may be effected on or very near the glacis, without being too much exposed: if the garrison be weak, or composed of ill-affected or undisciplined troops; the profiles of the works not according to the true principles of fortification; or any weak point be discovered after the covered way is taken: in any of these cases, the besieger is justifiable in precipitating matters, and omitting some of the steps taken in regular sieges.

86. Thus a smaller proportion of artillery, or at least of stores, is requisite for irregular than for regular sieges: and when before the investiture, the besieger is in possession of the necessary data (5, 6, 7) he may make out with the greatest accuracy, a state of the stores, and concert measures, to bring the expedition to a successful conclusion in the shortest

shortest space of time possible; which in military operations should ever be a leading maxim.

In irregular sieges that are of short duration, the batteries for the sake of expedition are constructed with gabions. When there is a scarcity of earth, as often happens in mountainous countries, every pioneer brings a sack filled with earth, which are laid together to form a parapet. In constructing batteries on a rock, wool-packs are preferable to sacks of earth.

87. In besieging towns surrounded with a single wall, or old castles, there is seldom a necessity for breaking ground, and never for making regular approaches; a field battery being generally sufficient for making a breach: it should be made in that part of the wall which leads to some square or spacious place, where the infantry after the assault may draw up in order to attack the garrison, in case they have retired behind intrenchments or palisadoes. The distance of the battery from the place should be about 400 yards; it may be constructed with casks or gabions ranged in two rows, and filled with earth; openings made in a garden wall or other building, may occasionally serve for embrasures, and a plank may be laid under each wheel by way of platform, unless the ground be firm enough without it.

88. With proper information concerning the state of the place previous to its investiture, the number of attacks, and the quantity of stores requisite for each, may be easily ascertained; thus, the garrison being distracted by several attacks at once, may be the sooner compelled to surrender. The general rule is to allot four or six 24 or 32 prs. to each attack, and 100 or 200 rounds for each gun, in proportion to the solidity of the works: the quantity of intrenching tools is regulated by the trenches intended to be opened.

89. A breach is sometimes made when the artillery is insufficient for the purpose, by undermining the wall: the miners are lodged in an opening not exposed to the fire of the garrison, and a shed of planks covered with sand-bags or raw hides, erected to shelter them from the hand-grenades or combustibles that the enemy may throw down from the wall: they then proceed to make the mines in the same manner as in the demolition of places.

If there be an aqueduct or subterraneous canal that passes under the wall, the miners should lodge themselves in it; and in the first place, form a barricado to secure themselves against

against the enterprizes of the enemy; and then in the *sides* of the canal excavate one or two chambers large enough to make a breach in the wall. In every case, the miner should be secured against the attacks of the garrison, by posting some grenadiers at proper places, and if necessary, by raising an epaulment across the ditch to the foot of the wall; which may be easily effected under cover of a fire of musquetry, by the means of wool-packs or mattraffes.

90. When the gates of a town through the negligence or ignorance of the garrison are insufficiently guarded, or badly constructed, they are sometimes forced open by petards: it is the business of the artillery-men to fix them: they are supported by the detachment of infantry intended to rush into the town the moment the gates are burst open.

The party destined for this service approach secretly during the night, and screw an iron hook into the gate, on which they hang the petard with its bottom flat against the gate, and propped behind by a strong iron fork: the fuse is then set fire to, and as soon as the petard takes effect, the column of infantry rushes in. As the opening made by the explosion of the petard may not be large enough to admit the men, some carpenters should be in readiness with their axes to cut away any obstruction.

91. *Blockades* are so termed when the besieger having invested a place, and carried on regular approaches, suspends his operations either through choice or necessity; confining himself to keeping up a fire from his artillery. This method of attack is practised in the following cases:

1. When a town is unprovided with casemates and magazines: whence the besieger may have reason to hope that by keeping up a continual fire, the inhabitants may be so harrassed as to rise against the garrison; or at least, that a part of the ammunition and provisions may be destroyed.

2. When a town full of inhabitants, strongly fortified, and well provided with troops, artillery, and ammunition, is destitute of sufficient supplies of provisions to sustain a siege: from which circumstance, the governor may in a short time be induced to surrender, provided that by the investiture his conduct is apparently justified.

3. When from morasses, inundations, rocks, ravines, or precipices, it is found impracticable to carry on the approaches

approaches in any manner likely to bring the siege to a speedy termination.

4. When from bad roads, or other circumstances, the artillery is insufficient to prosecute the siege with vigour.

92. In the first and second case, the engineers make trenches of communication from different parts of the line of circumvallation, at the distance of 700 or 1000 yards from the body of the place, and batteries mounted with heavy cannon are erected by the artillery-men : each battery is inclosed in a redoubt of respectable profile, and spacious enough to contain a guard sufficient to secure it against any attempts of the garrison. Guards are likewise posted in the hollows or ravines in the vicinity of the battery ; and when the ground is level, detachments are placed in the intermediate parallels, between the communications, to sustain the redoubts, and give time to the troops at the camp to come to their assistance in case of a general sally : but if the batteries be covered by a river, canal, morass, precipice, or defile, a strong guard in each redoubt will be sufficient for their security.

93. In the third case, (91), the besieger must exert himself to turn every accessible point, whence the town can be annoyed either with shot or shells, to the greatest advantage, by planting on them a proper quantity of artillery of large calibre.

The proportion of ordnance for this kind of siege is greater than for regular sieges, particularly when the blockaded town is very large ; unless in regular sieges, a fire is directed from every side on the most populous quarters of the town, in order to excite consternation and terror among the inhabitants.

94. In the fourth case, the lines or trenches judged necessary on the occasion, ought to be constructed with a view to their being useful, when an adequate quantity of artillery arrives, to convert the blockade into a regular siege ; the vivacity of which must depend on the knowledge the besieger has acquired concerning the strength of the garrison, the state of the fortifications, and the nature of the adjacent country.

An army sometimes sits down before a place of great importance, in hopes of inducing the enemy to abandon an advantageous post in order to relieve the place, and perhaps hazard a general engagement. The most vigorous
attack

attack should be made in this case ; which will induce the enemy to march with greater expedition to raise the siege.

95. Whatever be the motive for undertaking this kind of siege, the batteries ought to be amply furnished with cannon and mortars ; they should be fired at different elevations from 8° to 12° that the shot and shells may be thrown into every quarter of the town : and if there be a probability of setting fire to any of the principal edifices or magazines, hot-shot should be incessantly fired.

From a review of every circumstance attending the commencement and progress of sieges, it will appear that from the opening of the trenches until the surrender of the place, the nature of the siege may, from the variety of incidents to which military operations are peculiarly liable, be frequently changed.

C H A P. X.

DIRECTIONS FOR DEMOLISHING THE FORTIFICATIONS OF A CITY.

96. **I**T is generally deemed sufficient to demolish the revetements of the works, and blow up the magazines, casemates, &c. ; the destruction seldom extends to the terreplein, from the great expence and labour it would cost.

The chambers of mines for demolishing a building, the wall of which is not more than 7 feet thick, are of a *cubical form*, with one of the sides corresponding to the side of the wall ; but if the thickness of the wall exceed 7 feet, chambers are made in a *hemispherical form*, in the centre of the wall.

97. The following are the general principles to be observed in the disposition of mines :

1. The chambers should be made at the foundation, that the upper part of the building may be raised and shaken to pieces ;

2. And, if possible, some feet below the surface of the ground on which the wall stands ; as from the great resistance the explosion is more violent, and the effect greater : mines placed near the surface of the ground

ground sometimes act but upon one side, and cause a breach in the wall insufficient to destroy the building.

3. If the solidity and strength of a building depend on its counterforts, chambers should be made in them, though they be above the surface of the ground.

4. The largest chambers should be placed under the strongest parts, where the masonry has most solidity and cohesion; as at the point of intersection of cross vaults, and large buttresses or pilasters supporting roofs and arches.

5. In walls that are without any break, the chambers should be 12 or 15 times, the side of the cube or the diameter of the hemisphere, according to its figure, distant from each other.

98. The size of the chamber depends on the quality of the powder, the thickness of the wall, and the cohesion of the materials of which it is built; which differs in different climates according to the quality of the lime, and the time it has stood. The cohesion of walls raised above the earth, and cemented by the best lime and sand of *Piedmont* and *Lombardy*, is generally estimated at 16400lbs. for every 20 square inches; while that of subterranean walls cemented with materials of certain qualities, as the lime of *Superga* or *Casal* in *Montferrat*, and the sand of *Tribia*, is more than double. The cohesion of walls constructed on the coast of *Provence* and *Genoa*, exceeds 41000lbs. and that of buildings adjoining to the sea, and cemented with *Pozzolana*, is frequently triple.

The officer of miners, therefore, charged with the demolition of any place, should previously ascertain by experiment, the tenacity of the wall. The side of the cubical chambers should be a third part of the thickness of the wall, supposing its tenacity to be 16400 lbs. and the powder very strong. The same rule will serve for the diameter of the hemispherical chamber; its depth should be about $\frac{2}{3}$ of its diameter: its contents will then be about half as much as the cubical chamber. By the table (77), the quantity of powder for a cubical chamber of a given side may be easily determined.

99. To give an idea of the disposition of mines, the figure represents the plan of an insulated building, the roof of which is bomb-proof; (Fig. 4, Pl. 4) the principal chambers are made under the points A, H, I, K, L, M, N,
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O, P, where

O, P, where the walls intersect, and under the pilasters Q which support the fronts A B, C D, and on which the roof rests (97, No. 4). The chambers in the wall F F which is without any break, are distant from each other, and from the principal mines, 12 or 15 times the length of the side or diameter (97, No. 5); and if in the faces A B, C D, the chambers A, H, I, be too far distant to have proper effect, two intermediate ones S, S may be made. The wall G G in which are the chimnies and doors of communication, need not be undermined; but the size of the principal chambers K, L, M, should be increased by about $\frac{1}{4}$. The mines thus disposed may be divided into two classes; viz. those made in single walls, as Q R, S, and those made in cross walls, as A H, &c.

100. In this profile P P represents the plane of the ground surrounding a building: (Pl. 4, Fig. 5) the walls are single, and the chambers are to be of a cubical form: to make the excavation in the foundation D A E, below the plane P P (97, No. 1, 2), let a long trench be dug $1\frac{1}{2}$ of the thickness of the wall D E in depth as D B, and $3\frac{1}{2}$ feet in width as C D. Let the chamber G of a cubical form, be made $\frac{1}{3}$ of B D distant from the bottom B F, and a wooden box of proper dimensions for containing the quantity of powder ascertained by preceding experiments (98) placed in it; and if there be any reason to apprehend that the powder may be damaged by the moisture of the wall, let the box be lined with oil-cloth. At the mouth of the chamber make a ledge H, 3 inches broad, and of a depth proportioned to the size of the planks that are to close the opening. Any projections or cavities in the wall where the trench is dug, should be smoothed or filled up with well worked plaister. The planks for blocking up the chamber should be 2 inches, and the beams 5 or 6 inches thick, and a quantity of clay and rotten dung, (which is excellent for preventing the escape of the inflamed fluid) prepared. The box being filled with powder, and a saucisson laid in a pitched wooden trough, communicating with it, the opening is exactly closed; planks called mantlets as C F K L, B D I M, are placed vertically along the faces of the trench, and the beams N are driven in horizontally at right angles to the mantlets, and all the interstices filled with clay and dung well rammed.

101. To make mines of a cubical form in a cross wall A B ; let C, D, E, F represent a square pit hollowed in the adjoining ground ; (Pl. 4, Fig. 6) the side of which is $4\frac{1}{2}$ feet, and the depth $1\frac{1}{2}$ of the thickness of the strongest wall. At about $\frac{1}{4}$ from the bottom, hollow out in the wall B a branch F N G H $3\frac{1}{2}$ feet high, $2\frac{1}{2}$ feet wide, and $\frac{1}{4}$ of the thickness of the wall B in length ; then in K B the centre line of the wall B make the chamber K of a proper size : let a box be fitted to it, and at the mouth of it make a ledge F H. Let the box be filled with powder, the saucisson applied, and the opening l closed and blocked up with beams laid horizontally to L G : let the opening F N be closed in the same manner as I ; and disposing the mantlets around the sides of the pit, drive in horizontal layers of beams crossing each other alternately at right angles, till they reach the surface of the ground, always filling the interstices with dung and clay, and taking care to bring out the saucisson. It should be remarked here, that though in this case, where it is intended to blow up a greater extent of wall, the same charge is used as in the preceding paragraph ; yet greater resistance being opposed to the explosion of the powder, the effects will be proportionably greater.

102. If the wall be more than 7 feet thick, (Pl. 4, Fig. 7) the chambers should be hollowed in a hemispherical form, in the following manner : A A is the profile of a single wall ; dig a square pit B D C F the side of which is $4\frac{1}{2}$ feet ; then make the branch B L G E $3\frac{1}{2}$ feet high, and of such a length and breadth, that the chamber K hollowed out in the centre of the wall, may contain half the quantity of powder that a cubical chamber, the side of which is equal to the diameter of the hemisphere would contain : at the mouth of the chamber make the ledge H H, and smooth the roof and bottom of the branch with well worked plaister. Having charged the mine, applied the saucisson, closed the opening H, and laid two layers of mantlets horizontally, the one B Q L O on the bottom, and the other G E N M on the roof of the branch, drive between them strong beams R ; then close the entrance B E, and placing other mantlets against the wall and the opposite side C F, lay rows of beams horizontally between them, filling all interstices with clay and dung, and carefully bringing out the saucisson.

103. The figure represents the plan of two walls which intersect each other, and exceed 7 feet in thickness : (Pl. 4

Fig. 8) to determine the exact position of the chamber, draw the right line B B dividing into two equal parts the wall B, and another right line A A parallel to C C, and distant from it $\frac{2}{3}$ of the thickest wall A; then the point of intersection K will be the centre of the chamber, which should be $\frac{1}{4}$ larger than that made under a single wall. Make a square pit C D E F, the side of which is $4\frac{1}{2}$ feet; and in the wall A make the branch G H L M D, with an elbow or angle, and of such a length that the chamber may be hollowed in K: let it be loaded and blocked up as before (102); at M N close the opening with a frame, and lay horizontal layers of beams unto the opening D G, which should be well closed, and placing mantlets against the sides C D, E F, drive in horizontal layers of beams till the pit is filled, ramming dung and clay in all the interstices.

104. To undermine revetements; make pits in the ditch close to the revetement 6 or 7 feet deep: then piercing the wall, carry on in the terreplein two branches, the one to the right and the other to the left, at the extremities of each, and at the points where the revetement is supported by the counterforts, hollow the chambers (101), either cubical or hemispherical (103) according to the thickness of the wall, so that the two chambers on each side of the opening may correspond. In the proper disposition of counterforts to support revetements, the strongest points are at the flanked angles; viz. those of the shoulder and flank; the principal chambers should therefore be made in these angles, the others may be distributed along the walls that form the angles. If the revetement be built on a rock, and of no great thickness, the number of chambers should be increased and brought nearer together, that the whole revetement may be thrown down at once.

As the manner of charging mines in revetements is the same as that before described, we will dismiss this subject for the present; only remarking that in blowing up stone or brick bridges, the chamber should be made in the foundation of the piers, or in the shoulders of the arches. It frequently happening on service, that a tower or other slight building is to be instantly demolished: it may be effected by placing in the ground story some open barrels of powder close to each other, blocking up the doors and windows with strong planks, and covering the floor above with a thick layer of earth; then setting fire to the saucisson that communicates
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with the powder, the great resistance opposed by the earth upon the upper floor, prevents the powder from acting upwards, and directs its force against the walls of the tower, which being of no great solidity, easily yield and fall down.

S E C O N D P A R T .

OF THE SERVICE OF ARTILLERY IN THE DEFENCE OF PLACES.

105. **T**HE science of defence constitutes one of the most essential branches of the military art, since a few troops are thereby frequently enabled to make head against a very superior army, to the preservation of a whole country: and as in the prosecution of this system, the inferior army is often compelled to sustain a siege, the defence of places forms one of the most important parts of this science. Now the defensive system may either be the result of a premeditated plan; or a nation may be unexpectedly forced into it by the sudden invasion of a foreign enemy, or by a train of unfortunate events, that oblige an army which began the war with the fairest hopes of conquest, to change its system and act on the defensive.

106. When a defensive war is foreseen, some of the senior officers of artillery are sent to inspect the quality and number of arms and stores of all forts in the different garrisons; examine the condition of the magazines, works, and countermines; and take notes of every thing that may be wanting in case of a siege.

After the inspection, each officer makes a report in writing of the number and nature of artillery and carriages, with his proposed arrangement of them; and also of the proportion of tools, machines, arms, and ammunition, which in his opinion may be adequate in proportion to the strength of the garrison, for making a vigorous defence:

he farther explains the motive of each demand, and points out the place where every article can be lodged; distinguishing the magazines that are bomb-proof, and remarking particularly any that should be made so, previous to a siege.

An engineer is likewise detached to each fortress to report the number of troops necessary for its defence; make out a distribution of barracks and magazines; and examine the repairs and alterations for putting the fortifications in a proper state of defence, with the quantity of pallisadoes and fascines for repairing the damage, that the enemy's artillery may do to the works during the attack.

The governor then calls a council consisting of the artillery officer, engineer, and staff of the garrison; where the merits of the two reports are canvassed, and those propositions adopted that appear conducive to the best defence: the opinion of the council is then submitted to the sovereign for his decision, who orders the necessary mines and works to be constructed, and the stores to be provided. When they arrive in the garrison, they are deposited in the magazines allotted in the plan for each particular species.

107. But if a state be surprized into the defensive system, the officer commanding the artillery in a place menaced with a siege, should make the store-keeper give him an actual state of the disposition and condition of every article under his charge, and immediately examine those that are of the most importance: and in his report to the governor, should particularize what may be wanted in addition to the quantity at present in store, or to replace any that may be damaged. But if from the approach of the enemy, there be little probability of having sufficient time to draw the supplies from the arsenals or neighbouring garrisons, every thing in possession of the inhabitants that may be useful during the siege, should be taken after a just valuation, and proper receipts given by the store keeper to each proprietor. In forts where no such resources can be had, parties should be sent into the neighbouring towns and villages to seize and conduct to the garrison every thing they can find that may be of service during the siege. It is the maxim of every good government, to complete the stores of all frontier towns on the least apprehension of a war.

C H A P. I.

OF THE DISPOSITIONS FOR THE REGULAR DEFENCE
OF A PLACE PREVIOUS TO ITS INVESTITURE.

108. **T**HE first disposition that an officer of artillery should make for the regular defence of a place, is to form a state of the number and nature of guns, carriages, and stores. To do this with justness and precision, he should recur to the rules laid down in the former part of this treatise, and be not only acquainted with the service of artillery in all its branches, but capable also of judging in the fullest extent of all operations, in which the other troops of the garrison can bear a part; so that every thing may be adequate to its particular purpose, without deficiency on the one hand, or superfluity on the other. Thus two extremes equally prejudicial will be avoided; the one of making a provision of stores insufficient for the defence the place is capable of; the other of providing such quantities, that on the surrender of the place, a complete arsenal may fall into the enemy's hands.

109. The fundamental maxim in the defence of places, *is to retard as much as possible the progress of the besieger, and in proportion as he advances to multiply his dangers and difficulties.*

To this end, the artillery-officer should examine on the spot, the natural obstacles that the besieger may have to surmount in the attack of the works, and countermines; and after maturely weighing the weak and strong points, should consider how far the advantages of each front may be improved, and the defects remedied. Any strong position in the vicinity of the place, should, if possible, be rendered useless to the besieger; and every vulnerable part strengthened by additional works. If the first position that the enemy must from the nature of the ground take up, be very confined, the proportion of artillery and stores may be made out with the greatest accuracy, and there will be good reason to reckon on a successful defence; as the enemy will of course be extremely circumscribed in all his operations. But when he is free to choose his position, the artillery

officer should be informed whether the artillery the enemy can bring up be only adequate to a regular siege, or sufficiently numerous to enable him in a few days to beat down all the defences on the front of the attack, and keep up such a continual fire as to prevent the garrison from repairing the damages.

110. The present treatise supposes a fortress besieged in form; whether from the position that the besieger is obliged to take up, or from the insufficiency of his artillery to take advantage of one more extended. Those violent attacks, where the defences are in a few days destroyed by the first batteries, and the garrison prevented from repairing them, seldom occur but in small places: such examples are very rare in places of strength and importance; particularly when the enemy is obliged to bring his artillery by land, from the prodigious number of carriages and horses required for the transport. But if from circumstances there be reason to apprehend a siege of this nature, the state of the magazines and barracks should be examined, and any that are exposed to be cannonaded covered with substantial epaulments. When the profiles of the works are so advantageous that the besieger must effect a lodgement on the glacis before he can make a practicable breach; the most effectual mode of retarding his progress is by countermining with the utmost diligence. But when the barracks and magazines are secured; a breach in the body of the place impracticable from its being cut out of a rock; or, when made, is rendered inaccessible by some natural or factitious obstacle; every attempt on the part of the enemy will be futile, provided the garrison conduct themselves properly in this case, where perseverance and firmness, rather than courage and exertion are requisite.

111. The first step towards forming the estimate of stores for sustaining a regular siege in a fortified town, is to consider what front is most attackable, and what are the best measures to be adopted for its defence. But as the besieger may through incapacity or ignorance commence his attack on the strongest side, the proportion of stores should be large enough to take advantage of this error; and to avoid extremes (108), the defence of the two fronts should be carried to the same point, either by raising new works, countermining, or disposing to greater advantage and strengthening the old works. But if the shortness of time doth not admit
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of this, two estimates should be made out; one for the defence of the strongest front; the other, of the weakest; that the *Sovereign* may determine which of the two he thinks proper to adopt.

112. 32 and 16 prs. are mounted in the body of the place; 12 and 8 prs. in the outworks that are large enough to contain them: when the adjacent country is favourable for making sallies, or constructing lines of counter-approach, some light 4 pounders are included in the inventory. It was the custom in the last century to place some pieces of large calibre, resembling stone-guns or long howitzers, on the flanks, from which, when the assault was given, they fired case or grape-shot on the assailants: but these pieces are now disused, since the besieger covers himself with epaulments in the ditch and at the breach: instead of them, we fire round shot from heavy guns, to destroy, or at least retard the construction of, the epaulments.

113. In fortified towns constructed on mountains or eminences, the embrasures are generally made of brick or stone, and the curtain furnished with guns, when it bears on any position favourable to the besieger; the number of guns must in this case be regulated by the number of embrasures. But when the parapet is formed of earth, the following is the distribution of guns on each front: 10 or 13 toises are left on the faces of the bastions, and 6 from the angle of the shoulder to the flanked angle for the barbette batteries; the remainder is divided so, that there be never less than 20 feet between every two embrasures, to give room for the infantry, whose fire, when the enemy comes within musquet shot, is the most effectual method of retarding his progress; and with less distance between the embrasures, the merlons would be soon destroyed by the enemy's artillery: the same rule should be observed in opening embrasures in the outworks.

A few guns should be added to the above distribution, for the barbette batteries on the other fronts, and for the flanks corresponding to the attack.

114. To determine the number of guns for the four faces of the ravelins corresponding to the attack, 10 or 13 toises are allowed for the barbette batteries in the collateral ravelins, and the remainder divided into equal parts with intervals of 20 feet for the embrasures; but in the ravelin on the front of the attack, a greater space is left from the salient angle

angle for the barbette batteries, to avoid being enfiladed or taken in reverse on the adjoining face.

Pl. III. With a counter-guard before the bastion 10 or 13 toises are set off from the salient angle for the barbette, 2, 3, and embrasures opened at 3, 4 of the face corresponding to 5 of the barbette on the bastion, when the height of the bastion above the counter-guard is less than 10 feet; but when it is 15 feet or more, the whole face of the counter-guard should be lined with cannon, in order to have two stages of fire; as there will be no danger of the lower work being incommoded by the fire of the upper one. In the counter-guard before the ravelin, the same precaution should be attended to. Guns on the faces of horn or crown-works large enough to contain them, should be in the same proportion.

115. The guns on the front of the attack should be of brass, as they stand firing for a long time: on principles of œconomy, iron guns may be planted on the parts whence a very heavy fire cannot be kept up; as the barbette batteries on the fronts not attacked, and the points which there is reason to apprehend the enemy may endeavour to carry by assault.

116. The most advantageous and at the same time most œconomical use to which mortars can be applied in the defence of places, is to project stones and royal shells upon the approaches and lodgments of the besieger. There is so much uncertainty in the range of shells fired from large mortars against the first batteries of the besieger, notwithstanding all possible attention in the bombardiers, that they are only employed at great distances to project shells filled with combustibles, for discovering the progress of the besieger during the night, when the distance is too great for light balls; but when the besieger approaches within the reach of light balls from the stone-mortars, the large mortars are then reserved for enfilading the batteries and lodgments on the crest of the glacis, and destroying the shafts and slopes which the besieger has sunk on the glacis and covered way for the attack of the countermines. Hence, an officer aware of the manner in which the besieger can direct his attacks will necessarily conceive that two mortars of each nature should be employed against each approach, and against each of the batteries in breach exposed to be enfiladed.

117. The

117. The fire of the infantry is, as has been already observed, one of the most effectual methods of retarding the progress of the besieger. But in keeping up a continual fire during the night, the musquets being thin soon become un-serviceable; wall-pieces being better reinforced are more serviceable and less apt to burst. The greater part of these arms are mounted with locks, of which the cocks are of a serpentine form according to the custom of the last century; but the troops being unaccustomed to make use of them, it would be much better if they were furnished with common locks, with the use of which the infantry are perfectly acquainted. The proportion of wall-pieces should exceed by a half, the number of infantry destined for the daily defence of the covered way, for a siege of 30 days; for one of longer duration, the number should be increased.

There should also be a reserve of musquets with bayonets, to supply the place of any that may be damaged: for a siege of 30 or 40 days, the number in reserve should exceed by a third the number of infantry in garrison. Some large wall-pieces are also provided for firing at a distance against reconnoitering parties of the besieger.

118. There is no absolute rule laid down by military authors, for determining the number of men for the defence of a place besieged in form. The most general and unexceptionable one is, to reckon 3 men for every 10 feet in the covered way, on the front of the attack, including the two collateral places of arms; when the town is fortified in the common method with no outworks but ravelins. If the body of the place be constructed on a system of demolition; the fire from the flanks command the points where the enemy must erect his counter-batteries; or there be counter-guards before the bastions, the rest of the works being in the common method; then 4 men are allowed for every 10 feet. With counter-guards before the ravelins; or when with ravelins only, there is one stage of countermines, the number is estimated at 5: with two stages of countermines; or the body of the place constructed upon a system of demolition and covered by other outworks besides ravelins, at 6.

If to the number of men resulting from this estimate, be added the necessary guards for the parts not on the front of the attack, the gates, ditches, magazines, &c. and the whole
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be tripled ; the result will give the proper strength of the garrison for a regular siege.

In mountainous situations, where there is no covered-way, two men are allowed for every 10 feet along the magistral line of the front attacked, including the outworks ; to this add the necessary guards, and the sum tripled will give the number of the garrison.

119. For example ; suppose a regular pentagon, of which the line of defence is 134 toises ; this gives 56 toises for the faces of the bastion, and 25 toises for the flanks ; let the profiles of the ravelins, which are supposed to be the only outworks, admit cannon. The following will be the disposition of artillery.

		No. of Guns.	
		<i>Brafs.</i>	<i>Iron.</i>
On the two faces of the bastion on the front	}		
attacked		20	—
On the two faces of the collateral ravelins		12	
On the two faces of the ravelin between the	}		
bastions		12	—
On the barbette batteries and flanks		—	18
		—	—
Total		44	18
		—	—

This number, designed for the first part of the direct defence, will be more than adequate for the second part ; two or three light 4 prs. may be added for sallies or counter-approaches, when this mode of defence is practicable.

If the place be hexagonal with a line of defence of 134 toises, and the flanks a little longer, two pieces of brass and two of iron should be added to the above proportion.

Supposing the besieger can carry on his approaches upon the capitals of the bastions and ravelin, and erect batteries in breach on the crest of the glacis ; the number of mortars will be at least

6	Stone-mortars
6	Royal ditto
4	10 inch ditto
4	13 inch ditto
—	
Total	20

If the garrison consist of piece artillery, & of muskets constantly on duty, and 5 or 6 of these on duty, and 10 or 12 constant fire; there should be 100 muskets and 100 muskets in reserve; with 10 or 12 large magazines, for firing at reconnoitring parties.

120. This proportion is adequate to the defence of a place in a level situation, where the guns, &c. may be easily transported from one part to another, but if the ground be so uneven, that in the manner of communication, for want of traction and labour it is impossible to remove the artillery without making use of capstans or other machinery, then each attack & defence must be furnished with its proportion of artillery; and that there may not be a necessity of measuring the quantity of ammunition, in the same order, the guns of the same nature should be placed on each front; in a way that means the ammunition provided for one front will answer equally well for all the others.

If in the vicinity of a place situated in a high or mountainous country, there be any hollows not covered by the cannon of the ramparts, in which the besieger may expose himself to the great annoyance of the garrison, a great number of stone, iron, and rocket mortars should be provided for firing into them.

121. The number of rounds for each gun depends on the quantity of the besieger's artillery, and the length of the siege. If the position that the besieger must take up be so confined, that the besieged can oppose gun to gun, and have some pieces in reserve for firing at the base of the lip, &c. the daily expenditure may be calculated at sixty rounds a gun (20), in the first part of the direct defence: but if from the nature of the ground the fire of the besieger be superior by a third to that of the place, half of this number will be sufficient; for the garrison will be frequently obliged to slacken the fire, and probably many guns will be dismounted. With regard to the second part of the direct defence, the daily expenditure may be estimated at 20 or 30 rounds each, for those guns which from the small command of the lodgements on the crest of the glacis, can plunge into the batteries in breach erected opposite to them; and double this number of rounds for the guns that flank the epaulments raised by the besieger in the ditch: the expenditure depends greatly on the fire that the enemy's musquetry can keep up against the embrasures of the place.

The

The mortars always being placed under cover of the ramparts cannot be affected by direct firing: the interruption from curvilinear projections may be reckoned at about $\frac{1}{2}$ of the whole number of discharges that could be made from them in 24 hours; as this is generally computed at 60 from each mortar, it is thus reduced to 50. They may begin to fire with effect when the enemy is advanced within 134 toises of the covered way. From memorandums of the quantity of ammunition daily expended by the infantry, in some of the most considerable sieges, it appears that each foldier on duty on the front of the attack, fires from 35 to 40 rounds a day: now supposing the same number of men always to mount guard, from the day that the trenches are opened till the place surrenders; the full expenditure may be computed at 50 rounds a day for each man on duty, including the allowance for forties. The barbette guns, and wall-pieces should be provided with 200 or 250 rounds at most.

122. In calculating the duration of a siege, the natural advantages of the place for retarding the progress of the besieger, and the obstacles he must surmount before he can lodge himself in the different works, must be considered.

Suppose the place be such as represented in paragraph 119; that a practicable breach is effected in the bastion; and that the garrison is not in a condition to sustain a general assault; the duration of the siege if the besieger has been active and enterprizing will have been about 40 days, viz.

	<i>Days.</i>
From the opening of the trenches till the lodgment is completed on the crest of the glacis	} 15
For constructing and completing the batteries in breach	} 4
For making a breach in, and getting possession of the ravelin	} 7
For making a lodgment in the breach in the bastion	} 4
Total	30

When there are more outworks; or the bastions are constructed on a system of demolition, so that the besieger is obliged to bring up guns through the breach to batter the interior works, the defence may be prolonged for 10 or 12 days;

days ; and even for 25, if there be small mines in the ditch, to blow away the earth and stones, beat down in making the breach in the bastion.

With counter-guards before the bastion, the surrender of the place may be retarded 12 or 15 days: with one stage of countermines properly disposed under the glacis, the defence may be prolonged 20 or 25 days ; and with two stages of countermines, 40 or 50 days: thus with counter-guards before the bastions, and mines under the glacis, ditch and bastions, supposing the latter to be constructed on a good system of demolition, the defence of 30 days may be prolonged to 80 or 90, provided the proportion of stores be sufficient.

123. The number of rounds from each species of fire-arms having been thus regulated, it will be easy to apportion the quantity of shot, shells, grenades, lead and powder; allowing for each charge the quantity mentioned in paragraph 22: the allotment of powder for the countermines is to be computed from a general consideration of their number and extent.

To this proportion should be added 100 rounds of case-shot for every flanking gun; and a competent number of hand grenades, and large shells, for rolling from the top of the breach upon the besieger, when he has pushed forward his epaulment to the foot of it; this number may be estimated at 1000 grenades, and 100 shells a day for each breach.

124. For a siege of one month, the number of spare carriages and side-arms amount to half the number of guns; for a siege of six weeks, this proportion should be doubled; beside spare wheels and axle-trees. The mortar beds, &c. are in the same ratio. In case of assault, a number of pointed and cutting instruments, as espontoons and scythes, should be provided: and some petards, blunderbuffes and pistols for the service of the countermines.

The necessary articles for a complete laboratory, and for making up every species of combustibles form a very essential part of the ordnance stores; the quantity of the latter should be sufficient to light during the night the whole front of the attack, and to set on fire every part of the besiegers works that can be burnt. The carpenter's, blacksmith's, and armourer's tools for repairing the damaged arms are likewise included in the proportion of stores.

In the distribution, a particular remark should be made of the store houses, in which the articles that are generally locked up

up are to be deposited; distinguishing those that may be wanted for common use, from those that can be only wanted in case of a siege: likewise the laboratory, carpenter's, blacksmith's, and armourer's shops. In very large towns they are generally fixed in some buildings at a distance from the attack; but in citadels, forts, castles, and small places which are exposed on every side, they must indispensably be secured in bomb-proofs. The powder magazines are the most important and hazardous of all; they should be dry and secure. During the siege the powder ought to be distributed in several bomb-proof magazines at a distance from each other; that in case of accident, the whole may not be blown up at once; and that the enemy may not be able to find out the quantity in store. The nature also of the places in which the different articles are deposited should be attended to: since the powder, saltpetre, sulphur, cordage, iron, &c. ought to be deposited in dry places; whereas the grease, oil, pitch, candles and other articles subject to melt or evaporate, should be kept in very cool places. It being the duty of the engineers during the siege, to keep all the parts of the works in a proper state of defence, they are to make returns of the quantity of spare fascines, gabions, pickets and palisadoes, that may be necessary for that purpose: There is no danger of providing too great a number of these articles; for any that are not used in the repair of the works, may be collected together in the breach, and set on fire; which will serve to prolong the defence of the place.

125. The following is a particular state of the quantity and quality of the different species of ordnance stores requisite for sustaining a siege of 30 days in a fortress NN, (119).

Proportion of Guns, Carriages, Ammunition and Stores.
Ordnance, Carriages, and Side-arms.

	Nature.	No.
	<i>Pr.</i>	
Brafs guns	{ 32	12
	{ 16	18
	{ 8	12
Iron ditto	8	18
Brafs short ditto	4	4
		—
	Total of guns	64
		—
	Carriages	

IN TIME OF WAR.

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Carriages of different natures for the above guns	96
Setts of side-arms for ditto	96
Mortars	Stone — 6
	13 Inch — 4
	10 Inch — 4
	Royal — 6
	—
	Total of mortars 20
	—
Beds for the above mortars	40
Setts of side-arms for ditto	40

Spare Arms for Carriages and Side-arms.

Wheels with iron streaks for carriages of different calibres	36
Iron axle-trees for ditto	36
Checks for carriages	24
Spokes for wheels	200
Staves for spunges	100
Rammers for ditto	200
Sheepskins for ditto	100
Wad-hooks	12
Plates of copper for ladles	60
Copper nails for ditto	lbs. 20
Iron nails for side-arms	ditto 40
Iron wire	ditto 20

Shot, Shells, and Grenades.

Shot for guns	33200
viz. 32 prs. At 900 rounds a gun	10800
— 16 — At 600 rounds	10800
— 8 — At 600 rounds for each brass gun and 200 ditto for each iron ditto	10800
— 4 — At 200 rounds	800
Cafe-shot for 32 and 16 prs.	2000
Ditto for 4 prs.	400

Shells.

	<i>Number.</i>
13 Inch shells at 900 for each mortar	3600
Ditto to roll from the breach	1200
10 Inch ditto at 900 for each mortar	3600
Royal ditto at 1200 for each mortar	7200
Hand grenades	12000
Stones for the stone-mortars at 1200 } cart loads rounds each	1500
13 Inch fuses	5300
10 Inch ditto	4000
Royal ditto	8000
Hand grenade ditto	14000
Bottoms of wood for stone mortars	8000
Baskets for ditto	8000

Machines and their Apparatus.

Handspikes	600
Large ditto	40
Long levers with horses	10
Quoins	400
Gins complete	6
Hand-jacks	4
Capstans complete with ropes	2
Pullies	6
Skids	40
Sleighs	6
Sling-waggon	3
Limbers	12
Block-waggon	6
Common ditto	30

Cordage.

Ropes for guns	10		
Spare ropes for gins	6		
Ditto for windlasses and capstans	2		
Double slings	10		
Ropes of various sizes	18	<i>cwt.</i>	<i>grs.</i>
Packthread	1	—	—
Drag ropes	50		

Armoury

Amoury.

	<i>Numbers</i>
Long wall-pieces	12
Wall-pieces	600
Musquets	600
Pistols	20
Spare rammers for musquets	600
Espontoons	400
Scythes with handles	400
Cuirasses with casques	50

Ammunition.

Flints		40000	
Bullets for wall-pieces		3000	
	<i>cwt.</i>	<i>grs.</i>	<i>lbs.</i>
Lead for musquet balls at 20000 rounds a } day, including forties	274	—	—
Match	109	—	—
Powder	whole barrels		<i>Number,</i> 3600
	<i>cwt.</i>	<i>grs.</i>	<i>lbs.</i>
viz. For 10800 rounds from 32 prs. at } 10½ lb. each	988	—	—
For 10800 rounds from 16 prs. at 5½ lb. } each	494	—	—
For 10800 rounds from 8 prs. at 3 lb. } 4½ oz. each	316	—	—
For 800 rounds from 4 prs. at 1 lb. } 10 oz. 4 dr.	11	—	—
For 3600 ditto from 13 inch mortars } at 12 lb. 4½ oz.	395	—	—
For 1200 ditto to roll upon the breach } at 8 lb. 3½ oz.	69	—	—
For 3600 ditto from 10 inch mortars } at 6 lb. 8 oz. 14 dr.	210	—	—
For 7200 ditto from royal ditto at 3 lb. } 4 oz. 7 dr.	210	—	—
For 7200 ditto from stone ditto at 4 lb. } 1 oz. 9 dr.	263	—	—
For 12000 hand grenades at 3 oz. 4 dr. }	22	—	—

	<i>cwt.</i>	<i>qrs.</i>	<i>lbs.</i>
For 60000 cartridges for the infantry	182	—	—
For 3000 cartridges for wall-pieces	300	—	—
For artificial fire-works and combustibles	91	—	—
Add $\frac{1}{15}$ for accidents	360	—	—

Combustibles.

	<i>Number.</i>
Faggots dipped in pitch	12000
Iron grates for lighting the ramparts to be filled } with different combustibles	150
Light balls of the diameter of the stone mortars	400
Carcasses ditto	200
Port-fire composition to be put into the shells	<i>cwt.</i> 54 <i>qrs.</i> — <i>lbs.</i> —

Articles of different kinds.

	<i>Number.</i>
Oaken planks for platforms	1000
Sleepers for ditto	500
Ballast-baskets	1000
Hand barrows	100
Spare helms for intrenching tools	2000
Sand bags	20000
Large oil-cloths	100
Small ditto	100
Grease	<i>cwt.</i> 36 <i>qrs.</i> — <i>lbs.</i> —
Flannel for cartridges	yards 300

Iron-work and Nails.

	<i>cwt.</i>	<i>qrs.</i>	<i>lbs.</i>
Iron-work of forts for gun carriages and } mortar beds	36	—	—
Iron-plate for carriages, round, square and } flat	27	—	—
Nails for wheels	9	—	—
Ditto for platforms	18	—	—
Ditto 40 to the lb.	3	—	—
Iron wire	3	—	—
Steel	9	—	—

Articles

Articles for the Laboratory for making up Compositions of various kinds.

Powder; pulverized saltpetre; flowered-sulphur; powdered charcoal; crude antimony; rosin; tar; pitch; turpentine; spirits; spirits of wine rectified; oil of olives and lintseed; vinegar; yellow wax; fuet; greafe; affa-foetida; glue; thread; fine and coarse tow; linen and cotton cloth and barras; sewing thread; old linen and match; faggots; iron wire; thin cord; small iron chambers and pistols for the carcasses. The quantity of these articles depends on the number and kind of fire-works, and the nature of the compositions, which may be easily known from the laboratory books.

Articles for the Laboratory for making up Fire-works.

	<i>Number*</i>
Chest of drawers	1
Steel-yard	1
Balance with scales	1
Tables	3
Ditto for mealing powder and mixing compositions	2
Large copper cauldrons	3
Medium and small ditto	5
Iron trivets for ditto	6
Large pestle and mortar of bronze	1
Common hammers	3
Pincers	3
Large and small axes	3
Rasps for wood	10
Files	10
Drawing knives	10
Common ditto	6
Large and small scissars	6
Iron punches	10
Straight and crooked awls	10
Packing needles	12
Sewing ditto	100
Common and fine saws	8
Augres and gimblets	30
Common sieves	6
Fine silk ditto	3
U 3	Small

	<i>Number.</i>
Small wooden bowls for holding compositions	10
Benches for driving fuses	10
Drifts for ditto	24
Tin funnels of fizes	10
Tin measures ditto	50
Wooden letters for fuses	10
Small ditto	20
Oaken planks with holes for loading the hand grenades and fuses	1
Bench with 2 beaks, one of iron and one of wood	1
Benches for tying up the fire pots, &c.	3
Lanterns ordinary and dark	50
Eprouvettes for powder	1
Can-hooks	60
Quadrants	30
Priming wires	500
Copper ladles	2
Large buckets	4
Pails	6
Brass scales	2
Wooden ditto	12
Large and small oil cloths	20
Common compasses	pairs 4
Calibres	pairs 2
Glue brushes	12
Royal and common paper	reams 10
Pasteboard	ditto 2
Flints, steels, tinder-box and matches	
	<i>cwt. grs. lbs.</i>
Tacks and large nails	1 — —
Wax candles	3 — —

Intrenching Tools.

	<i>Number.</i>
Pick-axes	1000
Mattocks	1500
Shovels	400
Large and small axes	200
Hand bills	500

Tools

Tools for 12 Carpenters.

	<i>Number.</i>
Broad axes	12
Small ditto	12
Cross-cut saws	4
Common ditto of sorts	12
Triangular files for saws	24
Planes	30
Mortaise chissels	24
Hatchets	12
Square and round gouges	16
Chissels of sizes	36
Large and small compasses	8
Large gimblets	16
Small ditto	80
Drawing knives	12
Sledge hammers	4
Pincers	12
Whetstones	4
Hand-vices	8
Iron crows	4
Working benches	8

Tools for 6 Blacksmiths.

Large bellows with anvils and stocks	2
Forge tongs	16
Nail borers	6
Forge hammers	12
Sledge ditto	6
Files of sizes	24
Benches with beak irons, one large one small	4
Small vices	6
Small anvils	4
Iron prefs for binding and streaking wheels	1

Tools for 12 Armourers.

Forge bellows	4
Anvils with stocks	4
Small anvils	6

	<i>Number.</i>
Forge hammers of sizes	24
Forge tongs	16
Benches with iron and wooden beaks	12
Files of sizes	200
Rasps	50
Planes	24
Large and small gouges	48
Instruments for making screws of sizes	16
Drills with bows	12
Augres	12
Gimblets	60
Drawing knives	12
Hand vices	12
With a proper quantity of coals for the black-smith and armourers.	

If the place be countermined, there should be the same proportion of miner's tools as in the former inventory; taking care to increase the number of them in proportion to the number of miners, and to add the following articles. Oaken planks for mantlets; beams of 5 inches by 7; planks for occasional works, and for boxes to contain the powder; beams for making the frames of the occasional works; pitched wooden troughs; saucissons made of coarse cloth; large oil-cloths; sand-bags; petards of sizes; shells; pistols; blunderbusses; tin chandeliers. Lanterns; olive-oil; candles; nails of 40 to the lb.; powder; clay; old dung; inflammable and fetid compositions. The quantity of each of these articles must be apportioned to the manner in which the mines are charged, and to the method of carrying on the subterranean war, which will be enlarged on in the 4th chapter.

126. The number of artillery-men for the daily service of the guns and mortars contained in this inventory, may be easily inferred from the former remarks on that subject (57): three times that number will be the proper complement for the defence of the place; one part is on duty on the batteries, and the second is preparing and providing the batteries with stores, while the third is reposing. If the corps of artillery be not sufficiently numerous for all these duties, the line must furnish a certain number of additional gunners: four men at least, should be attached to every piece
of

of ordnance; so that if there be 60 guns and 20 mortars in the place, there ought to be 320 artillery-men, besides serjeants, to every piece of ordnance there should be a skilful expert man to direct the loading and laving, and the additional gunners should be allowed for in the demand of troops made for the garrison. Beside the commanding officer of artillery, there should be 5 or 6 others of inferior rank; and even more, if the place be capable of making a long defence.

The number of carpenters, black-smiths, and armourers will be regulated by the proportion of tools in the preceding inventory; part of them may be taken from the artillery, the rest from the infantry of the garrison, or the inhabitants of the place.

With one stage of countermines, and a large gallery, where it is possible that the miners on both sides may meet, their number should be 200; and 300, when there are two stages of countermines, with two officers, and two non-commissioned officers: part to be taken from the miners belonging to the artillery, the remainder from the garrison; taking care that the latter are men of approved courage and fidelity.

CHAP. II.

OF THE FIRST DISPOSITION TO BE MADE FOR THE DEFENCE OF A FORTRESS NN.

127. **T**HE magazines being furnished with the ordnance, ammunition and stores contained in the inventory; every article deposited in the place allotted for it in the distribution; the projected works completed, and the countermines prepared; the commanding officer of artillery on the apprehension of a siege, makes under the orders of the governor his dispositions for defence: distinguishing the operations necessary to be performed previous to the investiture, from those that may be deferred till the place is invested.

128. In the first place, the musquet cartridges are made up; light-balls, pitched faggots, and fire-pots prepared; the fuses drove; a certain number of shells filled; and in short, every thing in the laboratory put in such a state of forwardness, that in case of an attack, nothing will remain to be done

done but to fill the rest of the shells and grenades; and make up combustibles as fast as they are wanted. All the guns are mounted; part on the most attackable fronts, the rest on the barbette-batteries: each of which should be spacious enough to contain several guns, the better to command the adjacent country; and the governor directs the engineers to cut out the embrasures in the flanks.

If the place be countermined; a quantity of well sifted earth is laid in different parts of the galleries, and frames and planks prepared for carrying on fresh branches: an exact plan and profile of the countermines are taken, which should be very carefully preserved; and the miners drive small shafts on every side to determine the nature of the ground, with a view of ascertaining the time requisite for making an excavation of a cubical foot; and judging how far the sound of the enemy's miners at work can be heard; which entirely depends on the tenacity of the soil: that nothing, in a word, may be wanting to render the subterranean operations conducive to success; experiments are made, to determine the line of least resistance for a chamber, made between the surface of the ground and an excavation 9 feet below it (which is the depth of the work that the besieger should carry on in searching for the countermines) and to ascertain the charge for only shaking the earth, and burying the enemy's batteries without making a large *entonnoir*. The care of the miners is intrusted to an intelligent officer; some men are occasionally picked out from the infantry for that service. The carpenters, blacksmiths, and armourers shops are fixed, that they may prepare the several articles belonging to them; and some horses and oxen procured for removing the guns and stores to any part where they may be wanted, with a sufficient quantity of forage for their use.

As economy in the daily issues of stores, and in the extra-pay to the artillery-men and additional gunners is a matter of great moment; a commissary and some clerks of stores are appointed to keep an account of all issues and expenditures, that exact returns of every thing may be made out when called for.

129. At the second epoch (127) viz. when the place is invested; the commanding officer of artillery directs the powder and every other article that will be wanted during the siege, to be distributed in the different magazines; and the

the shells and grenades to be filled and deposited in secure places: this should be done before the enemy opens his batteries. The amuzettes or wall-pieces with their ammunition are carried to the advanced works, particularly on the side where the enemy is breaking ground; and the barbette batteries furnished with powder and shot, and a detachment of men for firing at the parties of the enemy that advance to reconnoitre the works, or drive in the out-posts of the garrison: the officer charged with this duty, after receiving directions from the governor with respect to the parties detached from the garrison, should remain on the batteries during the whole day, to seize every opportunity of annoying the enemy.

An officer of the civil branch is appointed to assist the store-keeper, through whose hands all issues of stores must pass, as he is best acquainted where each article is deposited; this officer is intrusted with the key of the magazine, whence the daily issues of powder are made: the keys of the other magazines remain according to custom with the governor and store-keeper.

It may be necessary during the siege to project shot and shells to different distances according to the situation of the besieger's park or powder magazines; the following table therefore shews the ranges of guns and mortars: the charges are supposed to be $\frac{2}{7}$ of the weight of the ball for musquets, &c. $\frac{1}{4}$ of the weight of the shot for 4 and 8 prs.; and $\frac{3}{8}$ for 16 and 32 prs. The chambers of the mortars are elliptical, and filled with powder; those of the stone-mortars are in form of a truncated cone.

Point Blank. Longest Range.

		<i>Yards.</i>	<i>Yards.</i>
Musquet		270	1348
Wall-piece		303	1550
Long wall-pieces		438	2360
Guns	{ 4 pr. 8 16 32	438	3035
		} 540	3372
			3541
			4046
Mortars	{ Royal 10 inch 13 ditto 17 ditto Stone		1348
			1686
			2192
			2697
			337

C H A P. III.

OF THE DISPOSITIONS FOR THE ACTUAL DEFENCE.

130: **W**HEN it is known either from the previous dispositions of the enemy, or from his breaking ground, which front he intends to attack; the commanding officer of artillery directs the guns allotted for that front to be drawn to it; placing those of the same calibre together, to avoid the confusion arising from mixing the shot; and makes the carpenters lay down the platforms for the guns in the flanks. The engineers construct in the works of the front attacked, occasional magazines for containing the powder and cartridges for one day's expenditure. The infantry furnish the necessary number of additional men to assist in working the guns; the same men should be always attached to this duty, to save the trouble of instructing every day a fresh set, and should be under the care of their own non-commissioned officers.

The commanding officer of artillery then makes out a plan of defence as far as respects the artillery, which he submits to the governor for his approbation; and afterwards communicates it to the several officers under him, that being acquainted with the principles on which the defence is to be conducted,

conducted, they may do their utmost to contribute to its success.

131. In this plan, the first axiom is *to retard as much as possible the progress of the besieger, and to multiply his dangers and difficulties*: this is effected by a *judicious application of fire-arms, sallies, and countermine*s. The whole front of the attack is lighted during the night, that the artillery may direct their guns with greater precision, and discover the movements of the enemy; which will enable the governor to judge when and on what side, a sally may be made or a mine sprung, to the greatest advantage.

132. At the beginning of the siege the garrison throw shells filled with combustibles to light the front of the attack during the night: when the enemy is advanced within 350 yards of the works, light balls are used for this purpose; and when he approaches the covered way, pitched faggots are thrown on the glacis to discover his works: and, finally, faggots and grates filled with combustibles are placed on the parapets of the advanced works, whenever the enemy is endeavouring to effect a lodgment.

133. It is an established maxim in making sallies, that they be supported by a heavy fire of artillery and musquetry, disposed in the most advantageous parts of the works for compelling the besieger to remain within the trenches, or exposing him to great loss if he advance to repel the attack: wherefore the sally ought to be previously concerted with the commanding officer of artillery, who should suggest any method that occurs to him of rendering the fire of the artillery more effectual in covering it.

134. The service of the countermine will be discussed in the subsequent chapters; at present we shall enter into a detail of the other dispositions for defence (131). When the besieger begins to break ground, the proper detachments are sent to the barbette-batteries, with injunctions to let the additional gunners assist in working the guns, that they may become expert: this party, and all others on the different batteries during the siege, are relieved every 24 hours. The fire from these batteries is directed during the day either against the unfinished parts of the trenches, or to enfilade the communications; as may appear most advantageous. In the evening, precautions are taken that the guns may bear during the night on the part most likely to distress

distress the enemy; shells filled with combustibles are from time to time projected to light the country (132).

135. When the situation of the enemy's first batteries is known, the embrasures on the faces of the bastions and the other works opposed to the attack are opened, and the platforms laid; this should be completed in 24 hours. The direction of some of the embrasures ought, in conformity to the established axiom (131), to be towards the ground on which the enemy must carry on his sap; the others against the batteries, opposed to the guns that fire upon the head of the sap: it would be a manifest departure from this principle, to oppose gun to gun without regarding the sap; and the error would be still greater, to fire against works that are already completed, and consequently proof to cannon-shot. The commanding officer of artillery points out the objects against which the fire is to be directed, enjoins the most exact attention in loading and laying the guns, and forbids them to be altered. He goes round the attack at least 3 times every 24 hours; early in the morning, to reconnoitre the enemy's works, and alter the direction of the guns, if necessary; in the afternoon, to take memorandums of what ammunition may be wanted; and in the evening to point out where the light-balls are to be thrown, and see that the fire both of artillery and musquetry is directed against the unfinished parts of the enemy's works.

136. When the batteries are mounted with cannon, the guns are withdrawn early in the morning from the barbette batteries, and brought back at night to enfilade the communications: this manœuvre is continued till the enemy's musquetry is advanced too close to the works. The 10 inch and royal mortar batteries are opened, as soon as the besieger advances his communications between the second parallel and the place: these mortars should be placed in such a situation that, in spite of the inevitable irregularity of the ranges, the shells may fall on some part of the approaches. During the night, light-balls are projected to assist the direction of the cannon and musquetry. When the approaches are advanced within 300 yards of the covered way, the stone-mortars come into use; they are planted in the salient angles of the covered way, against which the enemy is directing his approaches. All the mortars fire day and night: when the third parallel is nearly finished, the stone-mortars are withdrawn from the covered way,

way; and placed in the works immediately in the rear, at the foot of the barbette batteries, to fire into the enemy's lodgments on the crest of the glacis, when the garrison is obliged to evacuate the covered way.

While the besieger is working at the third parallel, great number of pitched faggots are thrown upon the glacis during the night from the covered way: the guns that enfilade the glacis are directed against the lodgments on the crest of it; and every embrasure that flanks the enemy's approaches is furnished with cannon.

137. The third parallel being completed, the enemy's dispositions should be carefully observed to judge whether he meditates an attack on the covered way by storm or sap; if the former appears to be his intencion, the guns that enfilade the crest of the glacis and the covered way, should be furnished with flannel cartridges for quick firing, and some rounds of case or grape-shot; and the men attached to them instructed how to conduct themselves in case of an assault: at the close of day, quantities of pitched faggots should be thrown on the glacis, and the fire-grates lighted in the saliant angles of the most exposed works.

When the enemy has gained the crest of the glacis, round shot should be fired from all the guns that enfilade it, till the garrison is compelled to abandon the covered way; then case-shot should be fired: the mortars should keep up an incessant fire on the returns of the saliant angles of the glacis, where the besieger must establish his communications.

The garrison will rally in the places of arms and the ditch, and endeavour to regain possession of the posts they have lost; the fire from the stone-mortars should cease the instant the troops are in motion for that purpose, and the cannonade re-commence.

In all assaults, the officers of artillery should be stationed in the works that contribute most to the defence, with directions how to act on every emergency: their commanding officer should take up his station at the point of the greatest importance.

138. When the besieger has gained the crest of the glacis by sap, all the mortars should play on the communications that will be made along the faces; and while the sap is carrying on, it should be enfiladed by the guns and mortars that bear on it. If the guns in any of the attacked works can plunge into the enemy's lodgments on the glacis, some embrasures

embrasures should be repaired: throwing light-balls during the whole night, that the firing may be the more exact and effectual. The same dispositions should be continued, while the enemy is constructing and firing from the batteries in breach; and be supported by a continual fire of musquetry, directed against the embrasures of the batteries.

139. The besieger having completed his descent into the ditch, and begun epaulments to cover his approach to the foot of the breach, every possible exertion should be made to retard his progress: the guns should fire incessantly against the epaulments with round shot; showers of shells, and hand-grenades be thrown from every part; and when the enemy has gained the foot of the breach, the largest shells should be set fire to and rolled down.

These dispositions intended for the out-works will be still more effectual from the body of the place, where the fire from the flanks that defend the breach is greatly superior to the enemy's: since, beside this flanking fire against the epaulments, a heavy fire can be also directed against the counter-battery.

A breach having been made in any of the out-works, the artillery should be withdrawn in time, and placed in some work in the rear of the one that is dismantled, in order to fire into it. When the guns are withdrawn from the ravelin, some embrasures should be opened in the curtain, that the besieger may be exposed to a heavy fire from many points at once, the instant he attempts to lodge himself in the ravelin.

140. The breach being rendered practicable, a great number of burning fascines and light balls should be thrown into it; and over these dry faggots and combustibles of all kinds: when this expedient is exhausted, all the guns and mortars should be pointed at the breach, to mow down the enemy's column in mounting to the assault.

From the different methods of repelling assaults explained in the second book of Military Architecture, the officers of artillery will see in what manner the defence of a fortress provided with stores of all kinds, may be protected by their skillful and judicious conduct, combined with the exertions of the other parts of the garrison.

Though the preceding regulations may seem to be adapted only to places where the works mutually support and command each other, and every point in the environs; yet they

they are equally applicable to fortresses situated on mountains with different profiles: provided that in the proportion of stores, an additional number of mortars and combustibles be allowed for the defence of the dead angles, which frequently occur in places in such situations; and the weak points be carefully distinguished from those that are inaccessible, even when a breach is effected.

141. When at length, the place is no longer defensible, the *chamade* is beat: at the surrender the commanding officer of artillery in terms of the capitulation, will give the enemy an exact inventory of the ordnance and stores. If permission be granted to take out any covered waggons, the largest guns should be carried out on block waggons covered with oil-cloths, and not inserted in the inventory given to the enemy. But if the siege be raised, all the stores liable to be pillaged should be immediately carried back to the magazines, and a general inventory taken, distinguishing the serviceable from the unserviceable; the guns and mortars should be also examined, and those that are damaged sent to the foundery.

C H A P. IV.

OF THE DEFENCE OF THE COUNTERMINES.

142. **I**N the greater part of sieges, the besieger has a decided advantage; for the environs of most places being sufficiently spacious, it is in his power to plant a very numerous artillery in his first batteries, and establish a fire superior to that of the place: but in the attack of a fortress where the countermines are judiciously disposed, the garrison at the instant the besieger is endeavouring to lodge himself on the glacis, and in the other works regains their superiority; since he is under the necessity of feeling his way with much danger and loss of time, in order to ascertain the safety of his lodgements and batteries; without knowing the points where the besieger awaits him, and often finding himself buried in his own works at the moment he least expects it.

143. To oppose the besieger effectually in his research for the countermines requires much discernment, an uninterrupted vigilance, and great exertions of bravery. The fun-

damantial maxim is *to anticipate the attempts of the enemy, and to reserve as long as possible the countermines designed for blowing up the principal lodgements, and the batteries in breach.* For this purpose;

1. The provisional branches should be completed by the time that the besieger reaches the foot of the glacis.

2. The enemy's miners should never be allowed to get below the countermines, since in this warfare whoever has lowest ground has the advantage.

3. Every attempt should be made with fougasses and petards to destroy the enemy's works at a distance from the permanent countermines.

4. The charges for ruining the enemy's works should be calculated to produce the desired effect without running any risque of damaging the permanent countermines.

5. When to frustrate the enemy's attempts, it is necessary to spring a mine at a point, that may interrupt the communication with some of the permanent countermines; a fresh communication should be immediately made from the branches, or the nearest galleries.

6. Provisional branches for feeling for the enemy will be most effectual, when made to the right and left at the same time.

144. To convey a general idea of this subterranean war, let us suppose a place with two stages of countermines; that permanent and provisional works are prepared along the front of the attack, when the besieger gains the foot of the glacis; and that the soil has depth and tenacity enough to enable the besieger to execute any work he may judge necessary. The objects of the besieger being to render useless the countermines of the place, in order to secure his principal lodgements and batteries in breach, he will be obliged either to attack them in front by the means of slopes and galleries; or to attack the passages leading to them by sinking shafts in the covered way (Part I. Chap. VII.): the following are the dispositions for opposing these attempts.

145. The front that the enemy intends to attack being at length known, a larger quantity of earth is carried into the galleries on that side: and when he approaches the foot of the glacis, filled sand-bags are ranged along the galleries without obstructing the passage, and a large quantity of dung laid in the ditch near the entrance of the countermines. A
miner

miner is posted in every three or four branches that point towards the enemy to listen whether he be at work: on hearing him, the miner should keep strict silence, and redouble his attention to ascertain exactly the situation, distance and nature of the work he is carrying on. If the enemy in making his lodgments meet with one of the ventilators of the mines, the bottom should be immediately closed with a sand-bag, and the space between the bottom of the gallery and the ventilator filled up very solidly. When from the nature of the soil the enemy can drive his shafts under ground without being heard, a well braced drum should be placed at the suspected points with some grains of sand on the parchment, which will move when the ground is stirred or shaken.

Having ascertained by one of these methods that the enemy is advancing towards the countermines, the five following cases may occur.

1. His shaft may fall on one of the branches of the first stage.
2. Or on a gallery of the first stage.
3. It may approach very near to a branch or gallery of the first stage.
4. It may fall on a branch or gallery of the second stage.
5. It may fall obliquely on the countermines of the second stage, without the besieger being overheard in working from the countermines of the first stage.

146. The general method of opposing above ground these attempts of the besieger is to throw shells into the shafts; the situation of which is easily discovered by the soil of the excavation: the explosion of a shell falling into a shaft, renders all further attempts for some time impracticable.

Another method equally effectual is to make a sally, and throw into the subterranean works of the besieger combustibles of a very fetid nature, to render the air unfit for respiration. Beside this, the following opposition is made underground.

147. Should a shaft fall on a branch of the first stage (145, No. 1), it should be immediately filled with sand-bags pressed close together for the space of 20 feet; in the middle of this space immediately under the shaft 4 or 5 loaded shells should be laid with the fuses of such a length that they may all burst together: they are set fire to by a saucisson the moment the besieger gains the roof of the branch, and by

their explosion destroy the shaft and loosen the soil, so that the besieger will be unable to renew his work without great trouble and loss of time.

In a tenacious soil, a hole about 4 feet square may be made, by taking some bricks out of the roof of the branch at the part where the shells are lodged, and supporting the earth with planks; the explosion of the shells will do more injury to the shaft and less to the branch.

When the shaft falls near the extremity of a branch, a box containing about 1 cwt. of powder may be placed close to it, the branch filled with sand-bags and dung for the space of 10 feet, and a saucisson laid in a wooden trough to set fire to the powder, the moment the besieger reaches the roof of the branch.

148. In the second case, viz. of a shaft falling on a gallery of the first stage leading to the advanced countermines; some strong-trestles equal in length to the width of the gallery, and about $3\frac{1}{2}$ feet high should be instantly placed under the shaft across the gallery, and at the distance of 5 or 6 feet from each other; and upon these should be laid a floor of planks 20 feet long, and the space between them and the roof filled with sand-bags: 4 or 5 large shells should be then placed on this floor, disposed as in the preceding paragraph, and set fire to the moment the besieger reaches the roof of the gallery. As by this method, the communication is kept open below the trestles, it is preferable to the other of filling the whole space with sand-bags. Beside, if the countermines to which the gallery leads be of great importance, a fresh communication may be made from the nearest branches or galleries, after the explosion of the shells.

The besieged should perform these operations as silently as possible; not using hammers to knock out the bricks or make holes in the roof, but forcing them out with levers, that the besieger may not be aware of his danger. But the operations of the besieged will not fail to be discovered in the three following circumstances.

149. When the shaft passes near a branch or gallery of the first stage (145, No. 3.); its direction and distance being known, the besieged should ascertain whether the shaft when sunk till it meets with water or rock will be near enough to any of the permanent countermines to destroy them: If that be the case, he should carry on horizontal branches on both sides to find out the shaft, and have every thing in readiness for

for charging a chamber instantly to destroy it. As the besieger must be aware of this, the besieged should attentively listen to find out when he ceases to work, which will be a sign that he is charging his chamber; taking care to distinguish between the sound that is made in hollowing out the earth, and a noise frequently made to counterfeit it, in order to deceive the besieged.

When the besieger ceases to work, the distance between the branch and the shaft should be compared with the distance between the bottom of the shaft and the surface of the ground; and if the line of least resistance be towards the surface, it will be sufficient to make a noise similar to that of removing earth, without proceeding any farther: which will make the besieger believe that the work is always going on, and induce him to spring his mine without doing any detriment to the countermines, yet greatly to his own disadvantage; since after the explosion the ground will be unfavourable to any future work. But if the line of least resistance be on the side of the branch, a chamber should be instantly charged with a proper quantity of powder and sprung. If the besieger, notwithstanding, continues his work, the branch should be advanced within 7 or 8 feet of the shaft, that it may effectually destroy it, without doing any damage to the countermines (143).

150. In the fourth case, viz. of the shaft falling on a branch or gallery of the lower stage, the besieged will make the same dispositions as before (147, 148), and set fire to the shells the instant the besieger reaches the roof of the gallery; when the shaft passes near any of the countermines of the first stage, the besieged will carry on horizontal branches as directed in the preceding paragraph, making at the same time the necessary disposition in the countermines of the lower stage, that are threatened by the enemy.

When the shaft without passing near the countermines of the first stage falls obliquely on those of the second, horizontal branches should be carried on from the lower stage in the same manner as directed for the upper one.

151. The subterranean war is still more in favour of the besieged, when the besieger attacks the countermines in front by the means of galleries or branches; since the former will be then enabled to dispute the ground inch by inch. When the enemy's gallery points towards a provisional branch, he should be waited for in silence, till arrived at a proper distance,

tance, and a mine sprung to destroy his works (147). But if he advance on a permanent branch at a distance from the provisional ones, the nearest provisional branch ought to be carried forward to meet him as before directed.

152. It may happen either through the negligence of the besieged, from the nature of the ground, or the instruments used in boring it, that the besieger may without being heard gain the wall of the countermines: in this case, a large petard well propped behind should be instantly fixed against the part he is approaching, and the screws that fasten it to the plank taken out, that it may act against the wall with greater force and do the enemy more damage: as soon after the explosion as the smoke will permit, the miners should examine if any communication be opened between the countermine and the enemy's works; throw in quantities of fetid combustibles; close the hole hermetically, to prevent the stench from passing into the countermines; and block up at the same time all access to the besieger.

Should the besieger gain an entrance into any of the countermines, some of the most resolute miners armed with cuirasses and blunderbusses should be sent to drive them as far back as possible, and the communication be interrupted and blocked up with sand-bags; all sorts of combustibles should be thrown into the intercepted part to compel the enemy to abandon it.

153. The garrison should never relax in opposing the designs of the enemy, even though all the permanent countermines are by degrees destroyed and they are thus deprived of the means of blowing up the enemy's batteries; since the defence of the place will be thereby considerably protracted: Whereas should they under the idea of preserving the permanent works entire, be too cautious in counteracting the besieger, he may by carrying on his enterprises under ground, render all the countermines useless; and deprive the garrison of every benefit that could result from them.

After springing a mine, the miners should never be too hasty in removing the earth or rubbish that chokes up the passage to it, or in examining its effects; this research being attended with no utility, and moreover, very dangerous: the smell and smoke should be drawn away, and the air purified by placing mantlets at the entrance into the countermines, with tin pipes fixed in them and communicating with the place where the mine was sprung. The miners in the
mean

mean time should be listening in the other branches to discover the enemy's operations.

154. The same directions are to be observed, in defending the countermines under the ditch, in the out-works and in the body of the place.

These operations should be always supported by the sallies of small parties, made unexpectedly in the ditch, to kill the enemy's miners, and throw fetid combustibles into their works.

From the method of attacking countermines, treated of in the first part, it will be easy to ascertain whether the provisional works, in either of the three cases mentioned at the end of the third book of military architecture, are properly combined: if not, the defect may be easily remedied, in making out the proportion of stores for the place.

P A R T V.

OF THE USE OF PERMANENT COUNTERMINES IN THE DEFENCE OF PLACES.

155. **F**OU GASSES and permanent countermines being intended to overturn the principal lodgments and batteries of the besieger, the following is the mode of attaining this object. When the besieger begins to make the third parallel, all the fougasses on the front of the attack are charged with the quantity of powder found by experiment (128) to be adequate to the line of least resistance; the saucissons of communication are laid in pitched wooden troughs sunk in the ground about a foot deep along the pallisadoes, that, if the enemy attempt to carry the covered-way by assault, he may not be able to cut them off. These communications begin at the saliant angles of the covered-way, and terminate at the re-entering angles of the places of arms; they are so disposed, that the fougasses at the most saliant angles may be sprung separately; then those before the faces of the bastions and ravelins; and lastly those in the faces of the places of arms: The saucissons ought to be frequently changed when there is reason to apprehend that they may be injured by the humidity of the ground.

156. Then, the covered-way being stormed, and the garrison forced to abandon the saliant angles and retire into

the places of arms; it will be a matter of consideration, (as the number and disposition of the enemy will be discovered by means of light balls, &c.) whether it will be more advisable instantly to spring the fougasses, or wait till their lodgments are completed: This must depend on the garrison, and the circumstances of the siege. Supposing the attack to be so vigorous that the garrison is compelled entirely to abandon the covered-way, a strong detachment should under cover of a heavy fire from all the works that command the places of arms force their way into them again, and set fire to the saucissons that lead to the fougasses; and immediately after the explosion, retire to their former post, and pour in a very heavy fire of musquetry.

157. If the besieger attempt to get possession of the covered way by sap, the fougasses should be sprung successively, accordingly as he makes his lodgments; taking care to spring them before the enemy can discover and render them useless.

158. The besieger having re-established his lodgments on the crest of the glacis, and begun to construct his batteries in breach, the chambers of the countermines of the first stage beneath the batteries are charged: the quantity of powder should not be too great for the following reasons.

1. Lest the besieger lodge himself in the excavation or *entonnoir*; the ground should only be shaken enough to overset the batteries and bury the guns.

2. Not to damage the contiguous countermines by too violent an explosion; which might render them of no effect in opposing the enemy in making his descent into the ditch.

3. Not uselessly to expend powder, which may before the conclusion of the siege be wanted for some essential purpose.

159. That the charge may act only on the side of the line of least resistance, the passage to the chamber should be very solidly filled up for a length and half of the line of least resistance. For example, suppose the chambers A, B, (Pl. 5, Fig. 9) are to be charged, and each branch C D, E F, be equal to the line of least resistance: in A C D, B E F, lay a layer of dung 4 or 5 inches deep, and place in each chamber a well-pitched wooden box of the proper size to contain the powder: having filled it and applied the saucisson, cover it with planks; and in case of damp with oil-cloth.

Then

Then having filled the space between the box and the sides of the chamber with dung, large stones and clay; close the mouth of it with planks and mantlets, placed along the walls C D, G H, E F, K L, supported by the horizontal beams M, N, secured by strong wedges, and fill all the interstices with sand-bags and dung. Continue this operation to D, F, where apply other planks supported as before by the horizontal beams P; fill up the interstices with dung, &c. as far as Q, so that the right lines A Q, B Q be each a length and half of the line of least resistance: at Q place some planks firmly supported by the beams R fixed in the wall S. The saucisson should be conducted in a pitched trough along the branches C D, E F, so that that the two chambers A, B may be sprung at the same instant: for it is evident, if they be sprung at different times, that the resistance will not be reciprocal, nor the effects of the explosion so great.

160. One of the principal maxims in the defence of a place is, to hold in *readiness a body of troops to march instantly after a mine is sprung, to take advantage of the enemy's confusion, and endeavour to regain the covered way, or any other post that may have been lost.* These sallies should be supported by a heavy fire of cannon and musquetry from every work that bears on the enemy.

A second maxim is, *never to spring any of the permanent countermines till every method of retarding the enemy's progress, or destroying his works above ground has been exhausted;* for a mine once sprung is henceforth unserviceable.

161. Keeping these maxims in view, let us suppose that the chambers under the batteries in breach which have opened, be charged, and the troops ready to sally: then the mines being sprung, and their effects ascertained, the troops advance rapidly to the batteries that have been overturned, throw in a heavy fire, and sally from the covered way to attack the nearest lodgments, the moment the enemy appears to be in disorder. In the mean time, the miners by the means of mantlets placed at the entrance of the countermines, and of tin pipes reaching to the chambers that have been sprung, endeavour as fast as possible to draw out the foul air and introduce fresh: they then immediately begin to extend the intermediate branches under the glacis, in order to overturn a second time the batteries in breach. If this be impracticable, they must employ the remaining chambers to bury the besieger in making the descent into the ditch.

When

When no further advantage can be derived from them, they make in the large gallery a chamber on both sides of the descent into the ditch to destroy it.

162. The countermines of the first stage being sprung, those of the second remain to overturn the new erected batteries in breach, and destroy the descent into the ditch; their chambers are charged with the proper quantity of powder for the line of least resistance, taking care to fill up the empty branches or galleries of the countermines of the first stage that are within reach of the shock; otherwise the force of the explosion will be spent against them, without overturning the batteries: when this cannot be done, the charges should be increased.

163. The besieger having at length ascertained the safety of his batteries on the glacis, and in the places of arms, begins to batter in breach; and having completed his descent into the ditch, advances under cover of a double epaulment towards the foot of the breach: the besieged then charge the mines under the different epaulments and breaches with a sufficient quantity of powder to blow away the rubbish that has fallen down from the breach; and make a large excavation in the ditch, that the besieger may be under the necessity of firing a great many more rounds in order to beat down materials to make the breach again accessible. The chambers thus charged should be set fire to, the moment the enemy mounts in column to the assault.

When the countermines under the ditch are sprung, those in the attacked works should be charged to overturn the lodgments that may be made in them; the charge should be very large in order to throw to a great distance the materials, and render the breach again inaccessible, which will lay the besieger under the necessity of keeping up a heavy fire for several days, to regain the advantage he has lost. The most favourable moment of setting fire to these chambers is when the enemy is giving a general assault; or when he has brought up cannon through the breach to batter the interior intrenchments thrown up by the garrison. Springing the countermines in the bastion will be the last effort of the besieged, unless the body of the place be constructed on a system of demolition, and well countermined; in which case, the conduct of the officers will be regulated by the preceding maxims.

C H A P. VI.

OF THE DEFENCE OF PLACES CONSTRUCTED ON A SYSTEM OF DEMOLITION.

164. **T**HE defence of places constructed on a system of demolition, and countermined, depends on the connection of the works that are to be blown up with those that are to remain entire (Military Architecture, book 3d) : as in these systems, a work that is in the event to be demolished, should remain entire unto a certain stage of the siege, and the mines act only on particular parts, without damaging others ; the greatest attention is requisite in determining their situation and size. The four following paragraphs contain the principal cases that occur, with a few reflections on each.

165. When from the combination of the works, the position, number, and size of the mines, can with accuracy be ascertained from an inspection of the plan of the place, without a necessity of performing any previous operation, they should be made before the place is attacked, (Chap. 10, Part 1) and charged a few days before they are to be sprung.

166. When the position and size of all the mines are determined, but their construction requires much time and labour, the officer of artillery detached to examine the place previous to the siege, should specify the necessity and extent of this operation : and, if the system be so combined, that the mines cannot be made before the siege, without weakening the defence of some other part, he should point out the several modes of defence that to him appear most feasible, and give his reasons in writing ; that the commander in chief in laying down the plan for the campaign, may know upon what length of defence he can safely reckon.

167. It being impossible from the construction of the works to determine the situation and size of the mines from an inspection of the plan, the officer of artillery must examine how the walls are connected together, in order to ascertain what parts can be demolished without injuring the others. For the sake of obviating these difficulties, it is to be wished that the mines were always made when the fortifications are constructed ; and that the walls which are to
be

be blown up were not built into those that are to stand, but merely joined to them, or disposed in the manner mentioned in the 3d book of Military Architecture.

168. The system of demolition ought to be perfected previous to the investiture of the place: when that has not been done, the artillery officer should specify whether it may interfere materially with the other indispensable operations of the defence: since instead of being beneficial, it may on the contrary prove very detrimental to the besieged, by occupying a space of time that can ill be spared during the actual defence.

C H A P. VII.

DISPOSITIONS FOR DEFENCE OF A PLACE IRREGULARLY BESIEGED.

169. **T**HE subject of this chapter applies to all fortifications constructed on the modern system; to those thrown up on the spur of the occasion, as well as to those intended to be permanent.

The motives that may induce an enemy to dispense with any of the steps usual in regular sieges, may be inferred from the ninth chapter, and be reduced to the four following cases;

1. When in the vicinity there are any favourable posts that can be used to advantage against the place.
2. When the fortifications are constructed upon a bad system, or are out of repair.
3. When the garrison is weak, and provisions and stores insufficient.
4. When the garrison, though sufficiently numerous, is composed of new levies, or of troops whose fidelity and courage cannot be depended on.

170. The common axiom, *that if the cause be done away the effect ceases*, holds good in this as in every other case; for by occupying or rendering useless all posts favourable to the enemy, repairing the fortifications, and filling the magazines, this kind of siege cannot take place. Thus, with a due degree of precaution, it may be wholly avoided in permanent fortifications; yet places fortified through necessity, or during a state of hostility, may either from defect in situa-
tion,

tion, or want of time to improve to the utmost the natural advantages, be exposed to it.

171. Suppose an officer of artillery detached to a fortress labouring under any of the afore-mentioned defects, with orders to make out a plan for the defence: he should attentively weigh every circumstance that can favour a precipitated and irregular attack, and in his demand of artillery and stores, confine himself to the necessary quantity for opposing the besieger when he arrives at certain given points. Any guns in the neighbouring towns not perfectly good, but competent to the expenditure of the proposed quantity of ammunition; or any guns of intermediate calibre should be sent to these places, since after the surrender they will be of no service to the enemy.

172. Again, suppose a place invested by the enemy under circumstances favourable to a precipitate attack, there are two cases to be considered: the one, with respect to places imperfectly fortified and provided only with stores, &c. for standing this kind of siege (171): the second, with respect to regular fortresses well situated, and abundantly supplied with stores of all kinds, but of which the garrison either from smallness of number, or want of experience or zeal (169, No. 3, 4), is incompetent to a regular defence.

173. In the first case, the artillery officer guided by the particular motives that influenced the commander in chief to adopt this plan, should exert every possible means to protract the siege; not keeping up too heavy a fire at the beginning, lest the ammunition be too soon expended: nor on the contrary, permitting the besieger through remissness in firing, to lodge himself on the works; which will greatly accelerate the capture of the place, especially when they are badly constructed or out of repair.

The only method of determining the precise line of conduct to be observed in this case, is to weigh on the spot the actual state of the place, with all its advantages and disadvantages; and from a general view of the whole, to lay down the plan of defence most likely to protract the surrender.

174. In the second case (172), the greatest efforts should be reserved, according to the strength of the garrison, for the body of the place, the ravelin or other out-work, so that from the time the besieger effects a lodgement on the glacis till the place capitulates, the defence will be almost regular: when

when there is a superabundance of powder, fireworks, and combustibles, large boxes full of powder may be buried at the foot of the breach, the mines on the front of the attack overcharged, large fires lighted on the breaches, and supplied with fuel till the whole be expended.

One of the most essential points towards prolonging the defence in this case, is not to expose the garrison to unnecessarily hard duty. Every avenue by which the enemy can get access to the place through the ditch, as canals, aqueducts, &c. ought to be effectually blocked up, and every precaution taken to guard against surprize: no more men should mount guard during the night than are absolutely necessary; and even this number should be diminished during the day: the garrison ought to be well fed, and for the sake of exciting emulation, any soldiers distinguished for activity or intrepidity, should be handsomely rewarded. But if the troops, though sufficiently numerous, be from want of experience or suspicion of their fidelity, unfit to be intrusted with the defence of the covered way; the governor and the principal officers should endeavour to instruct them in the most simple and material parts of their duty, and set them examples of indefatigable zeal and exertion: they ought to be particularly careful to prevent their being seized with a panic, check all irregularity, and be on their guard against mutinies, which frequently happen in regiments composed principally of deserters.

175. The four cases in which a fortress is blockaded, have been already mentioned. To render the blockade of no effect in the first case (91, No. 1), the magazines and barracks are made bomb-proof, and proper precautions taken to prevent and extinguish fire: in large cities exposed on every side to bombardment, where the houses cannot be secured from snells and red-hot shot, the governor to cover the inhabitants as much as possible, should endeavour by the most prompt and vigorous measures to keep the enemy at a distance; by making powerful sallies, throwing up lines of counter-approach, and seizing and fortifying with artillery every strong post in the vicinity of the city.

176. When a blockaded city has not the most distant prospect of succour, the garrison should keep up a very heavy fire from their artillery, and frequently make large sallies, that they may compel the enemy to raise the siege: by these means

means they will at least, expend their ammunition, and not leave a complete arsenal to the conqueror.

In the third case, the nature of the defence must be determined on the spot from the manner in which the enemy carries on and directs his attacks; the greatest efforts of the garrison should be opposed to the works and batteries that incommode the place most, without wasting ammunition against the others.

Finally, in the fourth case every advantage for which the enemy gives the least opening, should be seized; taking care at the same time to be sparing of the ammunition, that there may be sufficient for maintaining a regular defence, when the besieger has brought up the necessary artillery for pushing his attacks with vigour.

C H A P. VIII.

OF COUNTER-APPROACHES.

177. **C**OUNTER-approaches are those works which the garrison throw up either previous to or during a siege at different distances from the place, to enfilade and take in reverse the trenches and first batteries of the besieger: hence, by a judicious disposition, he may be sometimes compelled to convert into a blockade, a siege begun with regular approaches, and in the most vigorous manner. It should therefore, be established as a maxim, to *make counter-approaches whenever it can be done to advantage.* They may either form a part of a predigested plan, or may be adopted on the occasion from some sudden and unexpected circumstance that arises during the siege.

That the nature of counter-approaches may be perfectly understood, here follow some of the principal cases in which they can occur.

178. When a fortress with a numerous garrison is only attackable on one or two fronts, and the ground before them is commanded from some points within reach of the garrison, and secured from attack, being partly surrounded by a navigable river, ravine, precipice, or morass; or before which the enemy will be under a necessity of opening trenches before he can advance towards the place itself, a counter-attack

attack is then projected. The works to be erected in this case previous to a siege are forts and redoubts, far enough advanced in front of the place to enable them to enfilade and take in reverse the parallels and first batteries of the besieger: if exposed to attack, their ramparts are made of the same thickness as permanent fortifications with good profiles; and covered communications with redoubts at proper distances thrown up between them and the fortress, to cover them from any attempts of the enemy. They are planted with heavy cannon and mortars, with a proportion of stores adequate to their strength and importance.

Sometimes from the nature of the ground, a part of the fortress itself will serve as a counter-approach: in this case, the officer of artillery should insert in his plan of defence the necessary number of guns, mortars, and stores, for carrying on the counter-approach with vigour, independent of the proportion for the actual defence of the place.

179. When in the vicinity of a place situated on a navigable river, or on the sea-coast, into which succours can be occasionally introduced; there be any points that command the ground where the besieger must open his trenches, they should be strongly fortified, and amply supplied with artillery and stores; since the navigation being open, fresh supplies can be at any time thrown in.

180. A fortress is sometimes protected by an intrenched camp, that serves to keep the communication open with the country whence it draws its supplies; strong works should be thrown up to secure any commanding points in the vicinity: the necessary quantity of artillery and stores for this counter-approach may be ascertained with sufficient accuracy, by knowing the extent and nature of the ground where the besieger must open trenches, and erect his batteries; and any additional supply may be afterwards introduced under favour of the intrenched camp.

181. It often happens that an enemy in laying down before a fortress opens his attack against the strongest front: in this case, if the garrison be numerous, and the situation favourable; that is to say, if the ground, on which the works of a counter-approach can be constructed, be inattackable, or covered by the fire of the place, they should be instantly executed, and planted with the artillery designed for the barbette-batteries, and the other parts at a distance from the front of the attack. As the introduction of succours is not
supposed

supposed practicable, the fire should be directed against the batteries that most annoy the garrison; according to the invaluable maxim of *protracting the surrender as long as possible, by employing every thing in the most advantageous manner.*

182. An army or a considerable corps of troops having been worsted in action, has frequently taken refuge in a large fortified town, where was a depot of heavy artillery; and to which the victorious army has lain siege. When this happens, every strong post in the vicinity that may serve to keep the enemy at a distance from the place, and reduce him to the necessity of a blockade, should be occupied by strong detachments, and fortified: when the adjacent country is so favourable to the conqueror, that he can instantly break ground and carry on his approaches in form, the troops in the town should endeavour to form counter-approaches; this being the most effectual method of rendering the enemy's enterprizes abortive; or at least of embarrassing his operations, and lengthening the defence.

Counter-approaches cannot be made in low flat situations, except under cover of an impassable morass or river: in this case, a trench 25 feet wide should be made to connect the place and the morass or the bank of the river, and the front covered by the body of the place or some advanced work: in the rear of the trench may be erected the batteries for enfilading and taking in reverse the enemy's approaches; and some advanced redoubts may, if necessary, be thrown up at proper distances to secure the communications. The works of the counter-approach should be so combined with each other and the works of the fortrefs, that the enemy in advancing to attack them, may be taken in front and flank, whatever be the disposition or order of the attack.

It is the province of the engineers to project the counter-approaches; the duty of the artillery officer being only to furnish them with proper stores and defend them: it is unnecessary therefore to enter farther into the principles of their construction.

T H I R D P A R T .

OF THE SERVICE OF ARTILLERY IN THE FIELD.

183. **T**HE two former parts of this work were confined to the service of artillery in the attack and defence of places ; but the present object being the service of artillery in the field, and nothing having hitherto been advanced on this part of the art of war, it is necessary to give a general idea of tactics ; in order to explain the principles on which the several species of troops operate, and the various combinations that may be made according to the particular exigency.

184. The system of a campaign between two armies is called *offensive*, when one of them seeks an opportunity of forcing the other to action ; or of obliging him to retire and abandon the country he is master of : if both armies studiously avoid an engagement, yet secretly watch for an opportunity of attacking the adversary to advantage, this is called *a war between equal forces* : and, an army is said to be on *the defensive*, when from inferiority of numbers, or some other cause, the general shelters himself in strong posts, covers himself with lines and fortifications, or retires till he gains a camp almost impregnable ; under favour of which he keeps the enemy at bay, or at least, checks for a time the rapidity of his conquests.

185. Whatever be the system of the war, it always behoves the general to take such steps previous to the opening of the campaign, as may insure, as far as depends on human foresight, a successful issue.

The first point is to have the army properly *composed* : to this end, it is requisite to have a clear and accurate idea of the peculiar properties and service of each of the three species of troops, that constitute the military force of modern days ; viz. infantry, cavalry, and artillery. In the next place, the nature of the country that is to be the theatre
of

of war, and the proposed system of operations should be considered: since the army ought according to the nature of the country to be composed either of infantry solely; or of infantry and artillery; or of infantry, cavalry, and artillery. The proportion of each species of troops varies also, accordingly as the country is level or mountainous; intersected by rivers, ravines, and morasses; or covered with woods: the number and quality of the enemy's troops is likewise another point essential to be ascertained.

C H A P. I.

OF THE SEVERAL SPECIES OF TROOPS THAT
COMPOSE AN ARMY.

186. **U**NIVERSAL experience proves that the success of an army depends on its composition, and the manner in which its marches and dispositions in the day of action are regulated.

There are certain judicious combinations founded, in the opinion of the best military writers, on the different services of the several species of troops, and on the manner in which each can act; relatively to the nature of the country and the method in which the soldier is armed.

187. The musquet with the bayonet is an arm which the foot-soldier carries with ease: with it he can march through narrow paths, and over mountainous and difficult roads; and a bridge of slight construction serves for his passage over rivers, canals, or broad ditches.

In common marches that continue about 6 hours, a soldier walks with a free and natural step $2\frac{1}{3}$ miles in an hour; a regiment therefore when the roads are tolerably good, marches 14 miles in 6 hours. Within reach of the enemy, the pace is regular, but quicker or slower, according to circumstances: in the slow movement, calculating each step at 24 inches, and 60 steps in a minute, a regiment of infantry passes over 40 yards in a minute: and when it moves with an accelerated pace, it passes over twice this space or 80 yards in a minute.

188. From the constitution of infantry, the small space that each soldier takes up, and the arm he carries, this species

cies of troops is well adapted to offensive or defensive operations in all kinds of countries : since they can fight in line or column ; halting or marching ; firing with ball when at a distance from, or charging with bayonet when close to the enemy.

The intention of fire-arms being to annoy the enemy at a distance, the foot-soldier should above all things be taught to load his musquet properly ; and level and direct it well against the object : platoon firing by word of command from the officers is never so destructive as when each soldier takes his object separately : this is called *pallisadoe firing*, when the musquet rests upon any thing.

Infantry having occasion for very few carriages, are easily subsisted in countries where forage is scarce.

189. Cavalry are highly useful in marches and engagements, when the country is sufficiently level and open, to give them room to perform their several evolutions. The rate of marching of a regiment of cavalry for 6 hours is calculated at 17 miles ; but in case of necessity, it may be extended to 21 or even 28 miles. Wherefore from the celerity of their movements, they are excellent for making incursions into an enemy's country ; supporting a distant post, or corps of troops ; cutting off detachments, convoys, or foraging parties that imagine themselves in security ; and pursuing an enemy when routed and retiring in disorder. The sabre, carabine, and pistol, are the arms carried by the cavalry. In action their great advantage consists in the celerity of their movements, and the impetuosity of their charge, sword in hand. The velocity of the latter is estimated at four times the velocity of infantry, or from 3 to 400 yards in a minute ; but this exertion can last but a very few minutes. When an army is drawn up in order of battle, the cavalry is posted on the flanks to cover the infantry, and be ready to charge the flank of the enemy's army.

The fire of cavalry, from its great uncertainty, and the difficulty of re-loading on horseback, is but little considered in action ; it is serviceable on guard, in protecting their quarters, skirmishing, and increasing the disorder and confusion among the enemy's cavalry, when broken by a charge. The country, in which a large body of cavalry is to be subsisted for a long time, must abound in forage.

190. Dragoons are a species of troops that act occasionally as infantry or cavalry : in open and level countries they perform

perform the duty of cavalry, and in strong and inclosed countries, dismount and act as infantry: wherefore instead of a carbine, the dragoon is furnished with a musquet.

191. On considering the peculiar properties of infantry, and cavalry, it is evident that whenever these two species of troops engage each other, the safest method for the infantry is to act on the defensive, endeavouring to prevent the cavalry from surrounding them and charging their rear: they should therefore take possession of some situation that is naturally strong, or may be easily made so. But if nothing like a breast-work can be found, they should form in the best manner for keeping the enemy at a distance by a brisk fire, in order to enable them to execute the manœuvres best calculated for securing their retreat. In short, the dispositions of infantry consist in their order of march, and in regulations for keeping up a heavy fire in time of action.

Cavalry will have a great advantage over infantry when the latter are posted on a plain, and exposed to be charged the instant they have given their fire, or begin to be in movement; or when they are drawn up in such a manner, that they cannot well sustain the shock of a charge, as three deep.

192. Under the name of field-artillery are comprehended the royal regiment of artillery, the guns with their ammunition, horses for drawing them, and drivers for taking care of the horses. Hence, from the number of carriages, artillery cannot subsist long in a country where forage is scarce. The roads for artillery ought to be wide and good, and the bridges stronger than either for infantry or cavalry; then, the common rate of marching artillery is from 14 to 17 miles a day, and with the same expedition as infantry.

When guns are posted in the front line of an army that is advancing to the attack, the ground should be level and open, that they may preserve the posts assigned to them in the intervals of the troops: in inclosed countries, they should be preceded by a number of pioneers and carpenters for filling up ditches, making bridges, cutting down hedges, and opening roads: yet sometimes in spite of every exertion, they cannot reach their destination, and are frequently much embarrassed to keep their proper stations. Hence it results, *that artillery cannot always take the same route as infantry, nor accompany them on every expedition.*

When the army halts with an intention of giving battle,

or remains in a fixed post, the guns are drawn up at the distance of 8 or 10 paces from each other.

193. To lessen the difficulties that arise from the badness of the roads or the unevenness of the country in offensive operations, the guns should be made lighter; but not in such a degree, as render their effects uncertain. The 8 and 4 prs. described in the preceding treatise charged with $\frac{3}{4}$ of the weight of the shot are more manageable than those of the common length; and are sufficiently reinforced to resist the explosion, and project the shot with the requisite force for killing men and horses. In a word, pieces of this kind will be fully adequate to every purpose of firing round or case-shot; if regard be paid to the distance and dispositions of the enemy.

194. A round shot, fired against a body of troops drawn up in order for battle, can destroy but one file of three or four men, whatever be its diameter or velocity. But, if fired so as to enfilade the same body of men, or against a column, it will do execution till its force be entirely spent: its effects are then in proportion to its diameter and velocity. For it was proved in the Treatise on Projectiles, that the effects of shot are in a ratio compounded of their diameter and the square of the velocity with which they impinge: and in the preceding treatise, it was demonstrated that the initial velocities of 8 and 4 lb. shot being equal, their effects when fired against a body of men near to them, are in the ratio of their diameters, or as 5 : 4; but in long ranges, the resistance of the air being greater to shot of small than to those of larger diameter (Treatise on Powder); the remaining velocity of a 4 pr. will be less than that of an 8 pr. and its effects as 1 : 4. Each man may be struck in front or flank, in the most solid or least resisting parts of the body; it is impossible therefore to ascertain the exact number of men, that one shot will kill or maim: the only point that can be ascertained is, that a 4 lb. shot discharged from a light 4 pr. with $1\frac{1}{4}$ lb. of powder and well wadded, striking a column of infantry in the least advantageous circumstances cannot destroy more than 30 men; but under the most advantageous circumstances may kill or wound more than 60.

195. In action, case-shot is fired from 8 and 4 prs. when the enemy is at a distance of about 170 yards, and drawn up with such an extended front that it will do more execution than round shot. The number of men disabled by one case-

case-shot composed of 60 small balls projected from a 4 pr. within proper distance against an extended front, will far exceed what will be killed or wounded by a round shot of the same diameter.

196. Quick firing is of very essential service, either when the enemy's disposition can be enfiladed by round shot or exposed in front to case-shot: for the sake of expedition in loading, the powder is inclosed in flannel cartridges; which prevents the accidents that might otherwise happen, as the flannel leaves nothing burning in the gun.

In general, at the beginning of an engagement the enemy's army is at a great distance, and presents but a small front; in this situation, from the great care requisite in loading and laying the guns, some minutes elapse between every two rounds. If the enemy's front be very extended or he is advancing, the guns need not be laid with so much accuracy, and the wads may be dispensed with; which will tend to accelerate the firing. At length when the armies are very near each other, it is no longer necessary to lay the gun each time, the case-shot is fixed to flannel cartridges, the usual method of ramming the charge is discontinued, and the guns are primed with tin tubes: the artillery in this case fire faster than the infantry can do, and the gun is loaded in three motions.

1. The case-shot fixed to a flannel cartridge is put into the gun.
2. It is pushed to the bottom of the cylinder with one stroke of the rammer.
3. The rammer is drawn out, and at the same instant the tin tube is introduced into the vent. The gun, when heated, may be cooled with a wet sponge.

197. Different systems of artillery have been from time to time devised with a view of firing quicker in action: from an impartial comparison of these several systems with the 4 and 8 prs. in question, it might be ascertained how far the adoption of any of them would be really advantageous.

198. The distances at which artillery and infantry may engage, may be reduced to three; and the advantage of each arm is relative to the distance.

1. The distance may exceed the range of a musket; or
2. It may be from 200 to 260 yards,
3. It may be less than 170 yards,

In the first case, it is clear that the whole advantage lies on the side of the artillery; more especially when the enemy can be taken in flank.

199. But in the second case, the superiority rests with the infantry when drawn up three or four deep; since each gun is exposed to the fire of ten files, or 30 or 40 musquets, which may make great havock among the artillery-men; while the utmost execution that a gun can do, is to carry off one file at each discharge: the fire of the infantry may be also better directed, and quicker than that of the artillery from the necessity of laying the gun every time to ensure execution: moreover, the infantry always continue firing in proportion to the number of men that remain, whatever loss they may have sustained; whereas the fire of artillery decreases in a much greater ratio: thus, if half of the gunners be disabled, the fire diminishes in a quadruple or even greater proportion. Hence if a body of infantry be drawn up 4 deep at 200 or 240 yards from a field-battery, or be posted behind fences or walls, whence they can keep up the pallisade firing, the artillery will be more galled and sooner disabled than by opposing gun to gun. The idea which the greater part of military men have without due reflection adopted, of the vast superiority of artillery has not a little contributed to increase its effects; even veteran troops have under the influence of this terror been incapable of improving the advantages they had obtained; and new levies have been known shamefully to turn their backs at the very report of the guns and whistling of the shot: for when shot are not perfectly spherical or are full of cavities they make a hissing noise in the air, that strikes a panic into raw or unsteady troops; and the horses and drivers can with great difficulty be prevented from running away.

200. In the third case (198) the artillery has evidently the advantage; for they can fire faster than the infantry, and each gun projects at every discharge a greater number of balls than the ten files opposed to it (196).

When the infantry unable to bear any longer the galling of the case-shot, cease firing, and advance to the charge; the artillery should profit of their error and fire as fast as possible, putting over the case two or three round shot if the enemy be drawn up very deep. In doing this there is no reason to be afraid of bursting the guns constructed on the principles laid down in the preceding treatise.

To

To give an idea of the advantage that the artillery has in this case; let us suppose the enemy to advance in quick time or at the rate of 80 yds. in a minute; the guns will easily (196) make three discharges in a minute without being annoyed by the enemy, whose firing has ceased; so that while the infantry is marching the distance of 170 yds. to attack the cannon, they will be exposed to six rounds of case-shot from each gun, which will be more destructive the nearer they approach.

201. Artillery when opposed to cavalry, and covered in front by a broad and deep ditch, and secured in the rear by chevaux-de-frize, &c. has greatly the advantage; but when from the nature of the ground they are entirely exposed, the flanks and rear should be covered by detachments of infantry or in some other manner. Each gun should be fired twice in half a minute, being the time that cavalry takes to gallop at full speed over a space of 170 yards, which is the greatest velocity that cavalry can charge with.

Guns of the largest calibre should be opposed to cavalry, as they project a greater number of small balls, and with round shot do more execution in enveloping (194).

202. These several species of troops compose the bulk of armies; and from their solidity and mutual support when properly combined together, are destined for all great military operations.

There are other troops, which differ much from the former in their service and method of fighting: they are distinguished into light-infantry and light-cavalry, and are designed to act by detachment; for securing the tranquility of the camp; covering convoys; beating up the enemy's quarters; and harrassing them on marches. On them devolve all the more minute duties; but as they are never accompanied by artillery, it is needless to examine their constitution more particularly. The necessity of being acquainted with the method in which the several species of troops that compose armies can act, and be combined together on marches and in action, according to the nature of the ground and the disposition of the enemy, will from the perusal of this chapter be obvious to every officer.

C H A P. II.

REFLECTIONS ON THE COMPOSITION OF AN ARMY.

203. **T**O compose an army judiciously, the nature of the country, the quality of the troops, the number of the enemy's forces, and the plan of the campaign must be previously considered. A general, master of these points, may make the most advantageous and masterly arrangements: whereas, an army formed without attention to this general maxim, will labour under manifold disadvantages; and probably in the event reap nothing but disgrace and defeat, or, at most, but partial success.

204. The first requisite in the formation of an army is, that it be *quick and rapid in its movements, and subsisted without difficulty*: wherefore it should be limited in number, restricted in quantity of baggage, and free from every unnecessary incumbrance. The movements of very large armies are so slow and their marches so short, that their number by no means compensates for the heavy additional expence: beside, from the difficulty of providing such numerous bodies of troops with forage and provisions, a general is frequently obliged to abandon entire provinces, and to move into an open country within reach of some navigable river, by which the means of subsistence may be facilitated. When the theatre of the war is in a very strong country, a skilful general will turn this circumstance to advantage, and regulate the number of his troops accordingly. We find in history numberless examples of celebrated captains, who with small armies have by a judicious choice of posts and encampments, made head against an enemy greatly superior in number; and in the event, by a series of rapid and masterly manœuvres reduced him to the greatest straits.

By constant habits of surveying ground in a military point of view, and supposing the various cases that may occur on service, officers may acquire a quickness in discerning the advantages and disadvantages of posts; which has ever been esteemed among the first qualities of an able general.

205. After determining the number of troops of which the army is to consist, the next point is to ascertain the proportion

portion of each species of troops; taking care to distinguish those destined for the grand operations of war, from those that are to carry on the *petite guerre*: for if the light troops be too few in number, the strength of the army instead of being preserved entirely for great occasions, will be exhausted by the daily fatigues they must undergo: on the contrary, too numerous a corps of light troops militates against the maxim laid down in the last paragraph.

206. When the theatre of war lies in a very mountainous country, the army should consist solely of infantry; to whom may be attached some 4 prs. to be placed in fortified posts, when such points of support are necessary in a defensive system. But no artillery should accompany an army that is to act offensively in a mountainous country, unless it be to occupy an intrenched post in order to cover the operations of the troops; to attack a strong intrenchment to which it is practicable to bring up cannon; or take advantage of some commanding eminences to dislodge the enemy.

207. In flat countries intersected by rivers, canals, ditches, hedges, defiles, &c. the army should be composed of infantry, dragoons and artillery; the train of artillery consisting of a few 4 prs.

In open champaign countries, the train of artillery may be more numerous and consist of pieces of larger calibre: the principal strength of this army should lie in its cavalry; since by their means the general will be master of the country and oblige the enemy to keep close to his camp, or cover his convoys and foragers with large detachments; which will greatly harrafs and weaken his army.

208. The proportion between the infantry and cavalry depends also on the nature of the country. In flat extensive countries, the cavalry including the light-cavalry may be estimated at $\frac{1}{4}$ of the whole army; this number diminishes successively to $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{10}$ in proportion as the country becomes stronger; till at length cavalry is totally excluded and their place supplied by dragoons; who may amount to $\frac{1}{3}$ or $\frac{1}{2}$ of the army, when the country though level is very strong (207).

209. The number and quality of the troops being thus determined, they are formed into what is called *an order of battle*. The first line consists of at least half of the battalions

lions and squadrons : the remainder are disposed in the second line; and there is frequently a corps de reserve or third line, but less numerous than either of the others. Each line is subdivided into brigades; the brigades of infantry consisting of 5 or 6 battalions, and those of cavalry of 8 or 12 squadrons : each brigade is commanded by a major general and a brigadier; and every two or three brigades are under the orders of a lieutenant general. The light troops form a separate corps under the command of a general or field officer, whose rank is in proportion to the strength of the corps. The chief command of the army is given to a captain general; who has under him a general of cavalry, when that body is numerous.

C H A P. III.

OF THE FIELD TRAIN OF ARTILLERY.

210. **T**HE number and calibre of guns for composing a train of artillery to accompany an army in the field, is determined by the nature of the country, the system of operations, and the number of the troops; in order that the artillery may augment the resources and support the dispositions of the commander in chief, without causing the least delay or embarrassment.

211. When the scene of operations lies in an open campaign country, the train of artillery is the largest (206) : it has for a series of years been customary to reckon one gun for every thousand men; these pieces are worked by the royal regiment of artillery.

But during the war that commenced in GERMANY in 1740, field-pieces were attached to each regiment of infantry : they were served by them and comprized in the stores of the regiment. As several other nations have adopted this maxim, it will be for our interest to add to the strength of our infantry by pursuing the same plan, if ever we have occasion to act against any of them in a campaign country; notwithstanding the expence and trouble that such a quantity of artillery must occasion.

In flat but very strong countries, where the object is not to bring on a general action, but by marching and manœuvring

vring to occupy advantageous posts; the principal point to be considered is celerity of movement (204): wherefore, the army should be disincumbered of the battalion guns; the train of artillery diminished, and the nature of the guns adapted to the use for which they are principally designed, and to the condition of the roads and bridges; that they may never retard the march of the troops: in hilly countries, their number should be farther diminished.

In mountainous countries, the use of artillery should be entirely suppressed, unless some post of importance is to be occupied. From a desire of carrying cannon with troops that are to act among mountains, small guns weighing from 1 to 2 cwt. have been invented, and are transported on the backs of mules; but the advantages reaped from them are inadequate to the expence and trouble attending them.

212. For the sake of laying down some rule for forming field trains; let us suppose an army of forty battalions and as many squadrons, making in the whole 30,000 men, acting in a flat open country, with an intention of seizing every favourable opportunity of coming to action. In this case, beside the 4 pr. battalion guns served by the infantry, there ought to be twenty-five 8 prs. weighing from 9 to 10 cwt. each; four 16 prs. weighing from 17 to 18 cwt.; and four howitzers; with a proportion of ammunition, from 90 to 120 rounds a gun (one third of which should be case-shot); carried in tumbrils; with a certain number of waggons for the musquet cartridges and flints; to this must be added a proportion of intrenching, black-smiths and carpenters tools. That the service may be carried on with regularity and dispatch, draught horses should be purchased, drivers enlisted (1) and formed into a corps under officers and non-commissioned officers: the number of horses is regulated by the quantity of ammunition, &c. never allowing more than $5\frac{1}{2}$ cwt. to each pair of horses beside the weight of the carriage; that they may not be worn out before the end of the campaign. The guns are distributed into brigades of 5 or 6 pieces each, to be employed together or separately, as occasion may require, with a detachment of artillery-men to serve them.

Let the twenty-five 8 prs. be divided into five brigades; the howitzers and 16 prs. will form the sixth or park brigade; which is reserved for cannonading works that cover brigades, and strong posts of all kinds; and for firing against cavalry,

cavalry, or opposing very powerful attacks of infantry: the particular destination depends on the ground and dispositions of the enemy.

213. The following is a return of horses, &c. for one brigade of 8 prs.

	<i>Horses.</i>
Five 8 prs. mounted on travelling carriages, with limbers, side-arms, coins, and hand-spikes, with 4 horses to each	20
Two spare carriages, with limbers, carrying 4 spare wheels, 4 spare axle-trees, 4 sets of side-arms	4
Seven tumbrils carrying 500 rounds for the above guns	14
One light waggon with intrenching tools, &c. for repairing roads and bridges	4
One travelling forge complete	2
One waggon carrying 4½ cwt. of iron-work for gun carriages, 2 cwt. of spare rope, 1 cwt. of grease, carpenters tools, lanterns and 1 cwt. of candles }	4
Six powder waggons carrying 60000 musquet cartridges, 30000 flints for musquets, 2000 flints for pistols, 3½ cwt. of powder, 5½ cwt. of musquet and pistol ball, and 10 reams of cartridge paper	24
Two waggons carrying oats for the horses with spare harness	8
Horses for one officer, two non-commissioned officers and a farrier	4
Number of horses for one brigade	84

Beside the above, two country carts drawn by two pairs of oxen for carrying more intrenching tools, and the officers baggage belonging to the brigade.

When the brigade consists of 4 prs. two horses are allotted for each gun, and four tumbrils for the ammunition; the rest as above. Should the army move to a distance from the arsenals or fortified towns, a large depôt of ammunition both for infantry and artillery ought to be brought forward and lodged in some castle or walled town under the care of a detachment of infantry.

214. The detachment of artillery for the service of each brigade consists of a captain and two or three subalterns; six or eight non-commissioned officers; ten or twelve artificers; with eight or ten gunners to each gun, according to its calibre, and a conductor of stores for taking care of the ammunition, &c. All the brigades are commanded by a field officer, who has under him an adjutant and two assistants. The commissary general of artillery detaches a commissary, to make the issues and purchases during the campaign.

215. When a broad river runs through the country in which the army is to act, a sufficient number of large boats are provided for making bridges, and are left in the water till wanted.

When there are several smaller rivers, a number of pontoons accompany the army, carried on proper carriages, with baulks, chesses, cordage and every thing requisite for constructing bridges: an officer of the artificer-company with a party of artificers has the charge of this duty. The number of pontoons is regulated by the bridges there may be a necessity of making, and by the breadth of the rivers: the common calculation is a pontoon for every 16 feet of breadth, beside the two for the centre; if the river be navigable. The construction of these bridges has been already mentioned (37).

216. The following is a proportion of pontoons, &c. for laying a bridge over a river 300 feet broad.

	<i>Pairs of Oxen.</i>
Twenty pontoons mounted on carriages	60
Twenty-four carts carrying 360 chesses or planks } 13 feet long, from 10 to 14 inches broad, and 2 } inches thick	24
Fifteen ditto, carrying 120 baulks from 16 to 18 } feet long, and from 4 to 7 inches thick	15
Eight ditto, 10 anchors and cables, sheer-lines, } 6 capstans, artificers tools	8
Number of pairs of oxen 107	

Instead of pontoons, boats made of leather are sometimes carried in waggons folded up; when wanted for use, they are stretched out with cross pieces of wood, and 4 axle-trees fixed

fixed to the bottom furnished with small wheels, that they may run into the water without being damaged; upon them is laid a kind of stage, and over that the bridge is constructed.

In mountainous countries, small leather boats are carried on the backs of mules; each mule carries two. Bridges made of these boats will not support a weight exceeding 10 cwt.

In laying bridges of all kinds, whenever the river is so shallow that a heavy weight would sink the boat till it touch the bottom of the river, trestles should be substituted in their room, for reasons too obvious to need mentioning.

C H A P. IV.

OF THE ENCAMPMENT OF AN ARMY, AND OF THE PARK OF ARTILLERY.

217. **T**HE troops that are to compose an army are drawn out of their cantonments and quarters at the beginning of the war or of each campaign, and march to some particular place where they encamp in order of battle (209). As the place of rendezvous is always at a distance from the enemy, it is sufficient if it be dry and abounding with wood, water, hay, and straw: but the other camps that the army may occupy in the course of the campaign, independent of these requisites, must in other respects correspond with the views of the general: the first object is the security of the troops; wherefore,

1. There should be in the front of the encampment a spot spacious enough to draw up the whole army in two lines, and to engage without being embarrassed by the tents.

2. The front and flanks should be covered by houses, villages, rivulets, ditches, ponds or ravines, which the enemy cannot pass in order of battle.

3. Above all, the rear of the encampment should be secured, and a free communication established between the magazines.

4. Any villages, houses, or high-grounds near the camp, should be occupied by strong detachments.

5. If

5. If the camp be intersected by canals, ditches, rivulets, or other obstacles to a free communication between every part of it, bridges should be laid and passages opened, that the whole may easily move to the support of any part that is attacked.

218. In nothing is the ability of a general more conspicuous than in the choice of his encampments; and few circumstances have conducted more than this to gaining the most brilliant victories; but as the full discussion of this interesting part of tactics would be foreign to the purpose, our observations will be confined to a few points.

(FIG. 10, Pl. 6) The sixth plate represents a common encampment of 40 battalions and 40 squadrons; A, the encampment of the first line; B, that of the second, distant from the first 6 or 800 paces; C, brigades of infantry of five battalions each; D, brigades of cavalry and dragoons of 10 squadrons each; E, the park of artillery; F, head quarters; G, the village whence the camp takes its name; H, ground for the first line to draw up in order of battle, distant from A at least 600 paces; I, ground for the second line to draw up in order of battle; K, houses or barns occupied by the advanced guards of infantry; L, advanced guards of cavalry, as posted during the day; M, points to which the cavalry retires during the night to be covered by the infantry.

As many paces are allowed for the front of each battalion as it contains files; and an interval of at least 20 paces is left between every two battalions of the first line, that those of the second line may, if necessary, pass through them and form at I.

As many paces as there are files in each squadron and one half more are allowed for the front of each squadron; with an interval between every two of at least half the front of a squadron, that those of the second line may pass without interruption, and form at I. This disposition is nearly regular when the ground is level and open; but is deviated from, if superior advantages can be gained by a different position, or the safety of the camp better secured. When one flank is covered by a ravine, river, lake or impassable morass; and there is on the other a flat open piece of ground, all the cavalry is encamped on this flank.

219. This mode of encampment has been generally practised for these two last centuries; but in the defensive system,

other modes are adopted, such as the *close* and the *extended* camp. In the *close* camp, the army is encamped in three or four lines; and with the ancients, its form was square or rectangular, with little difference between the length of the sides in open and level ground; but the moderns without regard to the figure, attend only to the nature of the ground, endeavouring effectually to secure some of the sides, that they may be the better able to oppose the enemy at the vulnerable points. Such positions are frequent in mountainous countries; and those are esteemed the strongest, that are on a ridge between two vallies or rivers, or on a rising ground with a river in the rear; so that the enemy however numerous, cannot surround the camp or cut off the supplies. In the *extended* camp, the whole army is encamped in one line; when from situation or circumstances they are under no apprehension of being attacked, and wish to prevent an enemy from passing a broad river, or occupy a chain of posts in the mountains to cover a country.

220. The brigades of artillery being prepared, and the captain commanding each having inspected it, and received his order of march; they are put in motion along the high roads, and join the army in one or more days journey, according to the distance: when their route lies through a suspected country, they are escorted by a competent number of infantry or cavalry, as the country is more or less level or mountainous.

The commanding officer sends forward the quarter-master and camp-colour-men early in the morning to the village where he intends to halt, in order to prepare quarters and forage, and mark out a piece of ground for the park. When the brigades reach the army they are drawn up in four lines on the ground pointed out by the commander in chief, with 6 or 8 paces between every two carriages, and 20 paces between every two lines; that the horses may be harnessed and the march resumed without confusion: the guns, light-waggons, and spare-carriages in the first line; the tumbrils in the second; the ammunition-waggons in the third; and the waggons with the intrenching tools and the forge cart in the fourth: the brigades are called after the captains that command them, and are drawn up according to seniority; the first brigade on the right, the second on the left of the first, and so on successively to the last, which is generally the park brigade.

In front of the park and about the centre, a quarter-guard is placed sufficiently numerous to furnish centinels; and two alarm guns are stationed there, and kept unlimbered with a lighted match to give signals for the army to get under arms. The non-commissioned officers and soldiers tents are pitched on each flank of the park, at the distance of 20 paces from it; and 40 paces in the rear are pitched the officers marques in two lines. At some distance in the rear of the marquees, the horses are picketed in two or more lines with the tents of the drivers, &c. on the flanks.

221. The brigades being arrived, the commanding officer makes his report to the commander in chief, and waits on him every day for orders; and the adjutant goes every day at orderly time to take the detail of duty. When the camp is pitched the artificers examine the carriages, and the conductors of horse inspect the harness; at the same time the conductors of stores examine the tumbrils and ammunition waggons of their respective brigades, to see if any thing has been damaged or displaced during the march. The officer on guard over the park should go his rounds two or three times during the night, and cause them to be repeated by the serjeant and corporal of the guard: he should also take care that the cooking places are at a distance from the park, and all fires extinguished at sun-set, and even during the day if the wind blow hard. The next morning before the guard is relieved, each conductor goes round his brigade attended by a non-commissioned officer of the guard, to see that nothing has been stolen or broken during the night.

222. When the park of artillery is placed between the first and second line, it is supposed that there is no danger of being attacked: (Fig. 10, Pl. 6) but when the vicinity of the enemy's army renders precaution necessary, the brigades of artillery are posted between the brigades of the first line of infantry, and on the flanks between the infantry and cavalry. Each brigade is then subdivided: one part consists of the guns, light waggons, spare carriages, and tumbrils, with the officers and greater part of the gunners; the carriages are drawn up in two lines in the intervals of the first line of infantry, with the mens tents on the flanks, the officers marquees in the rear, and the horses and drivers behind them: when 100 paces are allowed for the front of each brigade, this disposition is called *the artillery drawn*

up in order of battle. The other part which includes the remainder of the brigade under the care of a non-commissioned officer with some gunners and the conductor, are stationed between the two lines of the army, or in the intervals of the second line: those subdivisions are frequently drawn up together, and go under the general name of the depôt; and then an officer is sent to command them.

When the ground in front of the field of battle is low, and there are any points that command the roads by which the enemy must advance to the attack, some guns should be posted there supported by pickets of grenadiers, or other chosen troops encamped on their flanks.

C H A P. V.

OF THE MARCH OF AN ARMY, AND OF THE DISPOSITION OF THE TRAIN OF ARTILLERY.

123. **L**ONG and frequent marches fatigue troops and occasion sickness; wherefore no march should be made, unless some real and essential object is proposed from it. Previous to a movement, a general takes into one point of view the plan of operations; the nature of the country the army is to pass over; the time requisite for performing the march; the enemy's force and distance: and thence determines in how many columns the army ought to be disposed, that the march may be easy and expeditious, and the troops soon formed in order of battle, in case of an attack on the march; how each column should be composed, and which road it should take.

When there are not roads enough for the several columns, the cavalry cross the fields, and the infantry march on the roads; the columns of artillery on the broadest and best. The light troops are sent forward early in the morning to reconnoitre the country; and if the enemy be near, they are supported by a considerable body of troops: in their rear march the detachment intended to guard the new encampment, with the camp-colour-men that are to mark it out. But if the enemy be at a distance, the camp-colour-men assemble at a certain time and place, and proceed with the camp-guard, and the quarter-master-general under the orders

orders of the general of the day, towards the new encampment. On their arrival, the quarter-master-general marks out the camp, and the general of the day posts the necessary guards.

Each column has a front and rear guard; the strength of the detachment that covers the artillery and baggage is determined by circumstances.

224. When the drummers *beat the general*, the quarter-master and camp-colour-men of the artillery repair to the place appointed for their assembly, and accompany the other camp-colour-men to the new camp; and every thing is prepared for the march.

At the beating *of the general*, the artillery-men strike their tents, pack their baggage, and harness and bridle the horses; at the second signal, or *the assembly*, the horses are put to the carriages, and they are all drawn up ready to march; and at the third signal, the whole move into the place assigned to them in the order of march. The brigades march according to the seniority of their captains, with the light waggons in front; then the guns, the tumbrils, the ammunition waggons, waggons with intrenching tools, and last of all the country waggons and forge carts. Each captain with the greater part of the gunners marches at the head of his brigade; a subaltern with a small detachment in the rear; and another detachment under a non-commissioned officer on the flanks near the ammunition, which is also the station of the conductor of stores. The artillery column is preceded by some pioneers taken by detachment from the several brigades; and some artificers to mend holes in the roads, examine the bridges, repair them or lay down new ones, and open avenues into the park, in case the camp-colour-men have not had time to do it. When the brigades reach the new encampment, they are drawn up as before.

225. The seventh plate represents an army on its march in five columns from the encampment A towards B: (Fig. 11, Pl. 7) the centre column of artillery C is preceded by a brigade of infantry D, and followed by a part of the baggage of the army: the remainder of the baggage F forms the fourth column with two brigades of infantry in front; H, the van-guards of each column; I, the rear-guards; K, the new encampment and the camp-colour-men; L, light troops detached in front to reconnoitre. When there is any

apprehension of being attacked on the march, a brigade of artillery marches at the head of each column preceded by the van-guard of the column. Accordingly as the ground on the flanks is open or strong, they are covered by columns of infantry or cavalry.

In a retrograde movement towards Q, the camp-colourmen and new camp guard march first; then the artillery and baggage followed by the army, disposed in as many columns as possible, in order to shorten the line of march: each has its rear-guard. In an open country, the light cavalry forms the rear-guard of the army; and in strong close countries, the infantry. When a movement is made by either flank, there are generally as many columns as the army was encamped in lines: the column of artillery and baggage marches on a high road behind the rear line, and is escorted by a strong detachment. The light troops march between the first line and the enemy, to give timely notice of their approach. In this manœuvre, if the first line march along a high road, and the artillery be disposed according to the order of battle, the guns should follow each other in file, and the tumbrils form a second line parallel to them, when the breadth of the road admits of it; but in narrow roads, they should follow the guns: if the enemy advance to attack the army, the tumbrils should be disposed in a second line behind the guns, in order to be ready for action.

226. If the army in marching from the camp A towards B must pass through a defile, and the enemy is posted on the other side, the mouth of the defile should be occupied by some grenadiers and other chosen troops, with a few pieces of cannon; under favour of which, the column on coming out of the defile may deploy in order of battle.

When there is a necessity of crossing a river by a bridge, and the enemy is at hand to dispute the passage, several pieces of cannon should be planted on the bank of the river to the right and left of the bridge, supported by some battalions, under cover of whose fire the army may cross the bridge, and form in order of battle on the other side. Intrenchments thrown up to protect the army in passing the bridge, should be lined with cannon and musquetry. Whenever the river is so broad as to render the fire from the opposite bank of no effect, an intrenchment should be thrown up, and embrace a large extent of ground; the better to ensure the safety of the troops.

The army that attempts to pass through defiles, or cross bridges in the face of an enemy, ought to be greatly superior in number.

227. An army in retiring from the camp A towards Q, is under a necessity of passing through a defile, and the enemy is at no great distance; the defile ought previously to be enlarged to render the march more secure: when that is impracticable, some chosen infantry with a few pieces of cannon should be posted on the sides of it. In cases of particular danger, a strong entrenchment must be thrown up at the entrance of the defile, or at least a chain of redoubts at proper distances from each other, lined with cannon and musquetry; the army should then retreat by night, and draw up in order of battle after having passed the defiles, to receive the artillery that covered the retreat; and the infantry that was left in the intrenchment will form the rear guard.

When the army in its retreat must cross a bridge, a detachment should be sent forward to throw up an intrenchment to cover the bridge; a large body of infantry thrown into the work before sun-set, and cannon planted on every point on the other side of the river that flanks the intrenchment. During the night, the remainder of the army should cross the bridge, and draw up on the other side of the river in order of battle, to receive the corps of infantry that was left in the intrenchment; and when the whole has passed, the bridge should be broken down. This manœuvre ought never to be practised but in case of necessity, unless the intrenchment can be made of a very respectable profile.

C H A P. VI.

OF BATTLES AND GENERAL ENGAGEMENTS.

228. **A**N order of battle is the most advantageous disposition of the battalions, squadrons and artillery, that compose an army, relatively to the nature of the ground, the number of each species of troops, and the strength and position of the enemy: hence it is easy to conceive, that the dispositions and combinations of troops may be infinitely varied; but as it would be foreign to our purpose to enter into a particular

ticular discussion, I shall only endeavour to give a few general ideas on the subject.

229. All orders of battle may be reduced to two, the *parallel* and *oblique*; and each of these may be either offensive or defensive.

In the *parallel* order, the troops are so disposed, as to bring the whole extent of the front line into action; this order was principally practised in the wars of the preceding centuries, particularly in level and open countries.

In the *oblique* order, a part only of the front line is engaged, the remainder being kept in reserve; this is performed with the right or left wing, or with the centre: or with the two wings reserving the centre; it is then termed the *double oblique*.

An army may either attack or be attacked; a general may from some particular advantage arising from the nature of the ground, combined with the disposition of the troops, be induced to stand an attack: as in the two following cases;

1. When the troops are drawn up in a position naturally strong, where they may receive the enemy's attack, and seize the first favourable opportunity of acting offensively.

2. When from the nature of the position, the defenders can throw in a fire so much heavier than that of the assailants, as to give a moral certainty of repelling the attack with great loss to the enemy, and but little to themselves: these cases excepted, it is very hazardous to receive battle in a position merely defensive.

The oblique has by the most able generals been preferred to the parallel order, whenever the ground admitted of it; since it affords an opportunity of displaying the most masterly and consummate knowledge of tactics, and is the best adapted to an inferior army.

230. From the definition of the several species of troops (Chap. 1.), it is easy to imagine a variety of orders of battle adapted to certain situations: but the primary object of every general should never be lost sight of; viz. of providing for the security of his own army before he attacks the enemy: wherefore the distribution of the troops and the figure of the order of battle should form a kind of a moveable fortification, where all the parts mutually cover and defend each other; and each species of troops should be posted in the precise spot where they can act with the greatest energy, and occasionally
change

change their operations from defensive to offensive: cavalry for instance, should be posted on level and open ground, that they may perform the necessary evolutions without impediment or embarrassment (189).

The artillery should be drawn up in the best situations for enfilading the opposite army with round shot (194), or firing case-shot against their front (195). In advancing with the line of the army, the ground in front should be level and open (192): this circumstance is not very material when the army is not to advance, but receive the enemy in their present position; it will then be sufficient, if their rear be secured by ditches or other obstacles against a charge of cavalry.

Finally, the infantry which is the soul and strength of every disposition, will be advantageously posted when they are drawn up three or four deep behind fences or hollow ways, whence they can keep up an incessant fire and manœuvre freely; or some paces behind the crest of a rising ground, which may serve as a kind of parapet: when they are to advance to the attack, the ground in front ought to be open; and that part of the first line which is to charge ought to be formed with very deep files or in column, not exposed to be taken in flank by the enemy's artillery.

231. The distance between the first and second lines is 300 or 400 paces; with the corps de reserve, 200 paces in the rear of the second line; or between the two lines, in which case, the distance between them is increased to 400 or 500 paces. When the army advances in line, an interval of 20 or 30 paces is left between every two battalions, to prevent them from crowding the files, which generally happens when this precaution is neglected; but these intervals are unnecessary when the army is to receive the attack: 8 or 10 paces are left between every two guns. The intervals between the squadrons of the first line should not exceed nor be less than half the front of one squadron.

In making a long charge in line, the squadrons should never touch each other, from the almost absolute certainty of their being in disorder before they reach the enemy.

232. (Fig. 12, Pl. 8) A B is an army drawn up in the parallel order of battle, to engage the first line of the enemy's C C; and may be supposed to be acting either offensively or defensively.

(Fig. 13, Pl. 8.) The army is drawn up in a parallel order of battle defensive; in this disposition the right wing G is

G is supported by the artillery A, planted on an adjacent eminence, and covered by some battalions B drawn from the second line. The left wing A joins to the village C in which are posted the guns D supported by the battalions F, drawn also from the second line.

(Fig. 14, Pl. 9.) The ninth plate represents two oblique orders of battle: the cavalry is advanced on the right of the army to attack the enemy; the left of this disposition is defensive, being secured by the height A, on which are posted some battalions B with artillery C, and farther supported by the columns D, kept in reserve.

(Fig. 15.) The cavalry C is on the left of the army in a defensive position; since the front line of cavalry being in a line with the second line of infantry is covered by the flank A, formed by some battalions, and the brigade of the park. The right wing D of the army is composed of the grenadiers and chosen infantry, some ranged in column and others in order of battle, in several lines to march forward to the attack. Before the troops advance, the artillery at B keep up a heavy cannonade, seconded by the first line. The squadrons S, stand ready to seize the first moment of the enemy's being thrown into disorder to charge.

When two armies engage in one or other of these orders, it is called a *pitched battle* or *general engagement*: but when from the nature of the ground, the troops cannot be drawn up in either of these methods, but are obliged to engage one after the other in a very confined space, it is termed an *action*. The difference then between pitched battles and actions consists in the issue of a pitched battle being always very destructive to the army that is routed: whereas in actions, the victory decides but little; though perhaps the loss of men may be much greater than in a general engagement: for which reason, the ablest generals have endeavoured to avoid actions; and when they have been forced into them, it has been owing to some accident, which the most skilful disposition and wisest precautions could not guard against.

The principal maxim is, *to adapt the disposition of the troops to the inequalities of the ground, in such a manner that they cannot be taken in flank; but may be able to attack in front and flank, or at least obliquely the enemy's army; and to bring into action a greater number of men than the enemy can oppose to them; this is obtained by drawing up the army with a more extended*

extended front, in order to out-flank the enemy; with the infantry four deep to throw in a heavy fire.

The artillery is posted at the points, whence from the nature of the ground and the enemy's disposition they can do most execution.

234. The commander in chief having resolved to give or receive battle, communicates his intentions to the generals and the commanding officer of artillery; that they may do their utmost to second them. If the commanding officer of artillery foresees that the several brigades may during the action labour under a deficiency of men to execute the several necessary manœuvres, he should apply for a certain number of additional to be attached to each brigade; either to assist in working the guns; levelling obstacles; filling up ditches; or laying down bridges: for the greater security, they should be under the command of their own officers and non-commissioned officers.

It is sometimes impossible previous to an engagement, to reconnoitre the country sufficiently, to know the points where the artillery ought to be planted; the commanding officer should in this case ride along the front, before the two armies come to close action; and submit his observations to the commander in chief, propose such dispositions of the artillery as appear the most advantageous, and instantly execute the orders he receives.

When the armies engage in the parallel order, and consequently the whole front is brought into action, the commanding officer of artillery, beside his staff, should be attended by some subaltern officers, that he may be able to send orders to the several brigades; since during the action he should never quit the commander in chief without permission; and then only to examine the state of his brigades, or transport himself to any spot where his presence may be absolutely requisite: it rests with him to demand extraordinary reinforcements for making a vigorous push against the enemy, or for sustaining a very lively attack.

235. The officers of the several brigades having received their orders, distribute the artillery-men and additional to the guns, and immediately open passages in the front and flank, that they may be able to move without impediment.

When the army advances in line, the guns are drawn by horses to the place of action; at the commencement of the action, the spare carriages and waggons are placed 250 paces in

in the rear, not to endanger their being blown up, and a tumbril is kept near each gun with the light waggons. The artillery-men and additional not actually employed should be sheltered behind the waggons; without which precaution, many men may be sacrificed to no purpose at the beginning of the action, and the guns become unserviceable long before it is over.

If infantry and cavalry be ranged in two lines, that the second may support and supply the place of the first; how much more ought the artillery, which during the whole action is exposed in the first line, to have some men in reserve to supply the place of those that are disabled, that there may be always the necessary number for keeping up a brisk fire?

The brigade is divided into two parts, each under command of a subaltern; who is to take care that the fire is well directed, and the service carried on properly, and without confusion: the captain inspects the whole brigade, replaces the men that are killed or wounded, and makes them bring up another tumbril when the ammunition in the first is nearly expended. When the action is likely to last long, he sends to the depôt (222) for more ammunition, and informs the commanding officer of his losses and expensure.

236. To derive the greatest advantage from artillery, the firing should be brisk and without confusion; and the utmost attention paid to loading and laying the guns, that the shot at the several distances may reach the enemy: an officer will shew his judgment by cannonading that part of the enemy's disposition, which it is of the most consequence to throw into disorder; or by firing case-shot, when the distance and other circumstances permit.

Confusion in the service of artillery arises either from the want of a proper distribution of the men; from their awkwardness; or from their being seized with fear, or a species of delirium, under the influence of which they are desirous of firing with the utmost precipitation. To prevent which;

1. The artillery-men should be exercised every day till they have habitually acquired a superior address in the management of the guns, according to the plan of exercise laid down in the school-practice: for if every officer takes upon himself to alter the mode of exercise, it must inevitably lead to confusion; particularly when the men are changed from one brigade to another.

2. The

2. The men should be posted to the respective guns, each man informed of his particular duty; and the additional practised in dragging them.

3. The officer should ever preserve an air of coolness and tranquility, and employ arguments rather than menaces, to encourage the timid, and repress the ardour of the violent; punishment should not be used but in the last extremity.

The guns should fire slowly at first, by which means the soldier not being hurried at the onset will preserve his presence of mind in the heat of the engagement, and perform his duty with coolness and alacrity.

237. The brigades follow the movements of the infantry, preserving the proper intervals. In the mean time, the waggon and ammunition carts, that are in front of the second line, follow the guns at the distance of 250 paces, till the contest is determined. If the enemy retire, the carriages are brought up and the guns limbered to follow more easily the movements of the army: but if the issue be unfavourable, the captains commanding the brigades, when ordered to retire, exert every means in their power to save their guns, though pressed by the enemy: with a view to this, they ought to have examined the roads, bridges and other avenues, previous to the action. When all retreat is impracticable, the guns should be spiked or rendered useless in some other manner, the ammunition blown up, and the principal articles destroyed or carried off.

238. The commanding officer of artillery, who has always remained with the commander in chief, should have foreseen the fatal moment of defeat, and have given such directions that the guns may not on the retreat, embarrass the movements of the troops. On the receiving the order to retire, he will cause the depôt that is stationed behind the second line to move instantly, and all the brigades of the first line to retire by the roads pointed out to them. He will in person repair to the spot where there appears to be the greatest difficulty and danger, that by his superior knowledge and experience he may extricate his officers and men out of the straight to which they are reduced; and as the limbers are sometimes broken and useless, he will apply for an additional number of infantry to assist in dragging off the guns. The brigades and depôt, should repair as fast as possible

possible to the place of rendezvous, that the troops may follow without confusion.

When the army is in security, the captains should examine the state of their brigade, and make a report of deficiencies to the commanding officer, who makes his demands accordingly; the artificers are instantly set to work to repair the carriages that are damaged.

C H A P. VII.

OF THE ATTACK AND DEFENCE OF FIELD FORTIFICATIONS.

239. **T**O conceive an adequate idea of the best mode of attacking and defending field-works, their construction and use should be first understood: to this end, some of the fundamental principles laid down in the Treatise on Military Architecture will be here repeated.

The object of field-works is defence: yet the mode of defence is very different from the method of defending regular, or even irregular fortresses. Since the latter are amply supplied with provisions and stores; whereas field-works are open on one side and communicate with the country, by which avenue the troops can always receive supplies of provisions, and are generally attacked without the dispositions and precautions usual in sieges.

240. Field-fortifications are constructed either with a view of covering an army that wishes to avoid an engagement, or securing its retreat; of occupying some important post, to impede or frustrate the enemy's designs; or of forming an intrenched camp in the vicinity of a fortress, to render a siege difficult or impracticable. These fortifications are distinguished into natural and artificial: in the first class, are ranked heights that the enemy wish to get possession of, at the foot of which are hollows or fences that are commanded: and eminences, houses, villages and woods near to the camp or field of battle, that may be useful as points of support, or as advanced posts to intrench on.

A position on a rising ground with steep banks is strong; and when on the side towards the enemy, there be a canal, river, lake, morass, quicksand, steep precipice or narrow pass through which the enemy must defile before he can
 attack

attack the camp, it is still stronger; indeed some positions of this nature are found that are impregnable.

241. When the ground is not naturally strong, it is rendered so with field-works: this occurs most frequently in countries intersected by large canals or rivers, &c. or in mountainous or strong countries, whither an inferior army is compelled to retire from the open champaign country to avoid being surrounded and cut off from its supplies.

In field-works constructed on the flat parts of a strong country, one stage of fire is generally sufficient; but in forts and large redoubts, that are to serve as points of support to other intrenchments or as insulated posts, there ought to be two stages of fire.

In mountainous countries, from the natural advantages of the situation, two stages of fire may be obtained with little expence or trouble.

242. In the construction of field-works, regard must be always paid;

1. To the nature and extent of the adjacent country,
2. To the interior area.
3. To the figure of the works, and the mutual support of the several parts.
4. To the profiles of the works.

243. Those field-works are the strongest, which from natural or artificial obstacles cannot be approached by the enemy in regular order (242, No. 1): when the intrenchment cannot be made inaccessible along the whole front, a part of it at least should be made so; always keeping in view this maxim that *the flanks be better defended than the front*. The ground before the accessible parts should to a proper distance, be cleared of trees, hedges, buildings, and every thing that can give shelter to the enemy.

244. The interior area should be so spacious, that all the troops may encamp in good order, and perform the necessary manœuvres for defence without being straitened for room. When the army is encamped in one line, 500 paces are left between the intrenchment and the tents for the troops to form on; and when in two lines, this distance is increased to 800 paces (242, No. 2).

The front of the encampment ought not to be unnecessarily extended, lest there be too few men to line the intrenchment: when there are any ditches, canals, precipices or other obstacles to a free communication between the several parts,

bridges

bridges should be laid and the heights levelled: and the encampment so disposed, that the army may move by either flank in the order that may appear the most advantageous for gaining any object in view, such as seizing an important post, &c.

From these remarks on field-works it may be inferred, that an officer ought to be complete master of the manner of attacking and defending this species of fortification, before he can be competent to decide upon the advantages or disadvantages of particular situations.

245. Redans connected by curtains is the most common figure for field-fortifications in a campaign country: when from the nature of the ground this figure must be deviated from, it should be a maxim that *every part be flanked, that the line of defence never exceed 260 yards, and even less when particularly vulnerable* (242, No. 3).

The figure of small forts erected to secure the flanks, or serve as points of support to the weakest parts, or as advanced posts, must depend on the nature of the ground: a covered way before the fort, or a smaller fort constructed within the larger one will give two stages of fire.

There are two methods of fortifying houses, villages, and other large buildings: the one is to close and barricado the streets, doors and lower windows on the side of the enemy and enlarge them on the opposite side, to give free room for the troops to enter for the defence: the other is to establish two stages of fire, the first from the intrenchment that surrounds the village; the second, from the upper windows of the houses. In tracing the intrenchment, an interval of 30 paces at least should be left between it and the houses, that the troops who line the works, may not be incommoded by the devastation occasioned by the enemy's shot among the buildings. When there is a free communication between the village and the army, the front and flanks only need be intrenched; except it is intended as an advanced post, then the work should be closed,

246. Field fortifications may be classed under three heads (242, No. 4)

The first kind is the most simple, and consists of a parapet $4\frac{1}{2}$ or 5 feet high and $3\frac{1}{2}$ feet thick at the top without banquettes: this is thrown up in places which the enemy cannot approach without being obliged to desile; but never on flat open ground, unless the army be but little inferior in number to the enemy.

The

The profile of the second kind consists of a parapet $7\frac{1}{2}$ feet high and 6 feet thick with a broad banquette, that the infantry may draw up two or three deep, and the troops at the foot of the banquette be sheltered from the enemy's fire: the ditch is from $7\frac{1}{2}$ to 9 feet wide and $4\frac{1}{2}$ feet deep. Both these kinds of intrenchment are liable to be insulted; or in other words, exposed to assault without any previous steps on the part of the assailant.

The profile of the third kind is a parapet from 12 to 15 feet high, and as many thick; with a ditch from 20 to 26 feet wide and from $7\frac{1}{2}$ to 11 feet deep: this intrenchment is said to be secure from insult; as it cannot be attacked but by a kind of regular siege, by opening trenches and erecting batteries. A row of palisadoes fixed horizontally half way up the parapet, or with a slight inclination at the foot of it, adds much to its strength. The banquette is from $7\frac{1}{2}$ to 9 feet broad, that the infantry may draw up two deep and maintain a heavy fire, when the ground in front is favourable to the enemy's attempting to carry the work by assault.

247. The troops for the defence of the two former intrenchments are disposed as follows:

1. The parapet is lined with one rank of infantry, who keep up the palisado firing when the ground in front is so broken that the enemy cannot approach in order; when the ground is less broken, they are drawn up two deep and fire by platoons. When the ground is so favourable, that the enemy may adopt whatever disposition appears the most feasible, the infantry are drawn up 4, or at least 3 deep, and fire by word of command from their officers. In this case, the two front ranks give their fire, and kneel down to give liberty to the two rear ranks to fire; they then rise and the whole reload. Of the various methods of parapet firing, this is the most simple and effectual, and produces more than any other, that solidity and consistence which forms the excellence of every body of troops.

2. Beside the troops on the banquette, there should be some posted in reserve at a proper distance in the rear, to be ready to move to any part where they may be wanted; and behind the points, where the most serious attack is to be apprehended, a second line of infantry should be formed 300 paces from the parapet; with some squadrons of cavalry, drawn up in the rear on a

flat piece of ground, ready to charge the enemy, the instant they force the intrenchment.

3. In the third kind of intrenchment, the disposition of the troops depends upon the mode of attack: when the enemy makes regular approaches, the same regulations are to be adopted as in the defence of fortresses. If the enemy attempt to carry the work by assault, the troops should be drawn up 3 or 4 deep on the banquettes to throw in a very heavy fire, in order to make him repent of his temerity.

248. The disposition of artillery in the two first species of field fortifications depends on the nature of the ground, and the order in which the enemy approaches. The general rule is,

1. To post the artillery at the parts where the most serious attack is apprehended, leaving to the infantry the defence of the other parts.

2. If the enemy advance in column, guns are placed on every point that can enfilade it; and if in line, case-shot is fired from all the guns that bear directly on his front: some others are brought to bear obliquely with round shot. An incessant firing is kept up, till he is obliged to retire out of gun-shot to rally: then the firing is suspended; and every thing prepared for giving him a warm reception when he returns to the attack.

3. When the ground is so favourable to the enemy, that he can by manœuvring alter his disposition at pleasure and keep the defendants in doubt which part he intends to attack; some guns are kept limbered and loaded, that they may be instantly drawn to the point of the greatest danger.

249. In attacking an intrenched camp with a profile of the first or second kind, the flanks should be first attempted; but if their profile is, as it should be, of the third kind, the troops must advance within 700 or 800 paces of the front of the intrenchment in the parallel order, and then make the attack in the oblique or double oblique order, taking care not to present the whole front to the fire of the intrenchment, unless the enemy weaken some part not attacked in order to reinforce those against which the attack seems directed.

When any defect in the works, or the interior of the camp, that embarrasses the troops in their manœuvres is perceptible, the weight of the attack should be directed against that part; otherwise

otherwise, the greatest efforts should be made at the point where the exterior ground presents some advantages : the infantry being disposed in several columns, connected with other troops and supported by a second line of infantry, with the cavalry drawn up in the rear, ready to gallop into the intrenchment the instant the infantry have entered and opened breaches large enough to admit them.

The previous dispositions being made and the signal given for the attack, the troops march forward in quick time ; since it is only by advancing rapidly, that the defendants can be deprived of the advantages they have over the assailants : for the fire of the latter is, at the best, but uncertain ; while they are exposed to a very heavy and well-directed fire from behind the works : common sense and experience agree on this point.

25c. In the assault of field-works, it depends on the position of the intrenchment and the nature of the ground where the troops form, whether the whole or a part only of the artillery can be employed. The general rule is for the artillery to keep a very heavy fire previous to the advance of the troops, that they may meet with less resistance and penetrate more easily. The principal cases in which artillery is useful in this kind of attack are :

1. When the artillery of the works can extremely annoy the assailants, a superior number of guns are brought up to silence them ; and when there is any commanding ground at 200 or 300 paces from the works, some infantry is posted on it to throw in as heavy a fire as possible (199).

2. When there are any forts or redoubts with two stages of fire within the works, the fire of all the artillery is directed against them to throw the troops that defend them into disorder ; the instant this is perceived, the infantry advance rapidly to the assault. Red-hot shot and howitzer shells filled with combustibles are thrown into intrenched villages or houses to set them on fire ; it should be laid down as a maxim in the attack of towns or villages, *never to let the infantry advance before the artillery has thrown the garrison into confusion.*

3. Any ground in the vicinity of the intrenchment, that enfilades or commands it, should be occupied by a sufficient number of guns to take full advantage of this favourable circumstance.

4. In the three preceding cases the distance of the guns from the works should be from 240 to 340 yards: and when very much exposed to the enemy's musquetry, they may be in some measure sheltered by casks filled with earth, or with the doors and windows of the neighbouring houses: Some officers from an absurd and false principle of honour have disregarded this mode of covering the artillery; but those who consult the real honour of a soldier will know, that it consists in advancing the interests of their country in the most certain and expeditious manner; it is therefore the first duty of an officer to cover his men as effectually as possible. Some guns ought to march in the rear of the column to seize any opportunity of acting to advantage.

251. Artillery is also employed in the attack of intrenched posts, in the following cases:

1. When the intrenchment is of great extent; as lines of circumvallation, and exposed to insult: some guns are sent with a body of infantry to make a false attack during the night, in order to cause a diversion of the enemy's troops: the false attack is made at a distance from the real one, and commences some hours before it with a very heavy fire.

2. When the profile of the intrenchment secures it from insult, a kind of irregular siege is carried on with batteries and trenches: these attacks are generally directed against the flanks of the intrenched camp, or some salient point.

3. In battering bridges built of boats, and covered by redoubts or intrenchments, some guns are brought to the edge of the river, whence they can bear on the bridge; and if the opposite shore be lined with musquetry or artillery, a superior fire must be directed against it, to cover the guns: when the intrenchment is injudiciously constructed, the infantry after the fire of the artillery has continued for some time, should advance and storm it.

4. When the enemy having laid a bridge of boats, endeavour to pass the river; the troops and artillery that are to dispute the passage, form opposite to the bridge, to enfilade the enemy, who having crossed the bridge in column, will endeavour to deploy in order
of

of battle; some guns are also planted on the bank to cannonade the bridge: and if the enemy cover his passage by a fire from the opposite side, a superior fire must be established. It may be remarked here, that whenever a bridge is to be attacked, or the passage of it disputed, and there are guns on both sides of the river, if the two banks be not on the same level, the troops on the highest bank will have the advantage, when the river is not less than a musquet shot across.

C H A P. VIII.

OF THE QUARTERS OF AN ARMY.

252. **I**T is customary to put the troops into winter quarters towards the end of autumn; and in some countries, into summer cantonments during the great heats of that season. They are lodged in the towns and villages, and distributed according to the order of battle in which they are encamped; that is to say, the troops that compose the first line are quartered in the houses nearest to the enemy, and those of the second in the towns in the rear; regard is also paid to the position of the wings and centre, so that the troops may on occasion march forward to the ground that is fixed on, for their general rendezvous, without confusion or danger of crossing each other in the march. The quarters are more or less extended in proportion to the distance between the two armies, and there is generally a river or defile in front.

253. The brigades of artillery are generally quartered together in some city or town in the second line, with a body of infantry to cover them.

At every halt during the campaign, the damages were repaired as far as circumstances would admit; and advantage is now taken of the summer cantonments, to examine and put every article in a complete state of repair, that on any emergency the brigades may be instantly ready: the ammunition, &c. is left in the waggons, and the park formed in the proper order, that the horses may be harnessed without confusion. When the ammunition is carried on beasts of burthen, it is unloaded and lodged in some building not exposed to fire, and spacious enough to contain it without mixing

mixing the several species together. The officers, non-commissioned officers, artillery-men, -drivers, conductors, and horses are quartered in the houses contiguous to the park, with a proper guard; particularly in conquered countries. The commanding officer of artillery having been previously advertised by the commander in chief, of the position each brigade is to take up in the field of battle, and of the route by which they are respectively to march, examines the roads and ground attended by his captains, and orders the necessary repairs to be made to facilitate the march: he explains to his officers the intentions of the general, that they may be enabled punctually to execute the orders they receive, whether by express or concerted signal; in the latter case, some attentive men are posted day and night to observe the signals.

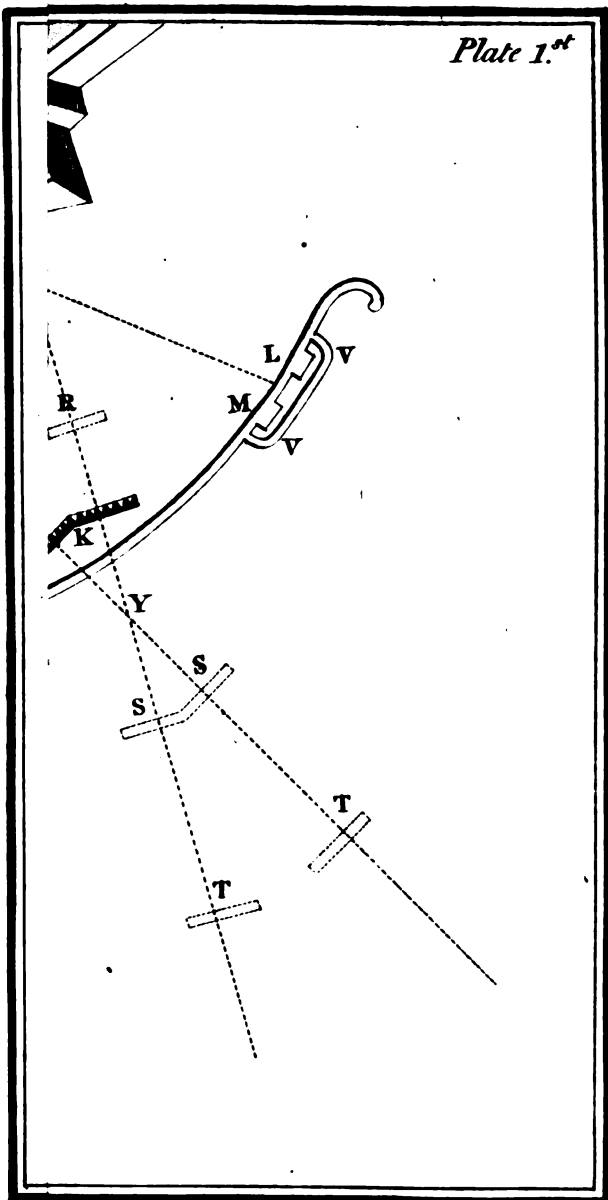
254. When in front of the line of quarters, or on the only road by which the enemy can approach the cantonments, there is any post or commanding situation; it should be occupied by a detachment of infantry, supported by one or two brigades of artillery, that it may be able to hold out for some days, and give time to the army to assemble and march to its relief. The officer who commands these brigades will consider attentively the nature of the post, and the adjacent country, and judge whether it be exposed to a coup-de-main; and whether it can be strengthened by any additional works: he will communicate to the commanding officer of the post, his ideas upon the plan of defence, and post his guns at the most important points, with a proportion of ammunition in case of attack.

255. At length, the season for military operations being over, and the commander in chief having ordered the army into winter quarters in the most convenient and plentiful country, that they may recover themselves from the fatigues of the campaign; the brigades of the artillery move towards the place of their destination under the escort of a body of infantry or cavalry, marching and parking as before directed. Being arrived at their quarters, which should be covered from every attempt of the enemy, the ammunition is lodged in the magazines, the carriages put under cover, and the necessary repairs instantly begun: during the winter, attention should be paid to the comfort of the men, and the forage of the horses, that the whole may be able to take the field in the ensuing spring with recruited strength and vigour.

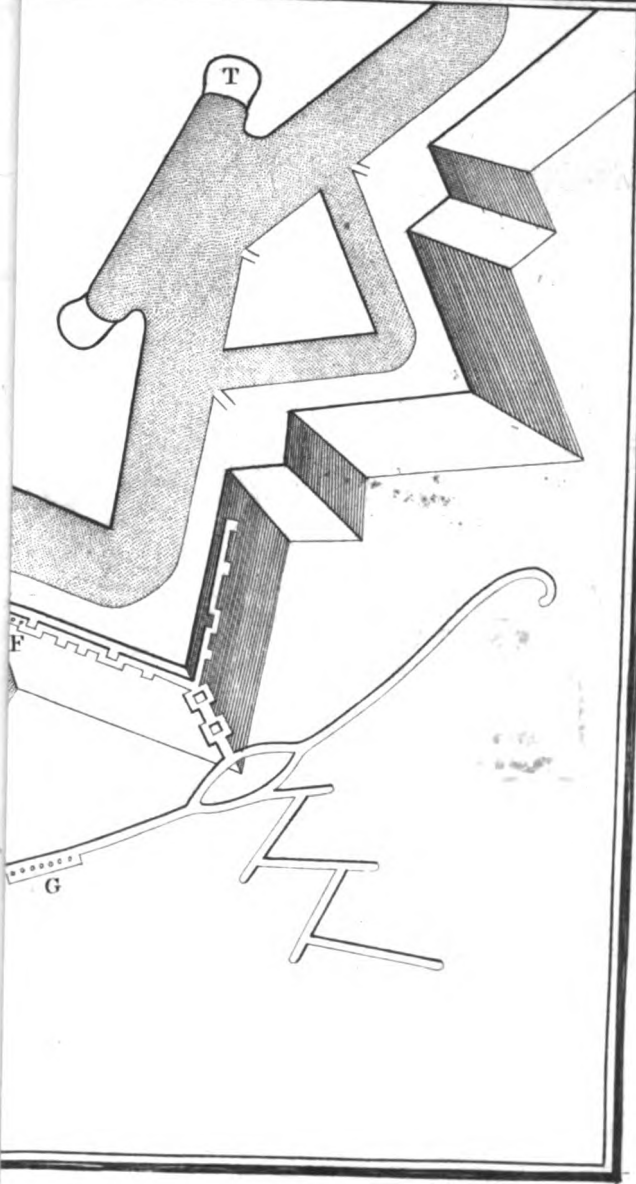
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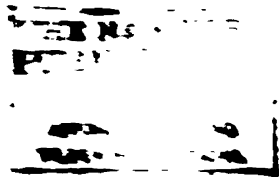
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—	xv	—	10, for adopted read adapted
—	6	Paragraph	18, for cinders read ashes
—	10	—	37, for fabric read manufacture
—	85	—	175, for '243 read '0303, and for 587 read '0606
—	91	—	183, for 472, &c. read 400, &c.
—	157	—	126, for n x read n x
—	ditto	—	ditto, for 1444300 read 1499800
—	158	—	128, for 2460 read 2490, &c.
—	302	—	122, for 40 read 30
—	336	—	178, for counter-attack read counter- approach

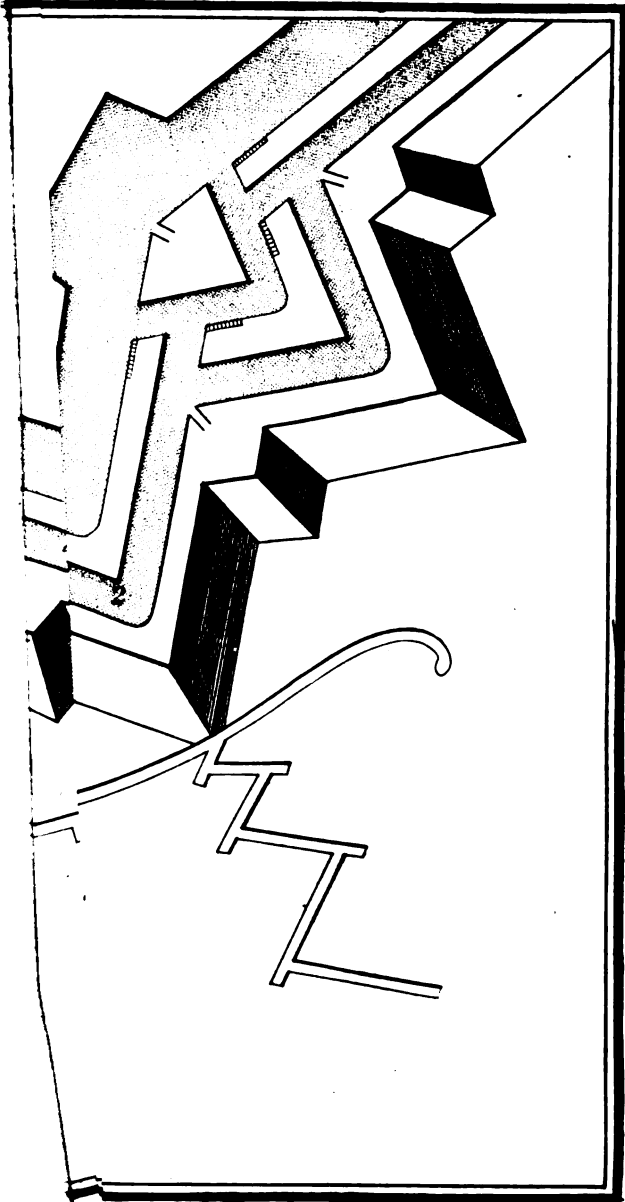




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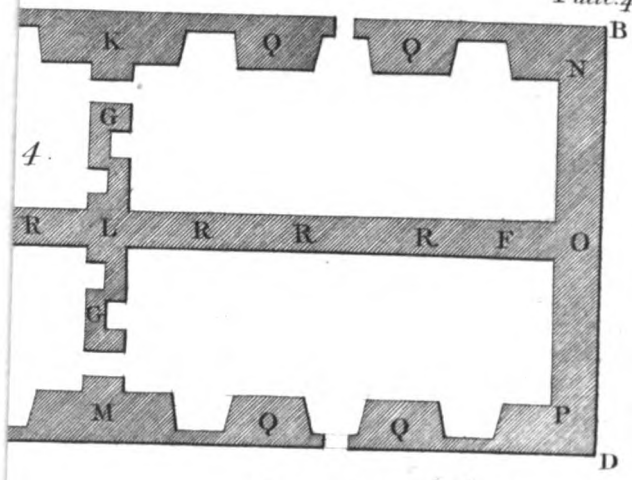
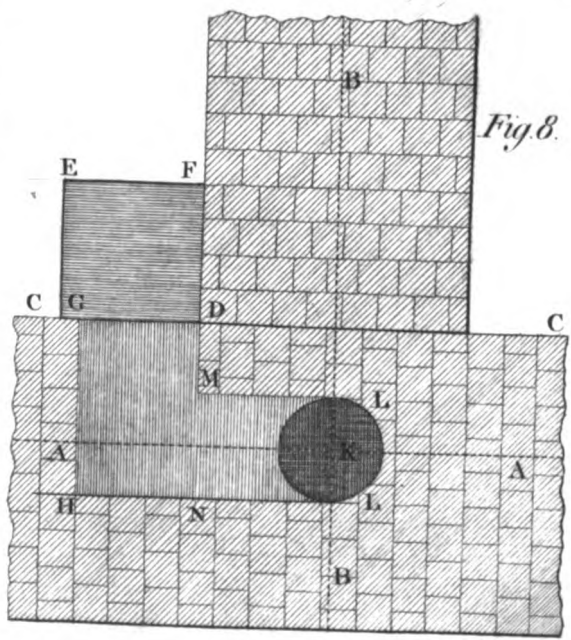
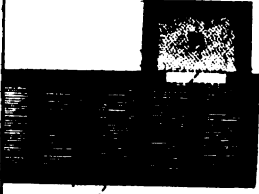


Fig. 8.



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Plate 5th



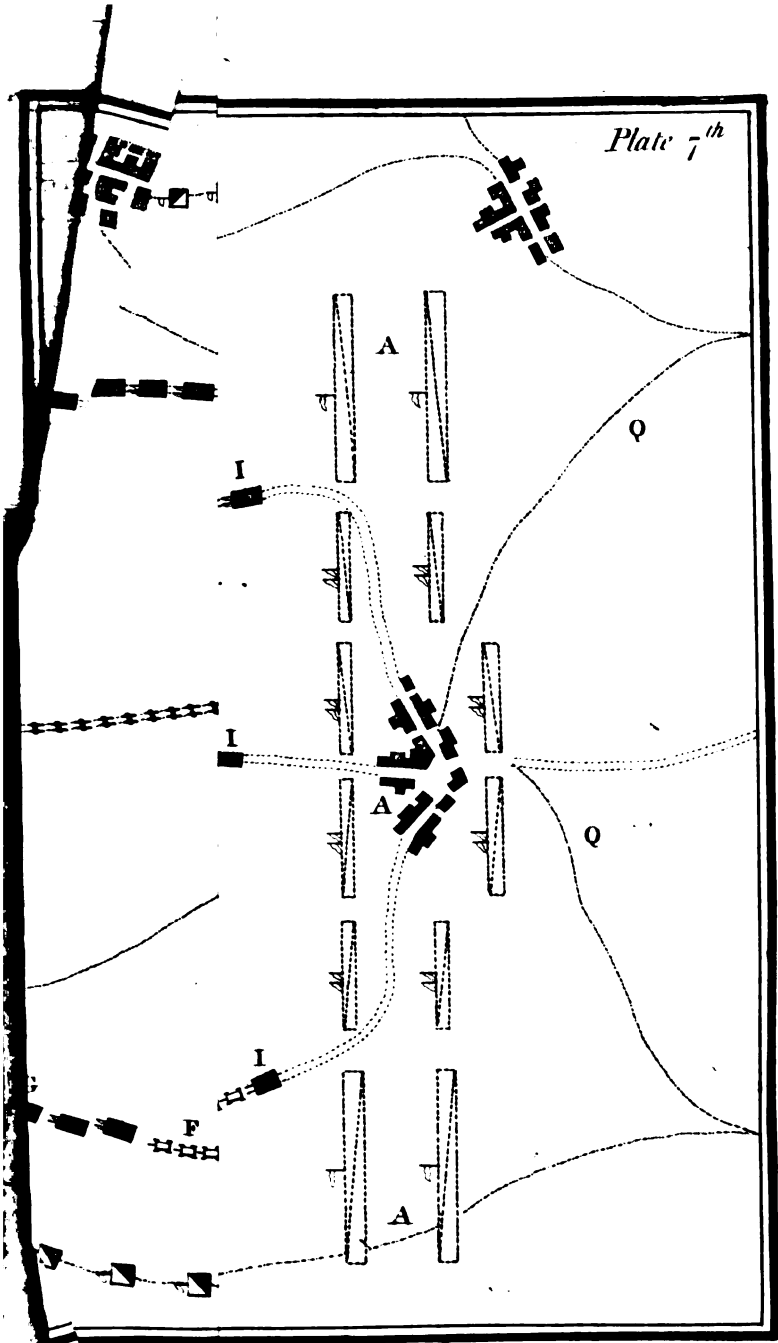
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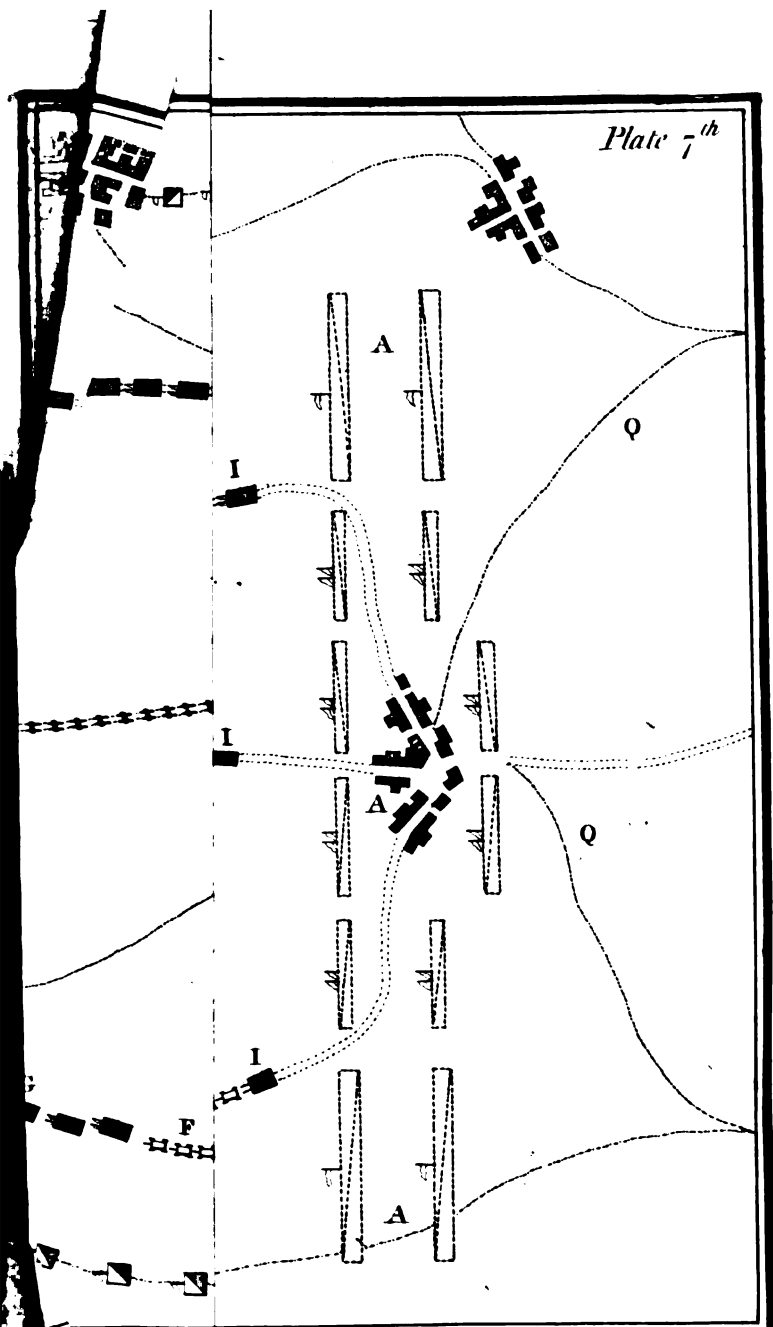
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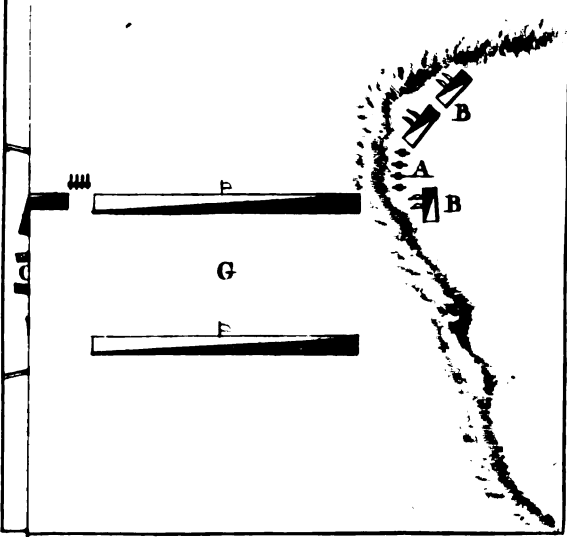
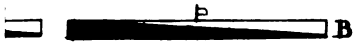
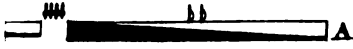
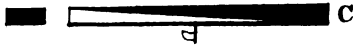


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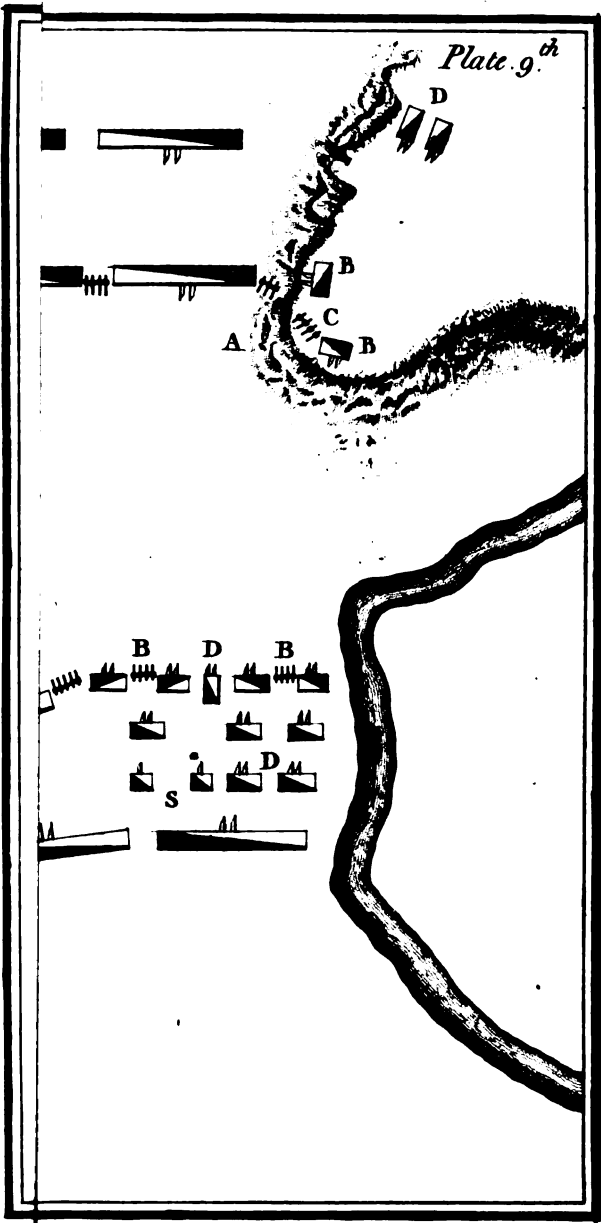
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