A

TREATISE

ON

GUN-POWDER, FIRE-ARMS,

&c. &c. &c.

Charles Cotesworth Pinckney

A

TREATISE

ON

GUN-POWDER;

A

TREATISE

ON

FIRE-ARMS;

AND 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.

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MDCCLXXXIX.

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

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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 æra 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.

THE

TRANSLATOR'S

PREFACE.

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 mere-"antur 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 ſun-ſhine 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 confest, 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, 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,

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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 gunpowder, 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 consequent, 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 developes, 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 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 difpofing the artillery in the day of action; and its ufe in the defence and attack of field-works, together with the principles of their conftruction; whether for covering a country or intrenching an army: and concludes with the duties to be performed in cantonments and winter quarters. Although thefe three treatifes did not immediately follow each other in point of time, yet as they are in a manner connected together and form the fubject of the following work, it was deemed expedient to clafs them together.

The firft book of military architecture is prefaced with a general idea of fortification and of the art of war, with a fuccinct account of the writers on thofe fubjects. The fituations proper for regular fortifications are pointed out, with rules and directions for the conftruction of the body of the place, and out-works of every denomination.

This firft book containing as it were, the elements of fortification, which is confidered under three heads, viz. the ancient, the primitive modern, and the prefent fyftem, is followed in natural order by the fecond 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 Inſti-"tutions," 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 arfenal are explained.

In the effay "On the Management of Guns, &c." are comprehended directions for ufing the feveral machines, as the gin, capftan, &c. and difpofitions for pofting the men numerically to the feveral duties.

This is a flight fketch of the contents of thefe volumes, which altogether form a complete fyftem of artillery and engineering; and perhaps, in a future day, fome individual whofe leifure permits may favour the public with a tranflation of them: well would the editor of this work deem his labours requited, fhould his example excite others of the corps to purfue the fame route; a route, not ftrewed, 'tis true, with many flowers, nor leading either to the temple of fortune or of fame, yet abounding with objects fufficient to afford matter of obfervation and reflection to a contemplative mind.

It will be a fource of fatisfaction to profeffional men to obferve, that the fame ideas and modes of practice prevail among men of genius in different countries. M. D'Antoni, for inftance, makes frequent applications to chemiftry, and recommends it in common with other branches of natural philofophy; a courfe of chemical lectures is eftablifhed at Woolwich by the mafter-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 excercise, and a system of practical knowledge.

It would be tedious to dwell on all the points wherein these two systems agree; the artillerist 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 the direction of Major Bloomfield, and the good effects refulting from it are too recent to need recapitulation.

There are fome points in which M. D'Antoni differs widely from the commonly received opinions: in his proportion of ordnance and ftores for the attack and defence of places, he omits howitzers and includes a large proportion of mortars. It is doubtlefs an object, highly worthy the attention of profeffional men to inveftigate, how far mortars can in moft cafes fupply the place of howitzers. The abfurd idea of fixing them in their beds at a certain elevation is at length, to the credit of the prefent day, in a fair way of being exploded: the adoption of Captain Lawfon's mode of elevation, which feems at once to unite ftrength and fimplicity, the two leading features in military mechanics, will go far toward the completion of this object. The field-howitzer, notwithftanding the apparent fairnefs of M. D'Antoni's comparifon, will ftill maintain its ground: it is true as he afferts, that the moral effects of howitzer-fhells cannot be calculated; yet, fuch is the conftitution of human nature, that though we cannot afcertain to mathematical precifion the force of terror, we are neverthelefs 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

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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 adoping 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 re-

marks

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 $6\frac{3}{4}$; and the 4 pr. to $5\frac{3}{8}$. 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 artilleriſt: reſerving the term light for thoſe ſhort, light guns which M. D'Antoni propoſes for ſallies, &c.

Some difficulty occurred in fixing the preciſe proportion between the Piedmonteſe and Engliſh weights and meaſures. The Piedmonteſe artilleriſts uſe the Lyprand foot: now the length of the ſecond-pendulum at Turin being $\frac{31}{16}$ of this foot, and at London $39\frac{2}{10}$ 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

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.

TABLE OF CONTENTS.

Treatise on Gun-Powder.

PART I.

PART II.

Treatise on Fire-Arms.

PART I.

PART II.

Treatise on the Service of Artillery in Time of War.

PART I.

PART II.

P A R T III.

TREATISE
ON
GUN-POWDER.

FIRST PART.

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.

CHAP. 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 agi-

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° 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° 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.

14. Where-

14. Wherefore, the force of gun-powder fired in musquets, 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.

CHAP. II.

Of Sulphur, Saltpetre, and Charcoal.

15. SULPHUR 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 chrystalizes 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 in

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° 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° 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 decompofition of faltpetre, an elaftic fluid is generated, which is permanent for a confiderable fpace of time.

CHAP. III.

Of Gun-powder.

36. GUN-POWDER is compofed of very light charcoal, fulphur, and well-refined faltpetre. Thefe materials are put into a wooden trough, where they are ground together, to render the contact of the nitrous and combuftible particles intimate and equal throughout the whole mafs. The mixture is occafionally fprinkled with water, to form an amalgam, which is afterwards granulated, and prevent the finer particles of the fulphur and charcoal from flying off, which would neceffarily alter the proportion of the compofition. The powder-makers employ more or lefs time in the operation of grinding, in proportion to the quantity of faltpetre. When they conceive that the ingredients are properly mixed together, they form from the pafte thofe little grains which, being dried, obtain the name of gunpowder.

37. There feems to be nothing in the fabric of gunpowder that can alter any of the properties of the conftituent parts, taken either individually or collectively. (35.) The neceffity of having a combuftible body capable of producing the total and inftantaneous decompofition of the nitre, makes fulphur and charcoal requifite ingredients: fulphur, becaufe it eafily takes fire, and propagates the inflammation, though the heat it produces is not fufficient to decompofe the nitre: charcoal, becaufe its inflammation, as well as the propagation of fire into all its parts, being flower, it acquires, when it becomes red-hot, a ftronger degree of heat than the fulphur, and is therefore more capable of producing the entire decompofition of the nitre. Therefore, from their combination with a proper proportion of nitre, the moft inftantaneous explofion may be expected; but if the quantity of nitre be too great, the fire communicating to the combuftible particles with fo much the more difficulty as the excefs is the greater, may produce no effects.

If to a compofition of 14 parts of faltpetre, 1 of fulphur, and 1 of charcoal, a burning coal be applied, thofe parts only

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°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, $\frac{1}{3}$ or $\frac{1}{2}$ of the grains will be found unfired upon the plate after the exploſion; and if the receiver be exhauſted, $\frac{4}{5}$ or $\frac{5}{6}$ 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 ned 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 $\frac{1}{7}$ or $\frac{1}{8}$ 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 furface; whence arife many varieties in the quicknefs of its inflammation and explofion. To remedy thefe inconveniencies, fome manufacturers put the powder into a barrel fufpended by two pivots; and having turned it for fome time, feparate, by means of a fcreen, the duft from the grains; which are, by this operation, fufficiently fmoothed and rounded. On comparing powder made in this manner with powder of an irregular form and uneven furface, the latter is found to take fire more quickly, though the proportion of ingredients be precifely the fame in both. Neverthelefs, as the interftices between the round grains are larger than between grains of an irregular figure, and as upon them the quicknefs of the inflammation greatly depends, the round grains may be fo fmall, that the interftices being equal in both, the fire may be able to fpread itfelf equally, and confume the powder with the fame rapidity; and as powder of an irregular grain takes fire more eafily than fmooth-grained powder, a proportional fize might be fixed on which would caufe the latter to inflame with greater, or at leaft equal promptitude.

54. As thefe 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 refult from the different proportion of the ingredients, the fize of the grains, their figure, and fmooth or uneven furface. If the ingredients, however good in quality, are not well mixed together, the powder will not fo readily burn, and the difference of the effects will be very fenfible.

55. The following experiment will prove, that from fired powder a permanent elaftic fluid (35. N° 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 fcrew at B C to receive D E F. G G is a key to open or fhut the communication between the parts of the funnel H H. To the fpiral F F, fix the air-gun M M, to receive the elaftic fluid generated in the cavity B P; and fcrew D E into B C. Put the powder into the cavity; and fcrew I K L, made of bronze, into A P. L *m* is the vent; *n o* a fmall moveable plate of iron, to which is faftened a fufe *o p*, and joined to the pin K, &c. *q r* is a fmooth bar of iron, made to flide in a groove by the fpring V *y*, which keeps it in the pofition *t s*, when not forcibly held back; and clofing the vent, totally prevents the paffage of the air; fo that, when

the ſeveral parts are properly adjuſted, and the bar of iron *q r* is in the poſition *t s*, the elaſtic fluid incloſed in the cavity B P, though very much condenſed, cannot eſcape. Q Q are pivots, or trunnions, to ſupport the machine.

In this experiment the machine muſt be placed vertically, that the powder contained in the ſpace B P may reſt on B X; the little funnel H *h* having been previouſly filled with hog's lard, that the powder, when fired, may not act immediately on the key G G, 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 *q r* is held back, the fuſe is charged with powder, and the vent L *m* primed. Then I K is ſcrewed into A P, 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 *q r*; which, preſſed by the ſpring V *y*, ſlides into *s t*, and cloſes the hole *m*. The fuſe burns from *o* to *p*, and ſets fire to the powder in B X: 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 B X is fired, which can only be known by the heat of the cylinder A B C Z, 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 B B, which can be ſtopped by C in any direction; then giving a half turn to the key G G, that the cavity B P 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 B P 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 G G 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 K I, the inſide B P X will be found covered with ſaline particles; which, collected and examined, form a fixed alkali

alkali that eafily attracts moifture, and falls in *deliquium* when expofed to an air abounding in vapour.

56. Since the fluid generated at the burning of powder preferves its elafticity for a long time, it follows, that at the inftant of explofion its elaftic force muft be the greateft. In proof of this, let a barometer be fixed to the pneumatic machine; and, having exhaufted the receiver, apply fire to the thimble. (FIG. I.) At the inftant of explofion, the mercurial gage defcends rapidly, then rifes; and, after fome undulations, feems to fix, for a time, below the point where it was before the explofion. This apparent fixation fhews that the elaftic fluid is reduced to the temperature of the air; and the finking of the mercury, in the beginning of the experiment, proves that the force of this fluid is much greater at the inftant of the explofion than afterwards. If, inftead of burning the powder in vacuo, it be fired in the open air, the elafticity of the fluid will be greater during the application of fire than when its effects totally ceafe.

57. From thefe premifes (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, fince it alone produces the fluid; as fulphur and charcoal, when burned, produce none. Other experiments might be made to confirm this, by burning different quantities of powder, of the fame or different qualities, under the receiver of the pneumatic machine; exhaufting the air to the fame degree in each experiment, and obferving the apparent fixed point of the mercurial gage: it would then be feen that it fenfibly falls or rifes in proportion to the faltpetre 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 faltpetre, yet they ought not to be attributed folely to that; as the fmoke and the common air contained in and between the grains of powder, are alfo rarefied by the action of the fire.

59. From all experiments hitherto made upon fmoke, it is found to be elaftic while hot; wherefore it is reafonable to conclude, that the fmoke produced at the explofion is one of the caufes that concur to give it force: but when cold, it not only ceafes to be elaftic, but even abforbs a portion of the permanent fluid. It is impoffible, at the explofion, by fepa-

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

be

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 inconteſtable.

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.

CHAP. IV.

The Properties of Powder are the same in Fire-Arms of all Calibres.

68. HAVING 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 purpofe to receive the difcharge: a certain number of grains will be found unfired; let thefe be collected and weighed. If this experiment be repeated feveral times, with the fame piece, and with the fame quantity of powder of the fame quality, and the piece be fuffered to cool after each difcharge, the number of unfired grains will be always nearly the fame. Inftead of repeating the experiments with the fame piece, let two or three, of the fame calibre, but the lengths of which are in the ratio of 1, 2, 4, be charged with the fame quantity and quality of powder, and fired as above, the fame number of unfired grains will be found in the veffel; 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. Thefe effects equally take place in mufquets or cannon: for if a thirty-two-pounder be charged with 8lb. 5oz. of powder, carefully collected together in the chamber, and lightly compreffed with a wad, and the gun be fired horizontally upon hard fnow 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 fame powder, a number of unfired grains will be found: again, with 50lb. of powder, the number of unfired grains fcattered upon the fnow will be greater. It evidently refults, from thefe 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 intenfity of the fire, and the denfity of the air contained between the grains; and that when thefe caufes vary, the quantity of powder that is burned in the fame piece varies alfo, though the charges be equal.

72. When one of the barrels is charged with the fame quantity of powder, of the fame quality, if a very high wad be rammed on it, or the refiftance to the explofion confiderably increafed by any other method, after the difcharge, fewer unfired grains will be collected. This not only correfponds with the refult of former experiments, (46.) fince the degree of fire is increafed by the refiftance, but ferves to confirm the progreffive inflammation of the grains. But it fhould be remarked, that the increafe in the quantity of powder that takes fire is not always proportional to the increafe of the refiftance; for, under fome circumftances, a flight

refiftance

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. (70.) 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, *cæteris 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 artillerists, 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 quantitity 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 quit-

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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 overcharged 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

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, independant 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.

CHAP. V.

Of the Charges that give the longest Ranges.

86. TO aſcertain the charges that give the longeſt ranges, has ever been one of the chief objects of reſearch among artilleriſts; 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.

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 $\frac{10}{17}$ 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 it's 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.	Weight of Powder.		Length of Range.		Recoil.
Pounders.	*lb. oz.*		*Yards.*		*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

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.

92. 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 leſs 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 coins, 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 coins 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 difplaced. If, on the contrary, part of the platform be raifed, the fame force that will draw out the wad will not be fufficient 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 queftion a practical folution, with refpect to charges that all take fire in the gun; let the gun and carriage be confidered as one body $= C$, the wads and fhot $= P$, the length of the bore from the fhot 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 fecond be fired with the addition of a fhot, 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 fhot is paffing 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 platform be very folid and even for $\frac{1}{2}$ an inch, at the fpot on which the wheels and trail of the carriage reft, the remainder of the platform is only ufeful in facilitating the operations of the artillery-men: indeed, as the value $\frac{BPD}{AC}$ may from circumftances vary a little, allowance fhould be made for it.

100. Let the fecond effect (90. N° 2.), viz. that *the charge which gives the longeft range in pieces of fmall calibre, is proportionally greater than the charge which gives the longeft ranges in pieces of large calibre*, be now confidered. This effect, which conftantly appeared in the foregoing experiments, could only proceed from the fize of the vent being equal in the four guns, and from the wads being rammed with the fame force. From the former circumftance, a relatively greater degree of fire is produced in the fmall guns; and from the force with which the wads are rammed, the powder is more compact, and the charge adhering clofer 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.
Pounders.	*Elevation.*	*lb.*	*oz.*	*Yards.*	*Inches.*
4	14°	2	1	2375	52
		2	8	2219	60
		2	14	2422	70
		3	5	2526	76
8	11°	3	5	2321	46
		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

102. It refults from thefe experiments, that the charges that give the longeft ranges when cannon are fired at the higheft elevation their carriages will admit of, are greater than thofe which produce the fame effect when fired horizontally (89). But the ranges do not increafe in the regular progreffion that might be expected. For inftance, in the fixteen 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. Thefe irregularities proceed from the different charges not having been fired on the fame 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 1ft of April; if they had been fired on the fame morning, the modifications in the explofion of the powder, and the air's refiftance to the fhot, refulting from the alterations in the ftate of the atmofphere, would have been avoided: in the 4th and 5th chapters of the fecond part, this matter will be more fully difcuffed.

On repeating thefe experiments with fuch precautions as to avoid the modifications arifing from changes in the ftate of the atmofphere, the charges (101) that give the longeft ranges will be found to be almoft double of thofe ufed in 1746; but the increafe of range is of little importance compared to the increafe of the recoil, and the greater fhock fuftained by the carriage; thefe large charges fhould never be ufed for common fervice.

103. In experiments of this kind, a remarkable inequality between two ranges from equal charges of powder will occafionally occur, though every precaution be taken to fire them under circumftances as nearly fimilar as poffible. Thefe inequalities were neither fo frequent nor confiderable in 1746 as in 1750; but it is impoffible totally to avoid them, for fuppofing the direction of the guns to remain unaltered at the explofion, yet there are two caufes which feparately or conjointly may render the ranges from equal charges of powder unequal.

1. The fhot in paffing 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, fo that charges though equal in quantity, have not the fame figure: large charges are more liable to this accident than fmaller 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 richochet-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 artilleriſts; 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 artilleriſts 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

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 $\frac{3}{8}$ of its weight.

The charge for eight and four pounders ſhould vary according to circumſtances, from $\frac{1}{2}$ to $\frac{1}{4}$ 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 richochet 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 $\frac{1}{5}$ 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 $\frac{8}{10}$ 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 $\frac{5}{10}$ of in 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 $\frac{5}{10}$ 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 $\frac{1}{10}$ of an inch in diameter, through which a part of the fluid might eſcape; and the third had a vent of $\frac{2}{10}$ 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:

		Inches.
In the discharges	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 -	$6\frac{1}{7}$
	with the vent $\frac{5}{10}$ 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 priming is erroneous.

SECOND PART.

OF THE FORCE OF FIRED GUN-POWDER.

112. IT 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 artilleriſts 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.

CHAP.

CHAP. 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. TO 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 *o o*, *p p*, that communicates between A A, B B. M N N M is a parallelipipedon of braſs fixed to the cube A B by the ſcrews M M, and the little pipe *q q* correſponds to *r r*. S R S is another paralellipipedon of the ſame metal, hollowed in the form of a cylinder; the opening *t t* is filled with a glaſs veſſel, containing a coloured liquor, the ſurface of which, &

may be diſtinguiſhed through the glaſs. At the upper part of the parallellipipedon 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 parallellipipedon 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 $\frac{1}{4}$ 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 9 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 9 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 *o o*. The elaſtic fluid generated at the exploſion, ſoon ſpreads from the upper cavity into the pipe *o o*, paſſes through *p p* into B L B; thence riſing through *r*, *r*, *q*, *q* it

q 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 heighth, 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 $\frac{1}{303}$ 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 F G L. 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 $\frac{1}{250}$ 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 *o o*. 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 *o o* into F G L, 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 $\frac{19 \times 16580}{10}$ expresses 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 & 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

the lower cavity in the same state. Observe the height of the water in the tube V W, 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 F G 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 density: 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

123. In the theorem $\frac{nc}{f-rm}$ (121), if the known values of c, n, f, m be fubftituted, and $r=\frac{19}{27}$; that is to fay, if the denfity of the non-elaftic fubftances be equal to the denfity of the fixed nitre, $\frac{nc}{f-rm}=942$; the denfity of the elaftic fluid is then 942 times greater when inclofed in the faltpetre, than when in equilibrio with the preffure of the atmofphere.

124. The quantity and denfity of the elaftic fluid contained in faltpetre being known, it will be eafy to find the denfity of that generated from a quantity of powder fired in a clofe veffel. Suppofe the veffel be expreffed by a mafs of faltpetre, the weight of which $=G$; the elaftic fluid will $=\frac{G}{3}$ the non-elaftic fubftances $=\frac{2G}{3}$, and their mafs $=\frac{38G}{81}$ (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 veffel G be expreffed by $h+p$, where h denotes the quantity of fluid contained in the powder, and p the fulphur, charcoal and fixed nitre; and after the explofion, the mafs of non-elaftic fubftances $=qp$, 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 denfity in the volume $G-pq$ would be to its denfity in the volume $\frac{43G}{81}$ as $\frac{nc}{f-rm} : \frac{nc}{f-rm}\times\frac{43G}{81\times\overline{G-qp}} :: 942 : 942\times\frac{43G}{81\times\overline{G-qp}}=\frac{500G}{G-qp}$. But if the volume of the fluid be only h, then the proportion will be $\frac{G}{3} : h :: \frac{500G}{G-pq} : \frac{1500h}{G-pq}$ the denfity required. For example, fuppofe the vef-

fel

G be filled with war powder: From the compofition of this powder $p=3b$, and a veffel which could contain a quantity of faltpetre = 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 fubftituting in the place of b the numbers and values of G and p, $\frac{1500b}{G-pq}=\frac{1500b}{G-\frac{7b}{3}}=\frac{1500}{\frac{152}{15}-\frac{7}{3}}=192$, that is to fay, the denfity of the fluid produced in the veffel G is equal in this cafe to 192 times the denfity of the fame fluid when its elafticity is equal to the mean preffure of the atmofphere.

125. To determine the elafticity of the fluid generated from a given quantity of powder fired in a clofe veffel, one of thofe two theorems

$$1\text{ft}, \; 9962nS; \quad 2\text{d}, \; 9962S \times \sqrt{\tfrac{3}{2}m - \tfrac{3}{2}\sqrt[3]{m \times \overline{m-n}^2}},$$

may be ufed: the firft when the denfity of the fluid is lefs than 20; the fecond when it exceeds 20: in the firft cafe, it will be fufficient to find, according to the method laid down in the preceding paragraph, the value of the denfity of the fluid, then fubftituting this value in the place of n in the firft theorem, the preffure of the fluid againft a fuperficies S will be expreffed in pounds. In the fecond theorem, inftead of m infert 942, which expreffes the denfity of the fluid when inclofed in the nitre (123); and inftead of n, the value of the denfity of the fluid generated from the nitre found as in the preceding paragraph. Then the preffure of the elafticity of the generated fluid on a fuperficies S will be expreffed in pounds.

CHAP.

CHAP. 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. If 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 phoenomenon, 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° 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

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 Q M N Q S 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 Q S Q 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 S T of the cylinder: at the ſides of the eprouvette two channelled uprights ſhould be placed ſo that when the body Q M N Q is raiſed, the teeth L L 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 E F of the cylinder be $\frac{1}{31}$ of a foot, S will be $= \frac{1}{778}$: then substituting 1800 in the place of n, $9962\ n\ S = 9962 \times 1800 \times \frac{1}{778} = 23048$lbs: the weight Q M N Q 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 A B C D, make a hollow cylinder C I K D of such a depth, (Fig. 8.) that on applying the screw G C P D H of a sufficient length to resist the greatest efforts of the powder, the height G I of the space I K G H be nearly equal to the diameter G H. In the centre of the screw drill a cylindrical canal O P, 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 V P 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 V P with teeth to slide up and down in the grooves of two uprights parallel to V P as in (Fig. 7.) Having filled the space G I K H with powder, and applied fire by the vent X, the elastic fluid acting on every point of the superficies, will raise up the pin O P, 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 tpounds, the value of S is equal to the base O in the pin O P. 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 longitudi-

nally

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 $9962nr = mq$ 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 n 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 I E F K equal in length to about $\frac{2}{7}$ 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 inflamed 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; fufpend from *o o* by the hooks 12, 12, and the chain 11, a bafon loaded with different weights till the bar breaks. The weight neceffary to overcome the cohefion of the bar S S being thus known, in the theorem $9962nS = P$ put its value expreffed in pounds, and fubftitute in the place of S the value of the pin O P, then the value of n will be found.

136. This machine may be combined in another manner. Inftead of the canal O P, and the other parts placed below C D; 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 thicknefs of metal of the cylinder, the exterior fide of which, 4, 4, is even with the fuperficies of the cylinder. 6, 7, is an iron ring which goes round the cylinder A B C D, fitting it exactly oppofite to 2, 3, and fo proportioned that the interior furface touch the plate of iron 4, 4. After each difcharge, 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 folid body, that it may confine the plate 4, 5, and 2, 3, after breaking the ring, for reafons already pointed out. The proper thicknefs for the ring having been determined, find the weight that can break another ring of the fame metal and equal to it in thicknefs; for this purpofe, apply the ring to a fhort cylinder of hard wood of proper dimenfions; 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 ufe of the fame plate, 4, 4, and the fame ring, that the part which preffes 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 elafticity = n; a particular theorem muft be conftructed, in which muft be inferted the values of the pin 2, 3, of the radius of the interior circumference of the ring, and of the thicknefs of metal at the part where the ring broke.

137. It refults from thefe experiments (133, 134, 135) that if a veffel be filled with fmall-grained powder without being compreffed, the greateft elafticity = n will be equal in dry weather to 1900 hundred times the mean preffure of the atmofphere, 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 (111).

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 troncated 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 troncated 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. WHEN 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 towardst he 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

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 $\frac{1}{4}$ 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 Inertiæ* 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 S 2 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 I 2, 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 I 2, 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 S 2 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, I 2; 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 =

E H = A E, and $KE = \frac{AE}{2}$, the preſſure of the charge A E in the ſpace A H, would be to the preſſure of K E in the ſpace H K 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 K H will be proportionally leſs than the preſſure of the larger in A H; the ſame may be obſerved of G Z, G M. If, on the contrary, A E be increaſed to E P, 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 E P will always be equal to E X; but the preſſure in P H, P G will be expreſſed by H N, G O longer than the correſponding lines H Y, G Z.

153. On firing two powders of different qualities, A E and R remaining the ſame, the ſcale of preſſures produced by the firſt kind of powder being X Y Z, that produced by the ſecond will likewiſe begin at X (151); but the remainder of the ſcale will paſs above or below X Y Z, 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 A B C O, D H P M, be the cylindric bores of two guns, the calibre D M of the one 7 the calibre D B of the other: expreſs D M 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 H N, C N will be in the ſame proportion: the perpendiculars that expreſs the preſſures N V, N X, 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

E 4 ordinates

ordinates L I, L Y will be greater than between N V, N X; for ſuppoſing the fluid in the ſpaces H P N, A C N 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 H P L than in A C L, as the fluid is more denſe in the former than in the latter: but the preſſure in H P N is already greater than in A C N, ſince they are in the proportion of N V to N X. 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 L I to L Y, will be greater than of N V to N X. 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 E X is equal to the reſiſtance R this latter may be expreſſed by (Fig. 15) E X; 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 X F Z 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 K H Y; in which the firſt preſſure E K is greater than E X, in proportion as the friction of the wads exceeds their weight; and all the ſcale K H Y will be farther diſtant from the axis E G than the ſcale X F Z: but though at the commencement of its motion K H Y diverges more from E G than X F Z, yet it ſoon converges towards it; thus its greateſt ordinate is much nearer the point E, than the greateſt ordinate of the ſcale X F Z.

It would be too tedious to enter into a detail of the ſeveral experiments that might be made in confimation 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 musquets 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.

CHAP.

CHAP. IV.

Of the Initial Velocity of Projectiles, and the Law under which they are Impelled from Fire-arms of cylindric Bores.

159. THERE 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 circumferene G K H is covered, the arch deſcribed by the firſt vibration of the pendulum. Inſtead of the arch of the circle, ROBINS 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 inertiæ 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 intertiæ 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 proportion $b : c :: d : \frac{cd}{b}$, 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 $\sqrt{\frac{64 \cdot 36 \cdot c^2 d}{2b^2}}$

$\sqrt{\frac{64 \cdot 36 \cdot c^2 d}{2 b^2}} = \frac{c}{b} \sqrt{32 . 18 d}$ (Philof. Inftit.) which multiplied by the weight of the pendulum and ball, fince this does not rebound, i. e. by $Pad + qd^2$, will give $\frac{c}{b} \times \overline{Pad + qd^2} \times \sqrt{32 . 18 d}$ for the quantity of motion. Let u be the uniform velocity with with the ball impinged on the pendulum; as from the moment it entered the pendulum, it followed the direction of its motion, uqd^2 will exprefs the quantity of the motion of the ball: thus in a ftate of equilibrium $uqd^2 = \frac{c}{b} \times \overline{Pad + qd^2} \sqrt{32 . 18 d}$, and $u = \frac{c \times \overline{Pa + qd} \sqrt{32 . 18 d}}{bqd}$ will be the velocity fought.

162. In the fecond place, let the ball ftrike a point D, not in the center of ofcillation: (Fig. 18) then if f exprefs the perpendicular diftance 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 $x \times \overline{Pad + qf^2}$, and if the ball impinged on the pendulum with the velocity u, its quantity of motion will be uqf^2. Then the equation will be $x \times \overline{Pad + qf^2} = uqf^2$, and $x = \frac{uqf^2}{Pad + qf^2}$. Now as the motion of a pendulum is as great, as if its whole mafs were united to the centre of ofcillation, and as this centre changes whenever the ball impinges on any other point; by expreffing its diftance from the axis of motion by the vis inertiæ $Pad + qf^2$ divided by $Pa + qf$, the diftance of C G from the point G taken as a new centre of ofcillation to the axis of motion will be $CG = \frac{Pad + qf^2}{Pa + qf}$. But the radii CD, CG, are proportional to the velocities of the points D, G, fince they defcribe the archs D O, G H in the fame time; then $CD : CG : f : \frac{Pad + qf^2}{Pa + qf}$ as the velocity of the point $D = x = \frac{uqf^2}{Pad + qf^2}$ is to the velocity of the point $G = \frac{uqf}{Pa + qf} = \sqrt{64 . 36 \, GI}$ where G I expreffes the verfed fine of the arch G H.

To

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

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

nd thus the uniform velocity of the point G will be exreſſed by $\sqrt{\frac{64.36 \, c^2}{2b^2} \times \frac{Pad + qf^2}{Pa + qf}}$; and on comaring the two expreſſions of theſe velocities

$$\frac{uqf}{Pa + qf} = \frac{c}{b}\sqrt{32 \, 18 \times \frac{Pad + qf^2}{Pa + qf}} \text{ and } u = c$$

$$\sqrt{32 \, 18 \times \frac{\overline{Pad + qf^2} \times \overline{Pa + qf}}{bqf}} \text{ the velocity ſought.}$$

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

164. Sig. Mattei, mathematical inſtrument-maker to ıe King, has invented a machine for finding with facility ıe initial velocity of balls meaſured near the mouth of the un.

Fig. XIX. A B is a horizontal wheel with a vertical axis C D turned by the weight Q, appending to the rope G G and raiſed by the winch N. It may be turned in any other manner, provided that its motion be perfectly uniform and rapid. A E, B F is a circular band of writing paper about 6 inches high, fixed round the circumference of the wheel. The gun for the experiment is immoveably 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 I L to the axis C D, 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 M R, 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 A B.

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 A B 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, $t = \frac{4}{5}$ 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 atmosphere.		Very dry Weather.
	Feet.		*Feet.*		*Feet.*
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. *Drachms.*		Initial velocity. *Feet.*
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. 6in. 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
		Yards.
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 $3\frac{1}{2}$ 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.
			Feet.
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 lefs weight have a ftill greater initial velocity.

170. The following experiments made under a mean ftate of the atmofphere, fhew the initial velocities of fhot impelled by different charges of fine war powder.

	Weight of Powder. Drachms.		Initial Velocities. Feet.
Mufquet, length of bore 3 ft. 6 in.	5	—	1399
	7	—	1736
	10	—	1984
Wall-piece, weight of bullet $2\frac{1}{2}$ oz.	$11\frac{1}{2}$	—	1504
	18	—	2056
	25	—	2060

A mufquet fired with the ordinary charge of 7 drachms of powder does not range fo far, as if the charge were larger; but as the barrel would foon become too hot, the fmaller charge is preferred. From the experiments made with the mufquet (167, 168, 169,) it will be eafy to deduce by analogy, the velocities of other fire-arms difcharged in very moift or very dry weather. For example, to know the initial velocity of a fhot 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 ftate of the atmofphere is 2060 feet, and that of the mufquet 1736 feet; and the initial velocity of the fame mufquet in very dry weather is 1829 feet, by making a proportion of thefe 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 eafy to afcertain the fcale of preffures which the elaftic fluid exerts upon the fhot in different points of the bore of the gun. For this purpofe, fire three or four guns differing in length but equal in calibre, charged with the fame quantities of powder: having meafured the initial velocities of the fhot, fet off from A to R (Fig. 20.) on the line A R the lengths of the guns taken from the part of the cylinder where the fhot is lodged to the mouth of the piece; and fuppofing A C to be the length of the fhorteft gun; A D that of the fecond, and A B that of the longeft; make the perpendiculars C E, D F, B G equal to the initial velocities of the refpective fhot; then a line paffing through the points A, E, F, G will be the fcale of velocities in the fpaces A C, A D

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.
Feet.	*Inches.*		*Feet.*
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 $ARS = \overline{RH^2}$, then $\frac{AS}{2} = 690312$ 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 $\frac{AS \times \overline{AR^2 - DR^2}}{2AR}$, but the initial velocity D F correſponding with this trapezium is expreſſed by the ſquare root of the ſame ſuperficies:

For example, Let A D be $\frac{1}{6}$ of a foot, D R will be 4 feet 6 inches or $\frac{27}{6}$, which ſubſtituted in the theorem, will give $DF = u = \sqrt{147926 \times \frac{784}{36} - \frac{729}{36}} = \sqrt{147926 \times \frac{55}{36}} =$ 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 C E, D F is leſs than the ſub-duplicate ratio of the ſpaces A C, A D, or of the length of the part of the bore from the ſhot to the muzzle, then the correſponding part S M N 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 S M N will be parallel to the directrix A D; 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 $u=\sqrt{\frac{96.54 n p l A}{2 r}}$ 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 × 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. $r=\cdot 243$ in.; and $u=1736$ feet; ſuppoſe $p=\frac{19}{30}$: then by ſubſtituting theſe values in the theorem, $1736=\sqrt{\frac{96\cdot 54\times 3.8\times 2.10\cdot 84\times\frac{19}{30}n}{\cdot 587}}$; whence $n=$ 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 $S=g D u^2$, where D expreſſes the diameter of the ſhot, g its ſpecific gravity, and u its velocity, then $u=\sqrt{\frac{S}{gD}}$ 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

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 confidered as the limit of the greateft velocity of the fhot.

179. In fire-arms of all calibres fired with large charges and wadded, fo that only the neceffary interftices for the propagation of fire remain between the grains, the thicknefs of metal muft be increafed gradually from the muzzle to the breech, that the gun may be enabled in every point to refift the actual preffure of the elaftic fluid: wherefore the fcale of preffures againft the fides converges toward the mouth of the gun, and the greateft ordinate of the fcale is very near the place occupied by the fhot. Then,

FIG. XV. In order to find the equation of the fcale of preffures, draw the right line K I parallel to the directrix E G, confidered as the axis to which the ordinates are perpendicular: let the preffure $KE = p$ and the abfciffa $EL = KI = x$. As the ordinate I H of the fegment K H y appertains to the abfciffa K I, I H may be expreffed by nx, and multiplying nx by the abfciffa, $= x$ and by m denoting the fraction that fquares the furface K I H the product nmx^2 will exprefs the furface K I H: now the rectangle $EKIL = px$, therefore the fuperficies $EKHL = px - nmx^2$; and call the velocity L B that anfwers to this fuperficies V, then $V = \sqrt{px - mnx^2}$.

180. Since mufquet barrels were firft made in PIEDMONT, none have been received at the Arfenal before they had been proved in the prefence of fome officers of artillery. More than a hundred thoufand 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 preffed into the barrel, and is afterwards rammed down with all the force that the armourer can exert: a leaden bullet weighing 18½ drachms is then put in and wadded as before. The barrels thus loaded, are placed horizontally with the breech againft a ftrong beam of wood, and each of them is fired twice. At every proof fome of the barrels have burft, and the crack is fometimes 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 unneceffary to make any alteration in the thickneffes of metal; fo that they may be reafonably regarded as proportionate to the preffures of the elaftic 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 F D, 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 A C B D being known, the inclination of the right line M O N which is the scale of the pressures of the fluid against the sides of the gun may be determined, the ordinates E M, H O, B N, being in the ratio of the corresponding thicknesses E F, H L, B D. If the right lines E B, F D be produced, they will meet at the point R, where the line M O N will always terminate, even when F L D and M O N are curves. Thus E R $=b$ will be known and considering $p=$ E M, the value of n will be $\frac{p}{b}$: then $\varphi\, o=\frac{px}{b}=nx$ and $m=\frac{1}{2}$ since M φ O is a triangle. Hence $nmx^2=\frac{px^2}{2b}$ 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 R E $=b$ describe the arch E G K, then the ordinates H G, B K, will express the relative velocities which the bullet would have at the points H, B, if the line M O N 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 refiftance, the ratio of the preffures will vary alfo. Thefe confequences are deducible from the preceding theory, and are confirmed by experience.

182. By the theorem $V=\sqrt{2bx-x^2}$ it may be afcertained with tolerable accuracy, how much the length of the gun affects the range. Take, for example, the gun A D P, (Fig. 21) in which the thickneffes from E to the muzzle, proportionate to the largeft charges; are determined by a right line. To find the difference between the velocities of the fhot; or in other words, the length of the ranges, by firing a fhorter gun as A H, or a longer one as A Q with the fame charge as A D P, the right lines E B, F D muft be produced till they meet in the point R, and from R taken as centre with the radius R E, defcribe an arch E G K: draw to A R the normals H G, B K, Q T, which will exprefs the ratios of the length of the ranges, correfponding to the lengths of the gun. It was obferved that this theorem would only give an approximation; in fact the line M O N being the fcale of preffures againft the fides of the gun; M Y Z which is the fcale of preffures againft the fhot, fooner falls on E R, which it cuts in the point S. Thus the true fcale of velocities is E I V X in which the difference between the velocities at the points H, B, Q is lefs than in the other fcale E G K. But whatever be the nature of the line M Y Z, it muft neceffarily when produced cut the right line R E in fome point S; for as the fluid expands in a fpace which is continually enlarging, and partly efcapes by the vent and windage, its velocity will be at length fo much diminifhed, that it will no longer impel the fhot. The point S is always the centre of a re-entering curve line E I V X, of which S E is the femi-axis, and E M the parameter; and by it may in all cafes be determined the greateft length that ought to be given to cylindric fire-arms, fince beyond this point the fhot receives no increafe of velocity. From thefe premifes may be likewife inferred, that in the fame gun the point S will be more or lefs diftant from A, in proportion to the quantity and quality of the powder, and to the windage and denfity of the fhot.

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

ined by experiment, the elasticity $=n$ of the fluid may be und by the means of the theorem $9962\,nr = mq$; and by bstituting in the theorem $V = \sqrt{\frac{96.54\,nplA}{2r}}$ the values $n, r, l, = EB$, $A =$ the height of a barometer made of the me metal as the shot, and p the ratio between the trapezium MNB and the rectangle EM×EB, the value of the itial velocity $= V$ of the shot will be likewise found.

FIG. 21. For example, suppose DAP to be a wall-piece, whose thicknesses of metal are in equilibrio with a given charge; let the diameter $DP = 2r = 2$ inches, EF 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 is wall-piece let $EB = l = 3\frac{1}{2}$ feet, and $p = \frac{2}{3}$; A will be out 3 feet; then substituting these values in the theorem $V = \sqrt{\frac{96.54\,nplA}{2r}}$ 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 $4\frac{1}{2}$ et, and the initial velocity will be

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

CHAP.

CHAP. V.

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

184. THE 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.

		Initial Velo.	Elevation.	Ranges. Experimented.	Ranges. Potential.
		Feet.		Yds.	Yds.
Rifled Carabines bullets weighing ¼ of an ounce.		1956	15°	901	19903
			24° 20″	938	29854
			45°	895	39806
Muſquet, weight of bullet 1 oz.		1736	7° 15″	948	7845
			15°	1305	15691
			24° 20″	1335	23537
			45°	1181	31383
Wall-pieces.	Balls weighing 3 oz.	1855	15°	1433	17897
			24° 20″	1753	26734
			46°	1629	35794
	Balls weighing 3 ½ oz.	1770	15°	1699	16307
	Balls weighing 3 oz. but equal in diameter to 3½ oz. balls.	2068	15°	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 carabine 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

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

188. From the preceding comparifon are deduced fome of the corollaries in the theory of the air's refiftance (Philof. Inftit.)

1. That the air's refiftance is greater in fhot of fmall than of large diameter, provided the fpecific gravity be the fame.

2. That in fhot of equal diameters the moft denfe ranges the fartheft.

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

4. That the lefs the diameter and denfity of the fhot, the more the elevation that gives the longeft range, is under 45°.

5. That the longeft range to be obtained with the largeft charge, depends on the direction of the gun, the initial velocity of the fhot, its diameter and weight, the denfity of the air, and the equality or difference between the planes of the gun and butt. Hence, (102, 103, 104,) in meafuring the ranges to afcertain the charges that will impel the fhot with the greateft velocity, the refults are liable to fuch modifications, particularly when the firft graze of the fhot is at a diftance from the gun, that it requires a feries of experiments, before any one point can be accurately determined.

189. In this comparifon between the actual and potential ranges, it was fuppofed that the charge that gives a certain initial velocity when the gun is laid horizontally, would give the fame at different degrees of elevation. To prove that this fuppofition is true with regard to fhot of fmall diameter, a mufquet (169) was directed againft a block of wood equally porous, placed at the diftance of 5 feet, it was fired horizontally with a charge that gave an initial velocity of 1736 feet: it was again loaded in the fame manner, and fired in a vertical

tical direction against the fame block placed at an equal diftance, the fhot each time penetrated to the depth of 12 inches.

190. Since the initial velocity of fhot of fmall diameter, is the fame whatever be the elevation of the gun, it follows that the increafe of the elaftic fluid produced when the piece is at the higheft elevation, is in the increafe of refiftance arifing from the elevation, in the fame ratio as thefe two forces are, when the piece is fired horizontally.

191. Let A E be a horizontal line making with the lines A F, A G, A H, A K the fame (Fig. 22) angles as the guns were fired under in the preceding experiments: fet off the lengths A B, A C, A D, A E of the correfponding ranges, and erect the perpendiculars B F, C K, D G, E H; the lines A F, A G, A H, A K, will exprefs the fpaces that the fhot paffed through by the impulfion of the elaftic fluid, and the perpendiculars B F, C K, D G, E H the fpaces paffed through by the power of gravity. Thus it will be eafy to lay down the curve that the fhot defcribed in its flight, either geometrically or by *Dulac's* inftrument.

192. A line drawn through the points A, F, G, H, K, will be a curved line of projections, and will fhew the point where the fhot will ftrike the horizontal line A E when the elevation is lefs than 45°: on the contrary, if the point of the line A E which it ought to ftrike be given, the proper degree of elevation may be found without tracing the curve defcribed by the fhot in its flight. If the guns in June, 1764 had been elevated above 45°, in order to know the correfponding length A N of the ranges, the curve A F G H K M L of projections would have been complete.

193. This method of finding the curve defcribed by projectiles, may be ufed when the initial velocity remains the fame, though the elevation be altered; but when both the velocities and elevations are different, the following method may be adopted. (Fig. 23) Chufe a piece of ground on which the guns may be placed at the different heights A, C, D; fire fome rounds from A, charging and laying the piece always in the fame manner; which in the prefent cafe will be fuppofed to be horizontally, and mark at each difcharge the firft graze of the fhot: then fire from C, D, E with exactly the fame direction, elevation, and charge, and mark the firft grazes L, B, Q. Erect the perpendiculars I H, L K, B M, Q F which will be the abfciffas of the curve defcribed

defcribed by the fhot, and the horizontal lines A H, C K, D M, E F will be correfponding ordinates; then from the value of thefe lines the nature of the curve may be deduced, or traced mechanically; and will be moft applicable to thofe elevations where the initial velocity remains nearly the fame. If the ground at the points I, L, B, Q be fuch that the fhot can penetrate in the fame direction with which it impinges, the holes being the tangents of the curves, the fub-tangents and fub-normals that correfpond with thefe points may be likewife known. Thus an equation to the curve may be found by the inverfe method of tangents.

194. The curve thus found may be refolved into the fimple movements of which it is compounded, by knowing the time that the fhot is paffing from the mouth of the piece placed fucceffively in A, C, D, E, to the points I, B, L, Q, where it touches the ground; for this purpofe, a common pendulum or watch that marks very fmall divifions of time as $\frac{1}{2}$ or $\frac{1}{3}$ of a fecond will anfwer. Place it near the men who are ftationed to obferve the firft grazes, and let them begin to reckon the inftant they perceive the flafh of the gun. Suppofe that the (Fig. 24.) time of the fhots 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 A E, the times A B $= a$, A C $= b$, A D $= d$, A E $= f$, and make the ordinates B H, C I, D K, E L, equal to the fpaces that the fhot acted on by the impelling power has paffed through in the correfponding times (193); A H I K L will then be the fcale of fpaces paffed through in thefe times, from which may be deduced the fcale of initial velocities; and again from this laft, the fcale of momentaneous refiftances of the air to the motion of the fhot.

Fig. XXV. Mark in the fame manner on the directrix M V, the times M R $= a$, M T $= b$, M S $= d$, M V $= f$ and erect the ordinates R r, T t, S s, V u, each equal to the fpaces that the fhot has paffed through by the power of gravity (193.); M r t s u will then be the fcale of velocities, and give the fcale of momentaneous refiftances oppofed by the air to the movement of gravitation.

195. If the law of the air's refiftance only be required, one of the following methods may be ufed, and will give refults more accurate than any of the former ones (186, 193, 194.): the firft confifts in finding the fcale of fpaces that the fhot

ot acted on by the impelling power has passed through in orresponding times. The second is to find by means of is movement of impulsion, the scale of retarded velocities corresponding spaces. To find the first scale, fire some Fig. 26.) rounds from the point S, in the direction S *r* ith equal charges, against a butt placed at the several dist- nces S *o*, S *l*, S *m*, S *n*. Now as two points on the rface of this butt will be always known, viz. the point here the line of direction *S r* falls, and that which the shot rikes, the spaces *o a*, *l b*, *m c*, *n d*, passed through by the ravitating principle, and the corresponding spaces *s o*, *s l*, *m*, *s n* passed through in the same time by the movement f impulsion will be known, and the curve S *a b c d* described y the projectile will be found. If the butt be placed at ch a distance that the longest line *n d* of descent does not ceed 150 feet; the resistance of the air to the movement f gravitation will be inconsiderable, and the theorem

$= \frac{32.18t^2}{2}$ will serve to determine the time $= t$, that the shot

passing through the spaces *o a*, *l b*, *m c*, *n d* in its movement f gravity; and also through the spaces S *o*, S *l*, S *m*, S *n* in s 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 pro- cted in the direction of the axis, but this does not always appen. To remedy this inconvenience; fire the gun with charge that will produce a given initial velocity, place the utt (Fig. 26.) at different distances S *o*, S *l*, S *m*, S *n*,

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.

TREA-

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 thicknesses; 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 spunge 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 embrazures, 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.

CHAP.

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*

CHAP. I.

OF THE METALS OF WHICH FIRE-ARMS ARE MADE.

10. THE 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 *cupel* 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 spungy. The

The copper met with in commerce is generally defigned of three qualities, viz. *pure*, *common*, and *impure*, as in fome mines the metal will not defray the expence of purifying it. For fome years paft the merchants have imported copper from GERMANY, SAVOY, and JAPAN, which is very well purified: that procured from AOST and SWEDEN is harder and lefs 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 fmall wire, as the ftrings of mufical inftruments; and beat into very thin veffels without breaking or fplitting: this is a certain method of proving its purity. This copper requires a very ftrong and long continued heat to melt it. If it be fufed without being in contact with any phlogiftic body, and the fire be ftronger than is neceffary to keep it in fufion, fmall particles will be feen fucceffively to calcine; and if the fame force of fire be continued, thefe calcinations will appear in the form of fcoriæ floating on the furface of the melted metal. If the fcoriæ be fcummed off, pounded and mixed with a quantity of charcoal, they will when expofed in the furnace to a ftrong blaft revivify and refume the metallic form. (Philof. Inftit. 91, 116.)

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

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

The copper of the third kind is of an inferior quality; lefs tenacious and ductile: if brittle under the hammer, or when offered to the wire-drawer, it is a proof that it contains many ferruginous or arfenical particles. If there be much arfenic, the copper fufes eafily; and if there be any antimony it accelerates the fufion: but then the flame inftead of being of a greenifh is of a whitifh caft, and is loaded with fmoke. If the flame at the folution of copper by oil of vitriol be yellow, it is a fign 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 fhort and brittle.

20. Tin

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 revivified 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 comprifed within certain limits.

3. That their natural hardnefs and tenacity be increafed by compreffion.

27. Pure copper (18) is the beft for artillery; as is the Englifh tin (21) on account of its fuperior quality. Tin in which there is any *lead* fhould be abfolutely rejected, fince this metal diminifhes both the tenacity and hardnefs. That gun-metal may have all the requifite properties (26), the quantity of tin fhould be between a 6th and an 8th part of the copper, when the powder is as ftrong as that now in ufe: it would be injudicious to diminifh the proportion, as was done when the powder was weaker. If the copper be very well purified, and confequently very foft and ductile, the quantity of tin fhould 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 fhould never be ufed. In order to increafe by compreffion the natural hardnefs and tenacity of the metals, the moulds of guns fhould be fo made, that the fuperincumbent mafs, commonly called the *head*, be as long as poffible.

28. Whenever brafs enters into the compofition of gun-metal, it fhould be in fmall quantities; fince, as has been already obferved, it tends to render it brittle, particularly when the gun is heated by frequent firing (23, 25): befides, as it muft be put into large furnaces by fmall quantities at a time, the zinc of the brafs firft introduced will be fublimed (23); which caufes an uncertainty with regard to the juft proportion of the materials. The advocates for the ufe of brafs think that it affifts and preferves the perfect mixture between the copper and tin; but this opinion is not fufficiently warranted by experience.

29. To the remarks already made on the hardnefs of fome particular metals (Inftit. Phyf. Mec. 66), let us add the refult of *experiments made on feveral compofitions* in 1759 by Major Ronzini, *director of the royal laboratory of metallurgy*. In thefe experiments, feveral rods of metal were expofed to the force of a piece of iron weighing 8$\frac{1}{3}$lb. which falling from the height of 1$\frac{2}{3}$ foot, on the head of a fteel punch with a conical point drove it into the rod of metal, upon which it refted; the effects are therefore expreffed by the fize of the holes made by the punch, which from the fimilarity 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. *Firſt Column.*		Effects expreſſed by the relative ſizes of the holes made by the punch. *Second Column.*
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.*	*1ſt. Col.*	*2d. 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 = I, then find the penetration of the same punch into the bronze proposed, and express it by Z; $\frac{I}{Z}$ will be the proportion between these penetrations. But by the experiments in the preceding paragraph $\frac{92}{40}$ is the proportion between the penetrations into the tin and the bronze D. If then $\frac{I}{Z}=\frac{92}{40}$, the proposed bronze Z will be as hard as the given bronze D; If $\frac{I}{Z} > \frac{92}{40}$ Z will be harder than D, and if $\frac{I}{Z}<\frac{92}{40}$, 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 lefs tenacious; it will be a proof that the proportion or quality of the component metals is different.

In the fecond place, the compofition of bronze may be nearly afcertained by found and colour; for if on ftriking it with a hammer, it be very fonorous, the tin abounds, and vice verfâ. When the filings of bronze appear red, it contains but little tin; when they appear fparkling and whitifh, the tin is in great quantity: a yellow colour denotes that there is a great proportion of brafs. If a piece of bronze be broken off with a hammer, and at the point of feparation hardly any particles of copper can be perceived, it is a fign that the proportion of tin is about $\frac{1}{6}$ of the copper; greater than $\frac{1}{6}$ when the fection appears of a whitifh caft; and lefs when many particles of copper are perceptible.

In the third place, fome idea may be formed of the proportion between the tin and copper, by knowing the quality of each, and afcertaining their fpecific gravities; but this method is not accurate, on account of the fpunginefs of the copper.

CHAP. II.

OF THE HARDNESS AND TENACITY OF GUN-METAL.

32. TO prove more clearly the neceffity of having a hard and tenacious metal for cafting guns, and be enabled to affign certain limits to thefe two properties, fo that the pieces may be fufficiently ftrong, without unneceffarily increafing their weight or incurring other inconveniences (8, 9), the forces that tend to deftroy the guns, and the manner in which thefe forces act, fhould be confidered.

Fired powder tends to deftroy guns in three different ways.

1. By the preffure of the elaftic fluid againft the infide of the cylinder.

2. By the effects produced by a wad, or other fimilar fubftance, when placed at a confiderable diftance from the powder, if the charge be fmall, or contiguous to it, if the charge be fuperabundantly large: for in either

either cafe, the elaftic fluid generated at the bottom of the cylinder, is fo much accelerated in its motion before it reaches the refifting body, that it acts with great force, and meeting with obftruction exerts againft the fides of the gun, a power much greater than that proceeding from the preffure alone.

3. By the irregular motion of a fhot, which ftriking againft the fides, makes cavities and furrows, and alters the figure of the cylinder; which would render the gun liable to burft, if the metal were not much thicker than neceffary to refift the preffure of the elaftic fluid.

33. To know how far tenacity combined with the thicknefs of metal can refift the force of powder (32 No. 1, pl. 1, Fig. 1.) Let the figure reprefent a fection 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 thicknefs of metal: fuppofe $m =$ the diameter BD, the theorem $9962\, nr = mq$ is the expreffion of a cylinder, which burfts longitudinally, and $m = 2r$; then fubftituting this value, and correcting the expreffion $4981\, n = q$; n fhews how often the fluid generated from powder is more elaftic than the natural air under a mean ftate of the atmofphere, and q expreffes in pounds the weight requifite to overcome the tenacity of the metal. Suppofe the elafticity of the fluid be at the higheft degree, *viz.* equal to that produced under a very dry ftate of the atmofphere, in a veffel that invariably preferves its form, whence it can only efcape by the vent, $n = 1900$ (Treatife on Powder 137): then $4981 \times 1900 = 9463900$ lbs. which is the tenacity reprefented by q in a thicknefs of metal equal to the diameter of the bore and in equilibrio with the given preffures. The tenacity of bronze compofed of common copper and $\frac{1}{8}$ of tin is 12909386; and of bronze containg $\frac{1}{7}$ of tin 11881360 (Philof. Inftit. 64); hence if either be ufed for cafting cannon in the proportions of heavy artillery, the tenacity will be greater than is requifite; particularly as in practice, the greater part of the fluid efcapes through the mouth of the gun, where it encounters no other refiftance than the friction of the wads, and weight of the fhot, fo that the elafticity never amounts under the moft favourable circumftances to $\frac{2}{3}$ of the greateft elafticity 1900. Wherefore gun-metal may be compofed of copper and $\frac{1}{6}$ of tin, without any rifk of the gun's burfting.

34. THE

34. THE OFFICERS OF ARTILLERY, in order to afcertain whether guns caft of the mixture M (29) oppofed fufficient refiftance to the greateft preffure of the elaftic fluid, made choice of a 32 pr. called the *Invincible*, in which the thicknefs of metal at the breech was equal to one diameter of the bore, and the thicknefs at the end of the firft reinforce 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 twifted hay, rammed down by fix ftrokes from two gunners; the reft of the cylinder was filled with clay very clofely preffed, and a tompion ot wood wedged into the muzzle: the gun thus loaded was placed in a ditch, prepared for the purpofe, and ftrong ftakes driven on each fide to prevent the leaft motion; a heavy beam was fixed behind the breech, and another before the muzzle, to force all the fluid to efcape by a hole made in the axis of a bouch fcrewed into the vent. The charge being fet fire to, all the fubftances 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 leaft flaw difcovered, though every inftrument and method were ufed for that purpofe: it was afterward filled with water, and fuffered to remain in that ftate for five hours, at fuch an elevation as to caufe a ftrong compreffion, yet not a fingle drop oozed through.

35. It has been already obferved that metals lofe their tenacity when heated, and compound metals more than fimple ones; wherefore *the oftener the guns are fired the lefs tenacious the metal becomes.* This heat however is never fo great as to fire the powder in loading the piece; befide the artillery men either ceafe firing or cool the gun with a wet fpunge, when they are apprehenfive of its being too hot: wherefore we will confider this heat as the higheft term in comparing different tenacities. Bronze containg $\frac{1}{7}$ of tin lofes at moft a third of its tenacity, when heated fo as to fire powder; or in other words, its tenacity is only equal to 7358758; and bronze containing $\frac{1}{8}$ of tin and heated to the fame degree lofes only a fourth of its tenacity, which is thus reduced to 9682040: then, if in the theorem $4981\,n = q$, 1200 be fubftituted in the place of n; (fince (33) in the common firing $n < \frac{2}{3} \times 1900$,) $4981 \times 1200 = 5977200$ equal to the

 preffure

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 $\frac{1}{16}$ of the copper; (Pl. 1, Fig. 2,) let the charge be equal to $\frac{2}{3}$ 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

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 16½ 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 22½°, the firſt time with 17½ lb. of *cannon powder*, the ſecond time with 22 lbs. and the third with 26½ 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 neceffity of having gun-metal fo hard as not to admit of any cavity being formed by the action of the elaftic fluid, which is more violent in proportion, as the charge occupies a greater length of the bore: wherefore, though *cannon powder* is lefs inflammable than *war powder*, (Treatife on Powder) and confequently generates lefs elaftic fluid in equal times; yet, in the guns formed of the common mixture, and fired with 26¼ lb. of cannon powder, the lefs quantity of fluid having a longer fpace to pafs through, acquired greater velocity; fo that notwithftanding the fuperior hardnefs of the metal, the cavity was of the fame depth as in the guns caft from R and charged with 16½ lb. of war powder.

40. To confirm the refult of the foregoing experiments, a 32 pr. caft from the common mixture was, in Auguft 1759, fired twice with each of the following charges of faluting powder, which was the ftrongeft then at hand; five ftrokes were given by two gunners to the wad over the powder, and three to that over the fhot: the piece was laid at the elevation of 22½°.

EXPERIMENTS IN 1759.

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

After the two firft rounds, the gun was examined, but no cavity difcovered; after the two rounds with the 13 lb. 2 oz. an orbicular cavity was formed, whofe greateft depth was $\frac{1}{12}$ of an inch, at the pofition of the wad between the powder and fhot; and after the two rounds with the 16 lb. 6 oz. the cavity was much enlarged, its greateft depth was $\frac{2}{12}$ of an inch at the place where the wad was lodged at the laft difcharge.

41. Some rounds were fired in September 1759, from an 8, 16, and 32 pr. caft of a metal fimilar to D, M, (29); in order to determine the proper degree of hardnefs for preventing the formation of orbicular cavities, even with extraordinary charges. The charge was of faluting powder, equal to ¼ of the weight of the fhot; the guns were laid at 15°, and the wads rammed as before; after the experiment,

 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 6½ 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 233rd, 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

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 8¼ lb. of powder. After the formation of the orbicular cavity, ſome rounds were fired with 6½ 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 22½°, with powder equal to ⅔ of the weight of the ſhot at the firſt round, ⅚ 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*, *Hector* 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.

CHAP.

CHAP. III.

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

49. WHEN 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 richochet 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 coins 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

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

CHAP. IV.

Of the Windage of Shot.

55. THE 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 (111) 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 $\frac{1}{3}$ lb. more than the proper weight; the diameter = D

=D of the second weighing $\frac{1}{6}$ 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.
	No. of Rounds.	*Yards.*	*Yards.*
With Shot of Diameter = C	1	*188	249
	2	198	*197$\frac{3}{4}$
	3	196$\frac{3}{4}$	224$\frac{1}{2}$
	4	198$\frac{1}{4}$	245
	5	*224$\frac{1}{3}$	248$\frac{1}{3}$
	6	197	*213$\frac{1}{2}$
With Shot of Diameter = D	1	221$\frac{2}{3}$	199$\frac{1}{3}$
	2	*193	*213
	3	226$\frac{2}{3}$	199$\frac{2}{3}$
	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.	2d. Col. excluding the irregular firings.
	Yards.	*Yards.*
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 $\frac{1}{13}$.

2. That with shot of 15 prs. it would be diminished nearly $\frac{1}{8}$.

3. That with shot of a larger diameter, viz. of $16\frac{1}{2}$ prs. the loss of velocity would be about $\frac{1}{5}$.

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 richochet 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 cylindric 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 C A D was made at the bottom C D of the bore F C D G 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 cylindric as F K L G, 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 cylindric chamber ranged 414 yards farther than that with the parabolic chamber.

CHAP.

CHAP. V.

OF THE FIGURE AND LENGTH OF THE BORES OF GUNS.

64. OUR 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.		
Pr.	*cwt.*	*qrs.*	*lbs.*	*cwt.*	*qrs.*	*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

confiderably ftronger than that ufed formerly: the charges then being neceffarily larger, occupied a greater fpace in the length of the bore Cannon not to be injured by long firing, and to project their fhot with juftnefs (9), fhould be fhorter than the guns anciently were: but excefs on this fide is to be equally guarded againft, as on the other; for fhort guns of large calibre foon damage the embrazures; the initial velocity of the fhot, the length of range, and effects on the object are diminifhed; and there is more probability of error in pointing fhort guns than long ones.

66. After the various opinions that have at different times been fuggefted on the proper length of guns, intended to fire through embrazures, all nations feem 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 fhorter, *fhort guns*. (Pl. 1, Fig. 2.) Set off on the line B F of a gun of any calibre three diameters of the bore, for the charging cylinder; divide the remainder C F into four equal parts at H, G, K, and make F L = F K: B L may be then confidered as the greateft length that guns fhould be ever made of, to avoid the inconveniences pointed out in the preceding paragraph: and if from B F, K F be taken, the remainder B K is the leaft length for guns with cylindric bores.

67. When 32, 16, 8 and 4 prs. (66) are loaded with the ufual fervice charges of powder and rammed with equal force, the initial velocities will in fhort ranges increafe in proportion as the calibres diminifh; but in long ranges, the fhot from the refiftance of the air will be projected farther from guns of large than of fmall calibre, in proportion to the diftance; as appears by the following experiments. The guns were loaded as above directed, and the fhot feverally fell on three fpots below the plane of the battery.

NUMBER

NUMBER OF YARDS BELOW THE PLANE OF THE BATTERY.

Nature of Guns.	1st. 1 Yard.	2d. 30 Yards. Length of Ranges.	3d. 190 Yards.
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 embrazures, 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 embrazures 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 promifed ; and that, independent of a heavy and ufelefs expence, they caufe much embarrafment in the difpofition and movements of an army.

73. Guns caft of iron of a very tenacious quality may be ufed in places of fmall importance, field works and thofe parts of permanent fortifications that cannot from their fituation be obliged to maintain a very long cannonade: they are generally two diameters fhorter than brafs guns of the fame calibre, it having been found by experience that when very long the muzzle is foon injured; wherefore *there are no long guns of iron.* Iron guns for fhips of war are made nearly of the length of fhort brafs guns (66), for the facility of loading them within the port-holes to fhelter the feamen from the enemy's mufquetry; for though their initial velocity be lefs, that is looked upon as a matter of no great moment, fince fhips can approach near enough to each other to make the fhot penetrate the fides.

74. In determining the length of the barrels of mufquets, it was not confidered which would impel the bullet with the greateft initial velocity, but which was beft adapted to the different methods of fighting: for mufquets that are too long or too fhort are equally inconvenient, and the foldier fhould *ever be affured of the goodnefs and effect of his fire-arm* (7). Dragoons being deftined to act occafionally, either as infantry or cavalry, are armed nearly in the fame manner as infantry; while that the carabine and piftol of the horfe being of no fervice on a charge, but only on detachments or fkirmifhes, the facility and eafe of managing them on horfeback are chiefly attended to.

75. Mortars in the firft year that fucceeded to their invention, were conftructed of different calibres, figures, and dimenfions, according to the various fervices for which they were defigned: the bore of the largeft was 20 inches in diameter, that of the fmalleft 5½ inches; the latter were called royal mortars. The largeft mortars at prefent do not exceed 15 inches; thofe of 13 inches are moft commonly ufed.

76. From the interior figure of mortars, the elaftic fluid generated in the chamber is dilated on paffing into the chafe; its preffure againft the fhell is ftill fufficient to give it a proper velocity, unlefs the charge be too fmall; as is feen in carronades and howitzers, which in refpect to their interior figure may be compared to mortars with cylindric chambers. 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 strikingagainst 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 tompion of wood over the earth

that

that is rammed upon the powder, and by pressing earth close round the tompion 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 troncated 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. THERE 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

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

84. This being premifed; let a gun (Pl. 1, Fig. 4) A B C D be caft of the fame metal, calibre, and length as thofe of which the thickneffes are fought, and its dimenfions determined by a right line C D drawn obliquely to A B, fo that the thicknefs A C of the breech may refift the preffure of the fluid; the thicknefs B D at the muzzle will be much lefs. Suppofe this gun (83) burft at the firft round in any point between A and B, as at G; fhould it burft in feveral places at once, moft attention fhould be paid to the opening next the breech. Let F G where the metal yields to the preffure of the fluid be thickened in the proportion of the tenacity of the bronze, heated by firing as much as it can be on fervice (35) to its tenacity when cold, and call it $= m$; then m expreffes the proper thicknefs of metal at the point G of the length A B. It is effential to remark, that the fracture in G was occafioned folely by the preffure of the fluid, and not by the percuffion of the fhot againft the fides of the gun, nor by any defect in the metal; as may be known by examination.

85. Let H E reprefent the bore of a gun, whofe thickneffes of metal are fought; (Pl. 2, Fig. 5) draw the fcale L O Q R (83) of the preffures 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 greateft ordinate of the fcale L O Q R, from the point T draw T Y parallel to P E for the thicknefs of metal from P to E; in order to find them from P to H make the following proportions; PO : NQ :: PT : NV, and PO : HR :: PT : HX, draw a line through the points T V X; then Y T V X will be the fcale of thickneffes fought. But if K L be the greateft 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 thickneffes from K to E; then Z S T V X will be the fcale of thickneffes in the whole length E H of the gun.

86. To apply this theory to a particular cafe; (Pl. 2, Fig. 5) let a 32 pr. be charged with 13 lb. 2 oz. of fine war powder, and the wads rammed fo as not to diminifh the volume of the powder. Let the proportion of tin in the gun-metal be $\frac{1}{6}$ and the gun be fo heated as to fire powder; its greateft thicknefs in a ftate of equilibrium will be K S. If the gun be fired under the moft favourable circumftances to the inflammation of the powder, that is, $n = 1200$ (33) the greateft thicknefs K S ought to be $\frac{14}{16}$ of the diameter

diameter of the bore, and the leaſt thickneſs H X between $\frac{1}{3}$ and $\frac{2}{3}$ of K S. If the proportion of tin be $\frac{1}{8}$ the greateſt thickneſs K S ſhould be $\frac{25}{32}$ of the diameter of the bore and H X $\frac{1}{3}$ or $\frac{2}{3}$ of $\frac{25}{32}$.

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 T L M of the velocities in the ſpaces T P, T C. 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 P L, and by the right ſine of the angle of incidence K V A. 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 K V A 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 P L. 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 = B N, then C M : P L :: B N : V Q; the line H Q N will be the ſcale of thickneſſes ſought, and will cut in the point R the ſcale S F R G D of the reſiſtance to the preſſures of the fluid (88, 89): therefore the line S F R Q N 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 unweildy. But as theſe direct ſhocks can only ariſe from ſome very uncommon cauſe, and the accelerated preſſures of

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 $\frac{15}{16}$; at the beginning of the ſecond reinforce $\frac{14}{16}$; at the end of the ſecond reinforce $\frac{13}{16}$; at the beginning of the chaſe $\frac{12}{16}$; and at the muzzle $\frac{8}{16}$. 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 breech to the firſt reinforce; but, at the beginning of the chaſe was only $\frac{11}{16}$ 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, $\frac{1}{4}$ 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 $= \frac{14}{16}$ of the diameter of the bore, and B F $= \frac{8}{16}$; 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 H at the muz-

zle

zle be not lefs than $\frac{12}{16}$, and be for greater fecurity connected with the muzzle aftragal, by the convex line H L K. Gun-metal not being fufficiently hard to prevent the fhot from making impreffion when they ftrike with great force againft any part of the chafe, it would be better, as a means of obviating this inconvenience in fome meafure, if the moulds were placed in a different pofition from what they are at prefent, with the breech up and the muzzle down, as in cafting mortars: by this method the metal at the chafe would be denfer than at the breech, and of courfe more hard and tenacious. This with proper precautions, may be done whether the guns be caft folid or with a core.

93. Guns conftructed on thefe principles (92) tho' fufficiently ftrong are defective in two points: they are too light, and confequently their motion being irregular, it is impoffible to fire with juftnefs; and there is a neceffity for placing the trunnions too near the muzzle, that the motion of the breech may not be fo violent as to render abortive every attempt to hit the object: from the latter circumftance alfo, they cannot enter far enough into the embrazures; which are very foon deftroyed by the explofion of the powder. The beft remedy for thefe defects is to reinforce the gun particularly at the breech, according to the proportions laid down in the firft book of artillery: it will then be fufficiently heavy to prevent any irregularity even with the largeft charges; the trunnions may be placed nearer the breech, and the muzzle will enter farther into the embrazures.

94. The dimenfions (7, 8, 9,) for the body of the piece being thus determined; the proper pofition of the trunnions, cafcable, bafe-ring and dolphins muft be afcertained. The trunnions fhould 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 raife it with their handfpikes, for the purpofe of laying it, and that it may enter far enough into the embrazure; their diameter is equal to one calibre. The pofition of the dolphins fhould be fuch, that when the gun is fufpended by them, the breech may preponderate a little, that by taking hold of the cafcable it may be the more eafily managed. It is cuftomary to engrave on the upper part of the gun, the arms of the king and the mafter general of the ordnance, with infcriptions, trophies, &c. which obliges the founders to raife the bafe-ring, and the fwell 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.

96. From

96. 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 $\frac{14}{16}$ 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 cylindric chamber made at the bottom of the bore, will lessen the charge of powder and of course preserve the embrazures.

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 cylindric 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 embrazures: 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 artilleriſts 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 artilleriſts 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 $nr^2 = \overline{2rm + m^2} \times q$ 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 tompion 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 [illegible], 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 chamb•r 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 enſueif the thickneſſes have been properly proportioned. Mortars caſt on theſe proportions, of metal containing $\frac{1}{5}$ 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 $\frac{1}{6}$ 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 purpofe expected from the ufe of them; viz. the burfting of the fhell in the mortar, or immediately on quitting it. This may proceed from a defect in the fufe, the negligence of the bombardiers in loading the mortar, or not priming it before the fufe is fet fire to, or from a hole in the fhell through which the fire from the explofion communicates with the powder. When from either of thefe caufes it burfts in the mortar, it generally renders it unfit for further fervice. Increafing the thicknefs of metal in mortars, whatever be the motive, will be always advantageous; provided they are not too unweildy: fince in all fire-arms folidity adds to the juftnefs of execution.

102. The trunnions if equal in diameter to the femi-diameter of the mortar will be fufficiently ftrong: they fhould be let into the bed throughout the whole length, or at leaft the points of fupport fhould be near the breech of the mortar; for when they are fupported 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 ufes for which they are defigned; thofe from 15 to 20 inches, are for throwing ftones to retard the progrefs of the befiegers, and are never fired to a greater diftance than 350 yards, as in longer ranges, the ftones are too much fcattered to do execution; their chambers therefore are in form of a troncated cone, with the greateft bafe towards the muzzle and contain but little powder. This mortar having no great effort to fuftain, may be lefs reinforced: the thicknefles allotted for ftone mortars will anfwer for every purpofe in which it is ufed, as in throwing fire balls, carcaffes, &c.

104. Thirteen inch mortars, with chambers fpherical, elliptical, or in form of a pear, are defigned for throwing fhells to deftroy magazines and other military edifices. If it be wifhed by increafing the range to add to the effects of the fhell by the height of the fall, the fpherical chamber is the beft; but then it is neceffary to increafe the thickneffes of metal, to infure proper refiftance and folidity. In the laft century, 20 inch mortars were made with curvilinear chambers to fire from very great diftances, that the fhells might fall with irrefiftible force on magazines and other buildings; but their exceffive weight has caufed them to be difufed in land fervice: 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 $4\frac{2}{5}$ 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.

CHAP VII.

Of Casting Artillery.

106. THERE 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

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 scoriæ are scummed off with a ladle: if brass 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 scoriæ 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 brass be used, the proper quantity of tin is put into the furnace after the scoriæ 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

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, $\frac{1}{4}$ in its greateſt and $\frac{1}{7}$ 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 in-

interſtices of the copper, already in part congealed, deſcends towards the bottom, and lodges in any cavities 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 ſpungy 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 procefs, the feveral pieces, when cold, will be homogeneous.

115. If an exceffive heat, whether produced by fire or a combination of folvents, be attended with bad effects; a deficiency in that refpect is not lefs pernicious: for independent of the imperfect mixture, the metal does not fet properly in the moulds; whence proceed the cavities and flaws frequently obfervable on the outfides of guns after proof: thefe can neither be attributed to the intrinfic quality of the bronze, nor the want of proportionable thicknefs, but to the defect of heat and mixture; fince the external flaws do not extend and communicate with the bore: from the fame caufe proceed the afperities vifible on the ornaments and bas-reliefs.

The deficiency, in point of heat, does not always arife from too fmall a quantity of wood being ufed to heat the furnace, fince with the fame quantity it takes fometimes 36 or even 48 hours, to effect what at other times 16 or 18 are fufficient to do. This can only be accounted for from a want of elafticity in the atmofphere, which prevents the wood from burning with proper activity; or from the neglect of the workmen in removing the cinders, which partly ftops the reverberation of the flame; thus the fire not being fo intenfe, it is longer before the metal acquires the proper degree of fufion.

116. There are fome accidents which baffle the utmoft caution, as they proceed from variations in the ftate of the atmofphere. If the melted matter while running into the mould be expofed to a cold wind, it may be fuddenly congealed, which will prevent a due tenacity in the particles when folid. After the mould has been heated, if the atmofphere become fuddenly loaded with vapour, the mould will imbibe humidity; and the melted metal will extract the moifture, which rufhing out and bubbling vehemently, will difturb its fetting. On the contrary, when the mould is perfectly dry, repeated experience proves that the metal on running into a hot recipient, fets better, and becomes more tenacious and denfe, but lefs hard than when the recipient is cold.

117. Since cavities proceed from the fpunginefs of the copper, or from the coldnefs and moifture of the atmofphere or mould; they are found in all parts of the gun indifcri-

 minately,

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.

CHAP.

CHAP. VIII.

OF THE VENTS OF GUNS.

119. THE position of the vent contributes also to modify the inflammation and explosion of the charge. (Pl. 3, Fig 8) If in the gun A B M the vent Q P correspond to half A N 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 A C corresponding to the bottom of the bore, which will obviate the ill consequnces 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 A B C D (Pl. 3, Fig. 9) of which the diameter A C was $1\frac{4}{10}$ inch and the length A B 2 inches, the communication F to the vent F G was distant from A $1\frac{4}{10}$: the part F N of the vent made in the gun itself was in length $3\frac{7}{10}$, the remainder G N was filled with an iron screw H L M K $2\frac{2}{10}$ in length, which had been well worked and tempered. After 500 rounds the metal was much corroded at F, and round the orifice A C of the chamber; and the upper part P A B F was considerably damaged towards N. This increased very much in the next 300 rounds; the clefts extending towards N were $1\frac{1}{4}$ inch in length; the pricked line Q Q Q shews the alteration that took place in the figure of the chamber. The part N G 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 $\frac{1}{8}$ 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 troncated 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 N B D Q; 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 B D be called = C and its length D Q = m, cm will be the section of the fracture; this section

fection multiplied into q = the tenacity of the metal will give cmq for the refiftance of the female fcrew. The formula 9962 ns, expreffes the preffure of the elaftic fluid againft a fuperficies = S. Then if half the diameter B D = r, and its circumference = C, $S = \frac{rc}{2}$ will be the fuperficies of the circle, againft which the elaftic fluid acts in the direction F G; then $9962 \, n \times \frac{rc}{2}$, will exprefs the force with which the powder acts againft the bafe of the bouch. For example, if under circumftances the leaft favourable to the refiftance of the bouch, $r = \frac{m}{4}$, $n = 1200$ (33) and the metal of a lefs tenacious quality be heated as much as it can be on fervice, $mq = 7358758$ (35) the refiftance of the bouch. Now fuppofing $m = 1$; then $4981\,nr = 4981 \times 1{,}200 \times \frac{1}{4} = 1444300$ for the action of the powder againft the bafe of the bouch: thus the refiftance of the female fcrew will be more than five times the force that tends to drive the bouch from its place; an equilibrium between the propelling and refifting powers will be then fully eftablifhed, if only part of the bouch $QR = \frac{1}{5}$ of D Q be fpirated.

127. When the bafe of the bouch correfponds with the upper part of the bore, the action of the powder againft it is as the preffure: but when the bouch only reaches to L R, and leaves the vacuum D L R B, then the elaftic fluid acts againft it with fo much the greater force, as L R is diftant from the upper part of the bore; and greatly exceeds the preffure that it would exert againft the bafe, were the bouch in the former fituation. The reflections in the 2nd chapter on the orbicular cavities formed in the bores of guns caft of foft metal, by the impulfion of the elaftic fluid, will convey a juft idea of this force.

128. To fhorten the operation of making the fcrews, and at the fame time to obtain a refiftance fuperior to the force of the powder, the bouch may be made in the following or any fimilar manner. (Pl. 4, Fig. 13) Let it be fpirated 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 troncated cone H K N H, the diameter H H being lefs 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.

CHAP.

CHAP. IX.

OF THE EXAMINATION AND PROOF OF NEW GUNS.

130. IT was obferved in the 7th chapter, that fuccefs in cafting guns does not entirely depend on the fkill and ability of the founders, fince it is greatly fubject to cafualties. The King's fervice requiring that, befide the precautions taken at the time of cafting, the greateft attention be afterwards paid to detect any negligence or error; every gun before it is ufed fhould be fcrupuloufly examined and fubjected to various proofs, in order to be certain that the founder has adhered to the inftructions he received.—The object of thefe examinations and proofs is to afcertain:

1. Whether the guns are conftructed on the proportions given to the founder.

2. Whether before the metal was run into the moulds, the neceffary precautions had been taken to avoid all feparations between the metallic particles capable of producing an unequal refiftance.

3. Whether the tenacity of the metal is proportional to the thickneffes of the piece; and its hardnefs fufficient to prevent orbicular cavities from being formed on firing very large charges.

131. To know whether a gun be properly conftructed, two inftruments are ufed: the firft ferves to fhew whether the piece has been truly bored, and the thickneffes of metal properly diftributed; by means of the fecond, the exact figure of the bore is traced upon the firft, whereby the leaft flaw or deviation from the cylindrical figure is difcovered and afcertained. A mirror is afterwards ufed to difcover by the reflection of the folar rays, what cavities, inequalities or other defects there may be; and with the little iron inftrument called the *fearcher*, their depths and diameters are meafured.

132. To know whether there be in any part fuch a feparation of the metallic particles, as to penetrate from the exterior furface to the interior cylinder, the gun is filled with water and placed with the breech downwards to increafe its force

force and make it more eafily pafs between any interftices of the metal; it is further preffed with a high fpunge; and in this fituation the gun is left for three or four hours. This proof fhould never be made when the water can freeze.

133. If during thefe examinations (131, 132) any defects fufficient to make the fhot ftrike againft the fides of the gun, or any holes in the charging cylinder or bore be difcovered; 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 unferviceable or dangerous, or that can tend to prevent the fhot from being thrown in a true direction, and no fafe remedy can be applied; the gun fhould be without hefitation rejected.

134. When no fuch defects are difcovered, the other proofs for afcertaining with the greater certainty the nature of the cafting and the qualities of the metal may be proceeded to. To this end, a few rounds fhould be fired in fuch a manner, that any defects may be difcovered 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 neceffary to advert to the circumftances 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; thefe modifications have been enlarged on in the Treatife on Powder, and may fummarily be reduced to the following:

1. The preffure of the elaftic fluid in the charging cylinder does not depend on the quantity of powder, provided that it be equally well collected; but on the refiftance oppofed to its explofion towards the mouth of the piece: and the other ordinates of the fcale of preffures increafe 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 refiftance of fhot and wads is oppofed, the preffures, excepting the firft by which the fhot is put in motion, are greater in proportion as the powder is ftronger: the difference between the correfponding ordinates proceeds from the greater quantity of fluid produced in equal times, in two powders of different qualities; whence it refults, 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.

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.

SECOND PART.

OF PROJECTILES.

141. THERE 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 *baliſta* and *catapulta*, for throwing large ſtones and arrows to great diſtances; and of *ſlings* and *bows* for throwing them to ſhorter diſtances.

The

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; it's 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.

CHAP. I.

OF THE INITIAL VELOCITY OF PROJECTILES.

143. THE 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 $\frac{3}{4}$; and the leaſt to $\frac{1}{2}$ 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 fufils and pieces of very fmall calibre; but not to guns of large calibre, fired with the common charges of powder: becaufe in the latter, the initial velocities are compounded of the impulfion and preffure, as has been explained in the firft part.

146. The initial velocities are found very nearly by the firft method (145, No. 1.) if the butt be perfectly homogeneous and confiftent. To determine its confiftence, fire a piece of fmall calibre, with an iron fhot 1 inch in diameter $= D$: and meafure the initial velocity $= u = 1200$ feet, (Treatife on Powder 164, 165). Then the piece being loaded and fired as before, the penetration of this fhot into the butt will be 15 inches $= S$; and fubftituting thefe data in the formula $fS = DU^2$; we fhall have $f \times \frac{5}{4} = \frac{1}{12} \times 1200^2$; then $f = 96000$ for the confiftence of the butt: let it be written in the formula, which then becomes $96000\ S = D\ U^2$. Place the gun, the velocity of whofe fhot is fought, very near the butt, and fire fome rounds in a horizontal direction, in order to obtain the mean $= S$ of the penetrations of the fhot; fuppofe it $= 8$ feet, and the diameter D of the fhot $= 4$ inches; then by fubftituting thefe 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 fought. In thefe experiments, the penetrations fhould be at fuch a diftance from each other, that the loofening of the earth by the firft fhot, may not facilitate the entrance of the others; the leaft difference will be then perceptible, fince the penetrations of the fame fhot are as the fquares of the initial velocities.

147. To determine the initial velocities, by analyfing the curve (145, No. 2); let us take the firft part of the curve, where the effect of gravity has not been fenfibly altered by the refiftance of the air. It is a matter of indifference, whether the fpace that the fhot pafs through by the gravitating or impelling power, be firft confidered; fince the latter may be deduced with equal facility from the former, as the former from the latter. Let us in the firft place examine the fpace paffed 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 folid platform, and laid in a horizontal direction A C; fo that the fhot at the firft 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 $S = \frac{32.18\, t^2}{2}$, it will give with great precision the time $t = \sqrt{\frac{2\,KG}{32.18}}$, 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 $t = \sqrt{\frac{2 \times 4}{32.18}} = \frac{1}{2}$ second; and suppose A K = 700 feet, then $\frac{q}{t} = \frac{q}{\sqrt{\frac{2\,KG}{32.18}}} = \frac{700}{\frac{1}{2}} = 1400$ feet, the initial velocity sought. The initial velocity 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

horizontal line. Fire some shot into the butt as nearly as possible in the same direction, so that after each round the vertical distance M H 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 M H = S (144, No. 3) and substitute it in the formula $t = \sqrt{\frac{2 MH}{32.18}}$; then by measuring the distance D L = A M = 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, $\frac{q}{\sqrt{\frac{2 MH}{32.18}}}$ will be the initial velocity sought (147). For example, let A M = 200 feet, M H = 6 inches, then $t = \sqrt{\frac{2 \times \frac{1}{2}}{32.18}} = \frac{1}{6}$ of a second, and $\frac{q}{\sqrt{\frac{2 MH}{32.18}}} = \frac{200}{\frac{1}{6}} = 1200$ 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 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.
	Prs.		*Feet.*
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.
Prs.		*Feet.*
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 $7\frac{1}{3}$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 1269 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 1lb. 10 oz. of powder, will be impelled with an initial velocity of 1061 feet; and a shot from a 16 pr. with $2\frac{1}{4}$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 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.

o. 2); a normal line L Q drawn perpendicularly from the ɔint L in the line A C, will correspond to the relative iniɩl velocity. To have the absolute initial velocity, make the llowing proportions: the relative velocity F P of a gun of ɩe length B F is to its absolute velocity, as the relative :locity L Q of the gun B L is to its absolute velocity; by .e same method the initial velocity of a shot impelled from gun of any length as B G may be found. The scale K R would serve for longer guns, but it should not be ed (65).

152. Experiments made with a view to determine how uch the initial velocities of shot are affected by the differɩce in the lengths of the guns, fired with different charges powder, will be found to vary very little, from those comued on the preceding principles.

153. From the theory of the inflammation of the pow:r in guns of cylindric bores, when all the grains are fired 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 en supposed to be fired horizontally, or nearly so: but the locities increase as the guns are elevated, which proves at the entire inflammation of the powder is accelerated by e greater resistance opposed to the explosion (Treatise on ɔwder). If a 32 pr. be fired with the medium charge 5c, No. 2) at 20° elevation, the initial velocity will ceed 1350 feet, and increase very much, if fired at 36°.

In the following chapter will be shewn the method of termining the initial velocities of shot fired from guns at ʒh elevations.

CHAP.

CHAP. II.

Of the Curve described by Cannon Shot.

155. THE 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 ſpot 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 $d g$ (Pl. 5, Fig. 17): turn the gun to the place 16 feet below its plane; fire ſome rounds, and call the mean $r p$; let $n b$ be the mean to the place 36 feet, and K y to the place 64 feet below the gun. On the directrix a K ſet off the times $t = \sqrt{\frac{2 S}{32 \cdot 18}} = a\,d$, $a\,r$, $a\,n$, a K, 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 a K, reſpectively equal to the means of the ranges already found; the line $a g p b y$ 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) H L A, at the bottom of which is a horizontal plain M Z, chuſe the ſtations A, L, H, of different heights; and from them fire the gun in the horizontal directions A K, L F, H X: then the perpendicular lines G K, P F, Z X 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 = D G, from the point L = R P, from the point H = N Z; mark upon the directrix a K (Pl. 5, Fig. 17.) the times correſponding to the vertical lines G K, P F, Z X; erect from the points d, r, n, the normal lines $d g$, $r p$, $n b$ equal to the means of ranges already found,

and

and drawing a line through the points *a g p b 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 *a g p b y* ſhould be a curve concave towards the directrix, and the differences *p m*, *b o*, *L y* 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.

				Differences.		
Seconds of Time.		*Feet.*		*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

Refults modified.				Differences.		
onds 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 fcale thus modified has the properties preffed in the preceding paragraph, we fhould proceed to amine whether the refults are juft and conclufive.

Fig. 17. For this purpofe, if $a\,g\,p\,b\,y$ be an equation of this fcale, and $i\,f\,b\,e$ the equation of the fcale of velocities in correfponding times (Treatife on Moving Bodies), which fhould be a curve-line convex toward the directrix, whofe greateft ordinate $a\,i$ drawn from a the beginning of the times muft be equal to the initial velocity of the fhot, the other ordinates will decreafe in proportion as the times increafe, and the fcale $i\,f\,b\,e$ will approach the directrix, and touch it when the fhot has entirely loft its impulfive motion. For example, fuppofe the equation of the curve $a\,g\,p\,b\,y$ to be $q^2+n\,q=m\,t$; where q expreffes the fpace paffed through by the fhot from the impulfive motion, t the time; m and n are two conftant quantities which exprefs the initial velocity: if from this equation be deduced the equation of the velocities in the times, $U=\frac{m}{2\sqrt{\frac{n^2}{4}+m\,t}}$ 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 fcale $g\,p\,b\,y$ be $p\,t^2=q^2$, where p is a conftant quantity, and e fcale of the velocities in the times be deduced; $U=\frac{2\,p\,t}{3\,q^2}$, iere $t=o$; the velocity is then equal to o, which is a maeft abfurdity, fince it muft be equal to the initial velocity the fhot. Again, if $p\,t-t^2=q^2$ be the equation for $a\,g\,p$ $b\,y$

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 $t=o$, 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 ſufficient 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; c 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.
Pr.				Inches.
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, $q=\frac{1349\times 12\times 2}{12+2}=2312$ feet; and in three seconds, $q=\frac{1349\times 12\times 3}{12+3}=3237$ 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 2509 feet.

In an 8lb. ſhot, with the initial velocity [illegible], the line of projection in 1 ſecond is 1302 [illegible]

In a 4lb. ſhot, with the initial velocity [illegible], 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 [illegible] 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 $q=\frac{c\,r\,t}{r+t}$, $S=\frac{32.18t^2}{2}$.

(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 $AK=DG=q$, and the line of deſcent K G are known; by ſubſtituting this laſt value in the formula $S=\frac{32.18t^2}{2}$, it will give $\sqrt{\frac{2\,KG}{32.18}}=t$, and by ſubſtituting the

the known values of q, c, t in the formula $q=\frac{crt}{r+t}$, 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 $S=\frac{32.18\,t^2}{2}$ 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 $c=\frac{q\times\overline{r+t}}{rt}=\frac{3478\times\overline{8.8+3}}{8.8\times 3}=1554$.

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

 angle

angle B A F and the side A B in the [illegible] triangle B F A are known, the sides A F, P[illegible] found; call A F $=m$, B F $=n$. Since the [illegible] $=$ $S=\frac{32.18t^2}{2}$, and the line of projection [illegible] $\frac{[illegible]rt}{[illegible]+t}$ $DF=\frac{32.18t^2}{2}\pm n$, according as the point B is above or below F. As in the rectangled triangle A F D, $\overline{AD}^2=\overline{AF}^2+\overline{DF}^2$, by substituting the analytical values we shall have the following equation, $\frac{c^2r^2t^2}{r^2+2rt+t^2}=m^2+\frac{1035t^4}{4}\pm 32.18nt^2+n^2$: 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 $n=o$, and may be struck out of the equation: the value of t being thus known, those of B D and A D may be afterwards found, which will give the angle of elevation D A F 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 H B L will not be $\frac{1}{2}$ second.

The distance B L between the gun and the object, may be considered as the line of projection $q=\frac{crt}{r+t}$, and substituting in this formula, the data q, c, r, the value of t may be found; which being again substituted in the formula $S=\frac{32.18t^2}{2}$ gives the value of S for the line of descent L G: draw the line B G; then, in the rectangled triangle B L G, the angle G B L will be known: make the angle L B H equal to the angle G B L; B H will then be the direction in which the gun should be fired to strike the point L. For example, if B L 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 numbers in the first formula, $1680=\frac{1350\times 12t}{12+t}$, and consequently fequently $t=1.4$ again fubftituting this value in the fecond formula $S = \frac{32.18 \times \overline{1.4}^2}{2} = 31$ feet$=$L G, and finding trigonometrically ∠ G B L$=1^\circ\ 3'$, the ∠ L B H that was fought is alfo $1^\circ.\ 3'$.

167. From the preceding theory, (Pl. 6, Fig. 20) it will be eafy to determine the value of r and the initial velocity$=c$, when thefe two quantities are unknown, by firing only two rounds. Fire a gun in any direction B D, provided that the line of defcent be lefs than 260 feet; and, fuppofing the fhot to ftrike the ground in E, find geometrically the line of projection B D$=q$, and the line of defcent D E$=$S; and, by the formula $S = \frac{32.18\, t^2}{2}$ find the time: then fubftitute thefe values in the equation B D $= q = \frac{c\,r\,t}{r+t}$. If the gun be again fired with the fame elevation, and exactly loaded as before, but turned to the right or left, fo that the fhot may ftrike another point G, higher or lower than the former one E; having found geometrically the line of projection B K$=q$, and the line of defcent K G, find the value of t, and fubftituting it in the equation B K$=q=\frac{c\,r\,t}{r+t}$; thefe two equations will give the values of c and r.

Suppofe, in the firft inftance, that B D$=1820$ feet, and D E$=36$ feet; and, in the fecond, B K$=3237$ feet, and K G$=144$ feet: then fubftituting thefe numbers in the firft formula, $1820 = \frac{c\,r \times \frac{3}{2}}{r+\frac{3}{2}}$; and again in the fecond, $3237 = \frac{c\,r \times 3}{r+3}$; from thefe two equations, $c=1348$ feet, and $r=12$.

In firing againft the height, R H (Pl. 6, Fig. 18) having fired one round from A, in the direction A M; the gun fhould be advanced to L, or retired to P; and, from one of thefe two ftations, a fecond round fired with the fame elevation; fince whenever it is altered, the initial velocities differ (154).

168. The elevation A D, (Pl. 6, Fig. 21) and the initial velocity$=c$ being given, and the value of r and of the line of defcent B D being known, to find the direction

 and

and the quantity K B of compound velocity, with which the ſhot ſtrikes the point B.

From B D 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 H K parallel to D A, 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 B K, 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 ∠ B H K is equal to the ∠ BDA which is known, the direction will be found, and alſo the quantity of compound velocity B K.

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 $S = \frac{32.18}{2} \times \frac{q^2 r^2}{c^2 r^2 - 2crq + q^2}$ 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 A D 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 $S = \frac{32.18}{2}$

$\frac{8}{-} \times \frac{c^2 r^2}{c r - q^2}$, whence the values of c and r may be
ced.

he application that will be made in the following chapters e doctrine here laid down on the unequal movement of lſion (161) will enable us with a moderate ſhare of nment, to derive the greateſt advantages (141) from ſe of artillery.

o. To determine the curve of the fourth kind; when eſiſtance of the air to the two unequal movements that itute it is great, and the ranges are long; it is neceſſary ake a courſe of experiments, which from the continual ion in the ſtate of the atmoſphere, and other circum-s, are very tedious, and require much accuracy and gence in thoſe that carry them on. As I had not an tunity of making all the experiments I deemed ſatiſ-y on this head, I have here only laid down the funda-al principles, that others may be enabled the more to proſecute the enquiry. Among the different methods nay be taken to determine the laws of this curve (156), ollowing appears the beſt.

uſe an elevated ſituation, where the gun may be turned y ſide; ſo that the ſhot may ſeverally ſtrike points, one the other, in ſuch a proportion that the lines of deſcent e 848, 1696, 3046, 5088 feet. From this ſpot fire l rounds in a horizontal direction towards the ſame , with a charge that gives a known initial velocity, in to obtain a medium of horizontal ranges and of lines ſcent. Perſons ſhould be ſtationed at different parts econd watches, to reckon exactly the time that the ſhot from the inſtant they ſee the ſmoke of the gun, till it the ground. Having found the mean of the two ments of impulſion and gravitation, turn the piece ds another object, in order to obtain a different me- then towards a third and a fourth, with the ſame itions as before.

eſe experiments ſhould be repeated with a gun of a very nt calibre, with the ſame care and attention (156), ie reſults may not be affected by the variations of the phere. Shot much lighter than the common ſhot may de for the occaſion, by ſuſpending in the center of the a ſphere of well-tempered clay, which will be thus completely enveloped by the melted metal; the refiftance of the air to thefe projectiles will be much more fenfible. If this hollow fhot be to a folid one of the fame diameter, as the weight of a fhell full of powder is to a fhell of the fame diameter caft folid, the refults may be applied to mortars in a much more fimple manner.

After the experiments, conftruct two fcales for each gun: one for the fpace paffed through during the time of a retarded movement of impulfion; the other for the movement unequally accelerated by gravity. The laft fcale fhould give a curve convex towards the directrix. The two fcales may be analyfed in the manner above fhewn (158, 159, 160); and if the experiments have been made with care, the equation of each movement will be fo expreffed as to ferve for all the different ftates of the atmofphere.

171. While the ftate of the atmofphere remains the fame, the refults of the experiments (170) will be conclufive, if they have been carried on with proper attention: but the fame inference muft not be drawn in the former cafe (157). For if a gun be fired from the different heights A, L, H, (Pl. 5, Fig. 16) and the lines of defcent G K, P F, Z X, be very confiderable as 848, 1696, 3046, and 5088 feet, the refults will be falfe and inconclufive, even if there be no alteration in the ftate of the atmofphere;

1. Becaufe fhot fired from different heights are oppofed by air of different denfities; the law therefore of the inflammation and explofion of powder is altered, though the quantity be the fame: of courfe the initial velocities will differ.

2. The lines of defcent G K, P F, Z X, and the lines A K, F L, H X, which exprefs the movement of impulfion, traverfe in an inverfe order the air which is of different denfities at different heights; whereas by firing always from the fame place H (170), the fhot will at the firft graze ftrike the points M, B, E, T, with correfponding lines of defcent; and traverfe the air in the natural order; the lines which exprefs the movement of impulfion will be in the direction H X.

To afcertain the modifications that take place in the inflammation and explofion of powder, and in the refiftance of the air to projectiles, owing to alterations in the ftate of the atmofphere, the following experiments may be made: Let a mufquet be fired very clofe to a butt in the bottom of a valley;

a valley; and another be fired with an equal quantity of powder of the fame quality againft the fame butt, at the diftance of 675 feet: at the fame time let another perfon, at a place 5000 or 6000 feet above the former fituation, difcharge a bullet from a mufquet of the fame calibre equally charged, and at the fame diftances as the former one, againft a butt equally homogenous and confiftent: the penetrations will be much deeper from the mufquet fired near the butt at the foot of the mountain, than from that fired near the butt at the higher fituation; but will be much lefs at the diftance of 675 feet, than from the upper one at 675 feet. Thefe effects were fo fenfible in the campaigns of 1743, 1744, and 1747, in the ALPS, that there were days when the mufquets fired at the top of the mountains ranged $\frac{1}{7}$ more than the fame mufquets at the bottom: fometimes the mountains were enveloped in thick clouds, while the vallies beneath were perfectly clear; at other times the atmofphere in the vallies was loaded with vapour, while thofe on the heights enjoyed a cloudlefs ferenity: in fhort, fo great and frequent were the alterations, that the experiments of one day bore no analogy to thofe of the next.

172. To determine in another manner the law of each of the unequal movements that conftitute 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 fame elevation K A M, and with a charge that gives a known initial velocity. Fire fome rounds from A, fo that the medium of the lines of defcent may be from 600 to 700 feet: fire again from P, at a greater diftance from K the foot of the mountain, that the fhot falling in I, the lines that exprefs the movements of impulfion and gravitation, may be longer: remove the guns ftill farther from K, and fire as before; and, having taken the mean refult, retire the gun to a ftill greater diftance from the mountain, fo that the fhot falling on the plane P L, may give the longeft lines of projection and defcent poffible, under thefe circumftances; always ufing a fecond watch to mark the time of flight of the fhot; and, taking every precaution to know whether the ftate of the atmofphere remain the fame. From thefe refults two fcales applicable to the ufes before expreffed (170) may be conftructed. Experiments conducted in this manner cannot be very erroneous, but, their refults are more complicated than the others, (170) fince

ſince the ſhot in aſcending, paſſes continually from a denſe to a more rarified medium, while the reverſe takes place when the ſhot deſcends.

CHAP. III.

Of the Effects of Cannon Shot on Works.

173. THE 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 richochet 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 embrazures, 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, unſupported 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 diminuhed. 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 multipled 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 $f=mV \times \frac{a}{\text{whole ſine}}$ 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 intial 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 B K of the shot, when it impinges on an object, was equal to the remaining velocity H K, 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 B K be determined (168), the gun having been fired at the highest elevation the carriage will admit of, B K is less than H K in the proportion of about $\frac{3}{4}$ in the 100; that is B K : H K :: 397 : 400; and if the gun be depressed as much as possible, B K will exceed H K in the proportion of about $\frac{1}{8}$ in the 100; that is B K : H K :: 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 $fS = Du^2$ (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 $V = \frac{c\,r^2}{\overline{r+t}^2}$ (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. lbs.	oz.	Diameter of Shot. Inches.	Value of *r*	Initial Velocities. Feet.	Relative Penetrations. Cloſe to the Butt.	At 340 yards.	At 680 yards.	At 1000 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	$14\frac{3}{4}$	3.653	7.6	1696	26000	18696	13069	8837
4	2.	$7\frac{1}{2}$	2.881	6	1720	[illegible]	14122	8902	5290
32	9.	$13\frac{1}{2}$	—	—	1350	26240	20262	15356	11430
16	4	$14\frac{1}{2}$	—	—	1416	[illegible]	[illegible]	11935	8255
8	3.	$4\frac{1}{2}$	—	—	[illegible]	[illegible]	[illegible]	8566	5311
4	1	$10\frac{1}{4}$	—	—	[illegible]	[illegible]	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 Du^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 richochet and hot-firing, is diſcuſſed in the ſubſequent treatiſe.

CHAP. IV.

Of the Effects of Cannon Shot in Engagements.

186. In 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 ope-

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,

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 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 di-

 ſtance

ſtance from the enemy; the formulas $q=\frac{crt}{r+t}$, $S=\frac{32.18t^2}{2}$ (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 ½ 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 $S=\frac{32.18t^2}{2}$ 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

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.	Distant from the Butt. 340 Yards. Line of descent.		Elevation.		680 Yards. Line of Descent.		Elevation.		1000 Yards. Line of Descent.		Elevation.	
	Pr	lbs.	oz.		Feet.	In.	Deg.	Min.	Feet.	In.	Deg.	Min.	Feet.	In.	Deg.	Min.
Of the common length.	32	9	13½	1350	10	6	—	35	48	1	1	21	120	—	2	17
	16	4	14¾	1416	9	9	—	32	46	4	1	18	120	—	2	17
	8	3	4½	1450	9	8	—	32	48	—	1	21	130	—	2	29
	4	1	10¼	1467	10	—	—	33	52	9	1	28	160	—	3	—
	16	3	10¼	1240	13	—	—	44	63	7	1	47	169	6	3	14
	8	2	7½	1265	13	—	—	44	67	4	1	53	191	—	3	38
	4	1	3¼	1283	13	6	—	45	75	—	2	6	236	—	4	30
Short guns (66.)	8	2	7¾	1206	14	6	—	49	76	—	2	8	220	—	4	11
	4	1	3¼	1222	15	—	—	50	86	10	2	26	278	—	5	17
	8	1	10¾	978	23	6	1	19	133	—	3	44	425	—	8	6
	4	—	13¼	978	25	7	1	26	164	6	4	36	633	—	11	55
	8	without wads. 1	10¼	675	57	3	3	12	405	—	11	13	1843	—	31	34
	4	without wads. —	13¼	675	65	7	3	41	596	—	16	18	—	—	—	—

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 richochet 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 comparifon of the effects that fhot of different diameters with different initial velocities produce at different diftances on a body of troops; they muft be confidered as a homogenous butt: then the formula $S = Du^2$ (183) will give the relative penetrations. The abfolute number of men that a fhot with a given initial velocity will pafs through may be determined by experiment.

The relative penetrations in the following table have been calculated on a fuppofition that from the refiftance of the air $r = 12$ in a 32lb. fhot, in order to compare together the number in this and the preceding table (183). The calculations are not carried beyond 680 yards, which is confidered in field engagements as the greateft diftance that fhot can range to, with a certainty of doing execution; in extraordinary cafes indeed, when the nature of the ground and the pofition of the enemy are very favourable (192), the range may be extended with tolerable fuccefs.

The relative Penetrations of Shot projected from different Diftances with given initial Velocities.

Nature of Guns.	Prs.	Weight of Powder. lbs.	oz.	Initial Velocity. Feet.	Clofe to the Butt.	At 340 yards.	At 680 yds.
Common length.	16	3	10¼	1240	17571	11878	8509
	8	2	7½	1265	14625	9360	5743
	4	1	3¾	1283	11840	6754	3479
Short Guns.	8	2	7½	1206	13329	8358	4919
	4	1	3¾	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		13¼	675	3241	1024	251

197. To reduce into numbers the relative penetrations infcribed in the tables (183, 196), make the following or fimilar experiment: with a charge that gives a known initial velocity, fire a gun againft a butt, and meafure the penetration of the fhot: then place two horfes or other cheap animals clofe to the fame butt, and lay the gun fo that the fhot after paffing through the moft folid 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.	No. Men.	No. Men.
Common Length.	32		13	2	1517	70	55	44
	16		6	9	1618	63	48	36
	8		4	14¾	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	10¼	1467	33	20	12
	16		3	10¾	1240	36	24	17
	8		2	7½	1265	31	20	13
	4		1	3¾	1283	25	14	8
Short Guns.	8		2	7½	1206	28	18	11
	4		1	3¾	1222	23	13	7
	8		1	10¼	978	19	10	5
	4		—	13¼	978	15	7	3
	8	without wads.	1	10¼	675	9	3½	$\frac{7}{8}$
	4		—	13¼	675	7	2	$\frac{7}{12}$

198. Several

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 $S = D u^2$ 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 $u\sqrt{\frac{1}{2}}$; 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 $u\sqrt{\frac{1}{2}}$: 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.

CHAP. V.

Of the Effects of Case or Grape Shot in Engagements.

201. THERE 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 counterſcarps: 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 [illegible] execution. The ſecond kind is [illegible] vice, 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 62 or 64 leaden bullets, each weighing ¾ 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 20 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 $\frac{1}{5}$ and $\frac{1}{8}$ 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 1½ lb. of powder; the number of balls that struck the target was between $\frac{1}{5}$ and $\frac{1}{8}$ 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 $\frac{1}{8}$ and $\frac{1}{9}$ 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 $\frac{1}{20}$ 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 judgement 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	Close to the butt.	At 170 yards.	At 340 yards.	At 510 yards.	At 680 yards.
ozs.						
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.	Close 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	$3\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{192}$
1	9	4	$\frac{5}{6}$	$\frac{1}{7}$	$\frac{1}{9614}$

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 close; 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 $\frac{5}{6}$; the ſame ball at the diſtance of 680 yards will hardly make a contuſion, which is expreſſed by the fraction $\frac{1}{30}$.

2. Balls of 1 oz. at 170 yards, thoſe of 3¼ oz. at 340 yards, thoſe of 6½ 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 6½ 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 that each ball takes after the cafe is broken; fince the contact of the balls and their reciprocal preffures at the difcharge and at the commencement of their divergence are unknown: It muft then as far as poffible be afcertained experimentally.

Experiments made with the greateft attention have given the following refults;

1. The conical figure is preferved for a certain diftance; after which it is entirely loft.

2. The proportion between the formation of the cone and the point where it begins to lofe the regularity of its figure depends on the fize of the balls, and their initial velocity: the diftance will be lefs in proportion as the balls are fmaller, or their initial velocity lefs.

3. At equal diftances, balls impelled from guns of the common length diverge much lefs than balls of the fame weight and diameter impelled from fhorter guns with the fame charge. This muft be a familiar remark to fportfmen who have ufed fowling pieces of different lengths.

4. When the balls are ranged in the cylinder in regular order, they diverge much lefs than when put in carelefsly; thofe of 13, 6½ and 3¼ oz. may be regularly difpofed in tin cafes of the diameter of 16, 8, and 4 prs.; and fuch only will be in future confidered: 1 oz. balls fhould be difpofed in the cylinder in the moft convenient manner, and fired at any diftance lefs than 220 yards.

5. From certain diftances a greater number of men may be ftruck by cafe than by round fhot, if the gun be properly laid.

209. The angle that the axis of the gun fhould form with the horizon is determined (165, 166) on a fuppofition that the balls in the tin cafe are impelled in the direction of the axis, which is not always juft; as they fometimes quit the cafe under different angles. The leaft error in loading or pointing a gun may render a round fhot of no effect, but be of little confequence in firing with cafe fhot.

210. In order to fhew in one part of view the moft interefting particulars in the ufe of cafe fhot, the following table has been calculated; the initial velocities of a 32 lb. fhot are fuppofed to be 1450 and 1206 feet, and $r = 12$ for the refiftance 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 Case 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.

Nature of case shot.	Initial velocity.	Distances between the battery and enemy.															
		[illegible] yards.				[illegible] yards.				[illegible] yards.				[illegible] yards.			
		Line of descent		Elevation.		Line of descent		Elevation.		Line of descent		Elevation.		Line of descent		Elevation.	
	Feet.	Ft.	In.	Deg.	Min.	Ft.	In.	Deg.	Min.	Ft.	In.	Deg.	Min.	Ft.	In.	Deg.	Min.
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]		[illegible]			[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			

211. From this comparison the following practical inferences may be drawn;

1. Balls of 3¼ oz. that with an initial velocitiy 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 $\frac{1}{151}$; but it is injudicious to fire 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 $\frac{1}{5817}$ and is hardly sensible.

2 Balls of 3¼ 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 $\frac{5}{8}$.

3. As a ball of 6½ 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 [illegible]
fible [illegible]

212. [illegible]
e refiftance [illegible]
her determinate [illegible]
actice; fince [illegible]
igned, but [illegible]
d leaft effects [illegible]
ld pieces to the beft advantage [illegible]
g particulars.

1. For [illegible]
the firft, [illegible]
with the [illegible] charge [illegible]
enemy [illegible]
in deeper [illegible]
the fecond [illegible]
its greateft range [illegible]
pofed in [illegible]
compofed of [illegible]
of the fourt[illegible]
never exceed [illegible]

2. There are [illegible]
contains [illegible]
charged [illegible]
contains [illegible] range [illegible]
340 [illegible]
may range [illegible]

3. [illegible]
the firft [illegible] range w[illegible]
the medium charge [illegible]
fecond contains [illegible] greateft range
fhould be [illegible]

4. The number [illegible]
the number of [illegible]
if the two guns be [illegible]
fame initial [illegible]
double that of [illegible]
be double that of [illegible]
guns of large calibre [illegible]
ftill a ftronger reafon [illegible]
fmaller calibre, [illegible]
the fervice ac[illegible]
with an initial velocity [illegible]

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 6½ oz. the fourth with 128 balls of 3¼ 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 artil-

lery 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.

CHAP. VI.

THE EFFECTS OF THE HOWITZER AND 8PR. COMPARED.

215. IN 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 *Guastalla*, 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 thofe of the 8 pr. (183), in order to afcertain the diforder that each of thefe pieces can feverally produce among a body of troops: leaving it to others to difcufs the moral effects refulting from the ufe of howitzer fhells, which have by many authors been fuppofed to be very great: a difquifition totally foreign to our purpofe, as the abfolute confequences 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 diforder by the fire of artillery, have at length recovered themfelves fo far as to defpife the former object of their fear, on finding that their apprehenfions had greatly magnified the effects of thefe feemingly terrific machines.

216. *A fhell is fired from a howitzer with a view of deftroying the enemy both by its fhock, and explofion on burfting*: its greateft effects are when, having enfiladed a body of troops and being quite fpent in ftriking men or other objects, it burfts in the midft of thofe that remain. To convey a juft idea of the comparifon we propofe drawing; let the howitzer be equal in length of bore to an 8 pr. of common length, and let them both be loaded with 3¼ lb. of powder: the elaftic fluid on quitting the chamber of the howizer dilates towards the chace, and exerts againft the fhell lefs preffure, than the fame quantity of fluid generated in the gun exerts againft the fhot; confequently its initial velocity is lefs. As a howitzer 6 diameters of the muzzle in length of bore is only half as long as an 8 pr. and as the largeft charge for throwing a fhell 16 lbs. in weight is 1 lb. 10 oz. of powder (215), this projectile muft have a much lefs initial velocity than an 8 lb. fhot impelled by 3¼ lbs of powder, with the wads well rammed. The initial velocity and the fpecific gravity of the fhell being lefs than thofe of the fhot, the air's refiftance will be greater; and confequently its penetrations into the fame butt will be lefs.

217. There are two methods of afcertaining the effects of howitzer fhells: the firft is, by firing againft a butt at different elevations and diftances, and comparing the penetrations of the fhell with thofe of a fhot fired from an 8 pr. The refult will exprefs the proportion between the effects of the two projectiles, though the hole made by the howitzer fhell will be much larger than that made by the fhot: but the velocity

velocity with which the ſhell impinges on the butt and its ſpecific gravit 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 $fS = Du^2$ (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 Du^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 Du^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.	*Yards.*	*Feet.*	Relative penetrations.
Shell fired cloſe to the butt		472	$5\frac{1}{2} \times 472^2$
At the diſtance of	340	364	$5\frac{1}{2} \times 364^2$
At the diſtance of	680	286	$5\frac{1}{2} \times 286^2$

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	—	1404
At the diſtance of	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 burst.

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 (21[illegible]), 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	—	9
At the distance of	340	3	—	[illegible]
At the distance of	680	2	—	5

The number of men wounded and [illegible] will be greater, if the least resisting parts of the body be struck [illegible] re-marked in the case of cannon shot.

220. On comparing the effects of a shell and [illegible], it is apparent that in respect to the shock [illegible] only common 8 prs. but [illegible] guns fired with [illegible] charge are more destructive than the howitzer [illegible] the only advantage [illegible] over them is when the shell bursts at 680 yards. A howitzer shell fired against the [illegible] of an army will [illegible] range [illegible] yards [illegible] it is mere chance, if it burst in the midst of a [illegible] should not this happen, or should it by accident [illegible]

a lone

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 richochets 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 170 yards.
oz.				
$6\frac{1}{2}$	—	803	—	138
$3\frac{1}{4}$	—	640	—	59
1	—	444	—	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 [illegible] number of men [illegible] howitzer [illegible] bases of the two [illegible] struck by the [illegible] one: but when the [illegible] the case that [illegible] the greater [illegible] greater the distance, [illegible] howitzer, on account [illegible] make the comparison [illegible] advantageous to the [illegible] strikes triple the [illegible] greatest effects [illegible] 1 : 11.

224. Again, if the enemy [illegible] in form of an amphitheatre, [illegible] strike one man; the effects [illegible] 8 pr. as 8 : 1 and to [illegible] case shot be put at [illegible] riority, the number [illegible] velocity of those projected [illegible]

$\frac{1450}{3}$ (200) than [illegible] they will range farther [illegible] is therefore to be preferred. [illegible] part of this work, [illegible] ing, if 3 cases be fired at the [illegible] fully confirmed by experience [illegible] 6 diameters of the muzzle in length [illegible] mon 4 pr. charged with [illegible] except when the enemy is very near and [illegible] amphitheatre of hills, will be more [illegible] than the former. If the length of the howitzer be [illegible] 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 cafes however, where the howitzer may be very ufeful; as in the attack of pofts where the enemy is perfectly covered from cannon fhot: the fhells from the curve line that they defcribe may then be of excellent fervice; or, in the attack of towns or villages, where large quantities of ftraw, hay, faggots, or other combuftible materials are depofited. Some pieces of port fire compofition may be put into the fhell, which on burfting will communicate the flame to every thing around: by thefe means, towns and magazines may be eafily fet on fire.

227. The howitzer may in the following cafes be ufeful in the attack and defence of places.

1. In a fortified town, when the cafemates or caponieres are too narrow to admit guns of the common length; howitzers are then preferable to fhort guns of cylindric bore, as the explofion of guns of large calibre foon deftroy the embrazures.

2. To prevent as much as poffible the inconveniencies arifing from the fmoke in cafemates and caponieres, and yet be able to project cafe fhot with the greateft initial velocity; the howitzers may be lengthened if there be fufficient room; this will in fome meafure bring back the *pierrier* guns formerly in ufe.

3. In the attack of places, fome howitzers may be planted on the batteries defigned to fire à richochet, to enfilade the covert way and its branches: effential fervice will be derived from this mode of ufing them; fince befide the deftruction they may caufe among the befieged, they foon filence the fire of the infantry, and cover the workmen in carrying on the approaches.

CHAP VII.

Of Shells projected from Mortars.

228. THIRTEEN and 10 inch mortars are much ufed in fieges: 15 inch mortars are now generally difufed; as from their great weight when properly reinforced, and the fize of their chambers, they were very difficult to work on the batteries: when the thickneffes of metal are diminifhed and the chambers reduced in fize, their ranges are fo much fhortened, that the fhells do not fall with more force than thofe

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 tompion of wood placed immediately over it, and both the tompion 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 freqently 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

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 enfilade works, 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 A P (Pl. 6, Fig. 22) has described a curve A F N B 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 B P, make B E equal to the corresponding velocity at this point, of a movement B P unequally accelerated by gravity; draw E H parallel to A P, and equal to the velocity which at the same point B corresponds to the retarded movement of impulsion A P; then the right line H B 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, F C 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 A B: 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 P A B 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 B A.

236. The formula $m \text{ V} \times \frac{a}{\text{whole line}} = f$ (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 $m \text{ V} = m \times \text{B H}$ is greater than its force at the point F, becauſe B H is greater than C F.

2. If the ſhell at the vertex F ſtrike at right angles a vertical plane, it will impinge with all the force expreſſed by $m \text{ V} = m \times \text{C F}$; 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, $a=o$; 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 y 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 *picciloide*.

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 *y* B Z, inclined to the horizon A B; the mortar muſt then be removed ſo much the farther from B towards A, as the angle A B *y* is the greater; the axis of the mortar produced ſhould paſs through a vertical plane, ſuppoſed to cut Y Z 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 A B, 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 mate-

rial 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.

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 oversetting 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 richochet firing, enfilade the works and harrass 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 embrazures during the night; and to prevent the several detatchments 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 exerciting 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 divifion of this work is into three parts: the firft treats of the fervice of artillery in the attack; the fecond, in the defence of fortified towns; and the third comprehends the various other branches of artillery fervice in the field.

FIRST PART.

OF THE SERVICE OF ARTILLERY IN THE ATTACK OF FORTIFIED TOWNS.

13. WHENEVER a town fortified according to rule is intended to be taken by fiege, the object of the befieger is to make a breach; which may be effected by the means of heavy artillery, or of mines: and the execution, in either cafe, refts with the royal corps of artillery.

CHAP. I.

OF THE FIRST DISPOSITIONS TO BE MADE FOR BESIEGING A PLACE IN FORM.

14. THE firft duty of an artillery officer, when it is refolved to lay regular fiege to any place, is to make out a ftate of the guns, mortars, ammunition, machines, and carriages of all kinds requifite for that purpofe. To be enabled to make a proper proportion of ftores, the commanding officer of artillery muft be mafter of certain data (6); that is to fay, the commander in chief, or the general officer charged with the direction of the fiege, fhould communicate to him a plan of the fortifications and environs of the place, accompanied with fuch profiles and remarks, as may enable him to afcertain what fronts are moft attackable; with the advantages and difadvantages 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 increafe the proportion, if the efcorts be large; and to diminifh it, when few troops can be fpared for this fervice.

17. The primary confideration towards deciding the number and calibre of the pieces of ordnance, is *to keep up conftantly a fire fuperior to that of the place.*

The following are the particular rules for the obfervation of this maxim, in the firft 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 creft of the glacis, ought to exceed by a third at leaft, the number that the garrifon can bring to bear on the attack, from the body of the place, or any of the outworks, capable of making a long refiftance.

2. The proportion of 16 prs. for difmounting the enemy's artillery in the ravelins, and other advanced works that may retard the progrefs of the befiegers, fhould exceed by a fourth at leaft, the number of guns in thofe works.

3. The richochet firing is from 8 and 4 prs. the number for enfilading any works fhould never be lefs than three.

4. Each of the works attacked fhould be enfiladed by at leaft three 10 inch mortars, when the object is to difmount the enemy's artillery; and, by perpetually annoying them, oblige them to abandon their works. But if the baftions be cafemated, the mortars fhould be 13 inches in bore, and the number increafed.

5. As the richochet firing may be ftopped for fear of incommoding the workmen in completing the third parallel, two or three royal mortars fhould be planted in the fecond parallel, againft each face of the covered way, to harrafs the garrifon during the ceffation of the richochet-firing.

6. Some ftone mortars may likewife be placed in the finifhed parts of the third parallel, for firing into the covered way.

18. Having determined the nature and number of the ordnance requifite for the firft part of the attack, the quantity neceffary for the fecond is then refolved on; making ufe, for this purpofe, of the guns planted in the firft erected batteries, which ceafe firing when a lodgment is effected on the creft of the glacis.

19. This

19. This artillery (17, 18) is only defigned for firing againft the front of the attack; but if there be any objects within the town expofed to the fire of the befiegers, the ordnance muft be proportionably increafed. If the barracks and the magazines, for inftance, can be cannonaded, a proportion of 32 prs. fhould be deftined for this fervice; 16 prs. will be fufficient for beating down the houfes, &c. and 8 prs. for projecting red-hot fhot to fet fire to buildings. When the barracks and magazines are covered from cannon-fhot, but not fecured from fhells, the number of 13 inch mortars for breaking through the cafemates fhould be increafed: in cafe the troops or ftores are lodged in the common edifices of the city, 10 inch mortars will fuffice for the bombardment.

20. The number of rounds fired from each gun and mortar againft the front of the attack; is eftimated 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 occafional fufpenfion of the firing, this calculation is feldom exceeded; it may therefore be confidered as the expenditure of every gun or mortar mounted on the batteries, from the day they are opened till the end of the fiege.

21. The calculation for the guns intended for firing againft barracks and magazines, (19) is from 250 to 300 rounds a gun for each 32 pr. when the diftance is fhort, and the line of direction nearly perpendicular to the objects: but for longer diftances, and very oblique directions, the number of rounds muft be regulated by the fituation of the place, and it's environs; on the principles laid down in the third book of Military Architecture, and the Philofophical Inftitutions, with regard to the effect of cannon-fhot on walls. Large fhells are the beft for penetrating cafemates; to produce the full effect, the mortars fhould be laid between 35° and 45°, and the fhells projected with the greateft initial velocity fhould fall perpendicularly to the plane of the object.

22. The number of gun-carriages and mortar-beds, as well as fpare articles of every kind, is proportioned to the duration of the fiege: we generally compute three carriages for every two guns, and two beds for each mortar, when the fiege is expected to laft about a month; the proportion is increafed for longer fieges.

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 $\frac{1}{8}$ 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 $12\frac{1}{4}$lbs. of powder; $6\frac{1}{2}$lbs. for the 10 inch mortar, and $3\frac{1}{4}$lbs. for royal mortars; the charge for the ſtone mortar is 4lbs. 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 $2\frac{1}{5}$ 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 œconomical 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 N N (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

neither particularly advantageous nor disadvantageous to the befieger.

2. That the works are reveted; the revetements of the common thicknefs; the height of the body of the place about 40 feet; and of the counterfcarp, about 20 feet; the profiles juft, and the works mutually flanking each other; no countermines, but cafemates and magazines covered from cannon-fhot; and an ample provifion of ftores of all kinds.

3. That from 16 to 18 guns may be mounted on the faces A, B, of the baftions in the front A B that is attacked; and the fame number upon the four faces C, D, E, F, of the ravelins.

4. That the garrifon is fufficiently numerous, compofed of veteran troops, and commanded by experienced and gallant officers.

25. The firft ftep towards making out the proportion of artillery for laying fiege to the fuppofed fortrefs, (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 refult;

Twenty-four 32 prs. for the royal battery G.

Twenty-four 16 prs. for the batteries H, K.

Twelve 8 prs. for the richochet batteries M, O.

Twelve mortars; four of 13 inches, and eight of 10 inches, to be diftributed in the batteries L, N.

Twelve royal mortars to be placed in the fecond parallel, for covering the fappers in the third parallel, when the richochet firing ceafes.

Six ftone-mortars to be placed at Q, in the third parallel, to annoy the befieged in the covered way.

26. Upon the fame principles may be computed the quantity of artillery neceffary for the fecond 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 filencing from the battery B, the guns on the baftion Q which covers the ravelin P.

Eight 32 prs. viz. five for battering in breach the baftion from C, and three to be planted in the battery O.

Six 32 prs. for firing from D againft 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.

No. and Nature of Ordnance.	No. and Nature of Gun-carriages.	No. of Pairs of Oxen.	No. of Carts.
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, 4 13 inch ditto, 8 10 inch ditto	Carried upon 7 block carriages with draught chains, for 5 pairs of oxen each	35	—
	Carried over	461	—

12 Royal

		Pairs of Oxen.	Carts.
	Brought over	461	—
No. and Nature of Ordnance.			
12	Royal ditto, carried in 2 common carts, with 2 pair of oxen each	4	2
30 Mortars	60 Mortar-beds at 2 to each mortar	22	22
	60 Sets of fide arms for the mortars	1	1
	Spare Articles.		
4	Block waggons, at 2 pairs of oxen each	8	—
24	Wheels fhod with iron for 32 and 16 pr. carriages		
12	Wheels fhod with iron for 8 pr. and block ditto	12	12
100	Axle-trees for carriages of all forts	10	10
200	Spunge-ftaves for guns	4	4
100	Sheep-fkins for fpunges	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-fhot, half for 32 prs. the other for 16 prs.	45	45
4800	13 inch fhells, at 1200 rounds for each mortar, and 7 fhells to each cart	686	686
9600	10 inch fhells, at 1200 rounds for each mortar, and 15 fhells to each cart	640	640
11520	Royal fhells, at 840 rounds for each mortar, and 40 fhells to each cart	288	288
12000	Hand grenades, at 500 to each cart	24	24
	Carried over	3187	2716

		Pairs of Oxen.	Carts.
	Brought over	3187	2716
	Shot, Shells, and Grenades continued.		
5500	Fuzes for 13 inch mortars } Packed up in sand bags		
11000	Ditto for 10 inch ditto ... }	12	12
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 }		
6	Hand jacks .... }	2	2
6	Ropes for guns, 25 fathoms each .... }		
4	Ropes for gins, 15 fathoms each .... }		
20	Double slings .... }	12	12
100	Ropes for tying the ammunition upon the waggons, 8 fathoms each .... }		
100	Drag ropes, 10 fathoms each .... }		
20	Cwt. of cordage for tying and packing	4	4
	Ammunition.		
5922	Whole barrels of corned powder, viz.	647	647
cwt. qrs. lbs.			
2635 1 12	For 28800 rounds from 32 prs. at 10¼lbs.		
790 2 24	For 17280 rounds from 16 prs. at 5⅛lbs.		
105 1 20	For 7200 rounds à richochet, 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		
	Carried over	3945	3474

Ammunition

cwt	qrs.	lbs.		Pairs of Oxen.	Carts.
			Brought over	3945	3474
			Ammunition continued.		
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 $\frac{1}{6}$ 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.

		Pairs of Oxen.	Carts.
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.	Carts.
Brought over	4576	4105
Iron-work and Nails.		
54 Cwt. of iron of sorts 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 — Packed in boxes	2	2
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

Instruments

	Pairs of Oxen.	Carts.
Brought over	4624	4153
Inftruments for the Laboratory and work-fhops.		
3 Mealing tables with treftles	2	2
40 Wooden troughs for mixing fufe compofition		
20 Heavy mallets for fixing fufes		
40 Setters for driving ditto	2	2
60 Drifts for ditto		
30 Ladles for ditto		
24 Small brufhes for glue		
24 Tin funnels of different fizes for loading fhells and grenades		
50 Rafps with handles		
50 Drawing knives		
6 Sieves of hair or fine filk		
6 Hand faws		
12 Pair of fciffars of forts		
30 Augers and gimblets		
6 Handfcrews		
12 Gouges		
4 Pair of pincers		
150 Tin meafures of different fizes	3	3
150 Can-hooks for fhells		
100 Quadrants		
1000 Pricking wires		
100 Lanterns of forts		
60 Wire fieves		
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; 10000 Mattocks with helves, ſuppoſing there are no lines of circumvallation to conſtruct	100	100
600 Spades with helves	5	5
300 Axes of ſorts; 1000 Hand bills	25	25
Tools for forty Miners.		
20 Iron mallets; 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	3	3
Tools for thirty Carpenters.		
10 Croſs cut ſaws; 20 Common ditto; 30 Broad axes; 20 Hammers; 10 Sledge ditto; 150 Chiſſels and gouges of ſorts; 300 Augers and gimblets; 6 Hand vices; 10 Iron crows; 6 Planes; 10 Pairs of pincers	4	4
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
10 Pairs of forge tongs of different ſizes		
8 Nail borers		
15 Hammers		
8 Sledge ditto	3	3
40 Files of ſorts		
2 Benches with beak irons and vices		
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 compleated. 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 pullies, 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

fuddenly changed, and the enemy take advantage of the unprovided ftate of the town to attack it.

Guns that are not perfectly good will anfwer very well for richochet firing and for battering in breach : when there are any fuch, therefore, in the town from whence the ftores are drawn, they fhould be included in the inventory, and after the fiege be condemned and fent to the foundry : likewife any powder, carriages, cordage, fand-bags, or other ftores that have been kept too long in the magazines ; fince a commanding officer of artillery may by fkilful and judicious arrangements employ them very ufefully, without detriment to the fervice, yet greatly to the intereft of his fovereign, by faving the money that the purchafe of new articles would coft.

Finally, if there be reafon after the trenches are opened to apprehend that the obftinacy of the garrifon may fo far protract the fiege, as to render the fupply of ammunition inadequate to the reduction of the place, the commanding officer of artillery fhould give timely intelligence to the perfons charged with fupplying his department, that the operations may not be retarded or fufpended.

32. The following return fhews the leaft number of officers, non-commiffioned officers and privates for the fervice of the artillery at a fiege under the prefuppofed circumftances (28).

A commanding officer	
Second in command	
Major	
An adjutant and affiftant	
Captains	12
Subalterns	36
Serjeants and corporals	92
Bombardiers and gunners	700
	840
Sappers	80
Miners	40
Artificers for laying platforms and bridges	40
Total	1000

Befide thefe, a detachment from the line muft affift the bombardiers and gunners in conftructing 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.

CHAP. II.

Of Convoys.

33. THE 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 ex[illegible]ed officer to the camp, the moment he hears that the [illegible]e is invested, to choose a proper place for the park; [illegible]hen 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 cheſſes $1\frac{1}{2}$ inch in thickneſs, and 12 or 14 feet in length. When the timber is green, the thickneſs ſhould be increaſed by $\frac{1}{7}$; 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 cheſſes 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

firft fignal, the quarter-mafter with the camp-colour-men and a waggon-mafter, goes forward to the place where it is intended to halt, in order to prepare quarters and forage, and choofe a fpot for parking the artillery; it ought to contain all the carriages drawn up in a fquare, leaving between each file a fpace fufficient for harneffing and unharneffing the oxen. The park is formed as faft as the carriages arrive; and guards pofted for the fafety of the powder and ftores, and to prevent the defertion of the drivers. The forage is diftributed in fuch proportions, that the cattle may be able to continue their route at the appointed time. The guards furnifh rounds and patroles during the night, and allow no perfon to approach the park, unlefs fent by the commanding officer. The fame order of march is refumed the next and following days, till the convoy reaches its deftination; never moving more than 14 miles a day, efpecially with oxen. To prevent confufion, the drivers are obliged to keep the fame place during the whole march; and for the fake of punifhing irregularity, each carriage is numbered, and the driver wears a ticket in his hat.

40. When part of the ftores are carried on beafts of burthen (23), in making up the feveral convoys, they fhould be kept totally diftinct from the carriages; and the officer who goes forward to mark out the park, fhould pitch on one or two houfes for lodging the ftores, where they may be ranged in their feveral claffes, and the powder and other articles effectually fheltered from rain. If no fhelter can be found, fome mules laden with planks and fleepers fhould 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, fhould be laid over the whole.

41. When the artillery and its appurtenances are to be tranfported in boats, fome fkids fhould be laid under the guns and mortars, and fmall floors made of planks for fupporting the fhot, fhells, match, &c. always leaving a clear fpace in the middle of the boat for baling.

The ftores are tranfported in waggons from the magazines to the place of embarkation, which fhould be fpacious enough to admit of many men being employed at the fame time, without confufion or danger of mixing the ftores of different fpecies 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 palliſadoes 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

and keep them in check, till the whole have paffed. When the line of march can be covered by a large river, this route fhould be preferred, though it may be the longeft. The third method is when the efcort that marches with the convoy is ftrong enough to repel any attack of the enemy: the artillery fhould in this cafe contribute towards it's own defence; it is neceffary therefore to enlarge a little on this head.

44. In open champaign countries, the van and rear guards confift of cavalry; the infantry, which is the main part of the efcort, forms the centre. But in a ftrong country interfected by rivers or canals, by forefts, moraffes, ravines, or defiles, the number of infantry is increafed, and the cavalry diminifhed, by fubftituting in their place dragoons, who occafionally act as cavalry or infantry. If the route lie through a mountainous country, the efcort is compofed folely of infantry.

The command of a numerous efcort is generally given to a general officer, who makes the following difpofition previous to the march, that every perfon may know their pofts in cafe of attack: a few hours before the convoy fets out, he fends detachments to reconnoitre the country, and divides his troops into four parts; the firft forms the van-guard, the fecond the rear-guard, and the third, which is the largeft, and confifts folely of infantry, is referved for the centre: the fourth part is diftributed in fmall detachments along the flanks, to feize pofts and occupy crofs roads, &c. till relieved by the rear-guard. When the road is 25 feet wide, the carriages move two a breaft, to fhorten the line of march, and be the more ready to repel an attack.

Previous to croffing a bridge, or entering a defile, the country on the other fide fhould be reconnoitered for fear of an ambufcade, and the carriages drawn up in feveral lines clofe to the bridge, that the efcort may be as much as poffible collected together: on moving forward, the former order of the march is refumed. If during the march an order be given to prepare for action, the officer of artillery will inftantly form the carriages into an oval or oblong figure, prefenting the longeft fide to the enemy, with the heads of the horfes or oxen turned toward the centre, that there may be no poffibility of their running away: the infantry may be fometimes 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 from 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.

CHAP. III.

Of the Park of Artillery.

45. THE 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 patrole 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 primer when fired, and break it, ſo that the ſhell will not burſt. The fuſes ſhould be examined before they are driven, 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.

CHAP. IV.

Of the Construction of the first Batteries.

48. THE object of the beſieger, in the conſtruction of his firſt batteries, is to diſmount the cannon in the front attacked, deſtroy the embrazures, 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 embrazures, 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 *a ricochet*; the batteries for this purpoſe are made without embrazures, 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 embrazures; 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 richochet 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 richochet 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 ſaliant 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 embrazures, viz. G, H, K; each of which has two faces preſenting a ſaliant 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 embrazures, and ſunk; and 20, or 25 when it to be raiſed, the exact number of men being determined by 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 embrazure. 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 embrazures, 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 embrazure. 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 2½ 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 embrazures 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 ſally 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 between the battery and the place. Too many pioneers cannot be employed in this work during the night; but during the day fo many only as can be covered from the enemy's fire; and to expedite the work, the foil neareft at hand is ufed. The breadth at top fhould be at leaft 45 feet, and the flope two thirds of the height. A berm of 5 feet is left towards the place, and the dimenfions of the battery are the fame as before directed (53). In the rear of the battery a proper flope is made for the drawing up the cannon, and adjoining to it is conftructed the powder magazine.

The battery for fchool-practice on the other fide of the river Po will convey a juft idea of this fpecies of battery, and be at the fame time a convincing proof that works which require fo much time and labour, fhould never be undertaken at a fiege, without an abfolute neceffity.

It has been advanced by fome authors, that the firft batteries fhould always be erected on cavaliers, even if the ground be on the fame plane with the place, that greater part of the ramparts may be thereby difcovered: but if we reflect how high the cavalier muft be raifed before a fingle foot of the revetement can be feen, it will appear that fuch a trifling advantage by no means compenfates for the lofs of time and labour; befides, as the firft batteries are intended to difmount the artillery of the place, and deftroy the defences, this end will be fully anfwered when the befieger from them can fee his objects without endangering the lives of the fappers, or interrupting their progrefs.

55. So foon as the fecond parallel is completed, the firft richochet and mortar batteries are conftructed at the points whence the faces of the covered way, and the attacked works can be enfiladed with moft effect (17). Thefe batteries fhould be completed in twenty-four hours; wherefore, 14 or 16 pioneers are allotted to every 20 feet; the parapet is faced with fafcines, and the trench enlarged as much as may be neceffary: paffages of communication are made round the rear, to prevent any embarraffment; and the powder magazine is conftructed in the fpace between this communication and the battery. When the richochet batteries can be incommoded by a plunging fire from the cannon of the ramparts, embrazures fhould be made from 6 to 8 feet wide, floping inwards: by this expedient the guns will be concealed, and may be placed clofer to the parapets. When the fappers begin the third parallel, the

fire

fire from the richochet 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.

CHAP. V.

OF THE DAILY SERVICE OF THE FIRST BATTERIES.

57. THE 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 richochet 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 is frequently miffed from the violent fhock that the carriage fuftains, a great quantity of ammunition is ufelefsly expended, and the guns are often rendered unferviceable, before the conclufion of the fiege.

58. In making the diftribution of artillery-men, the following is the proportion to be relieved every 24 hours; *viz.* eight men to a 32 pr. fix to a 16 pr. 13 inch or ftone mortar; four to an 8 pr. and 10 inch mortar; and two to a royal mortar. An officer and non-commiffioned 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 difmount the artillery and ruin the defences, that the garrifon may be unable to work their guns when the befieger has eftablifhed himfelf with his mufquetry in the fecond or third parallels. The firing from any battery fhould never be diverted from the particular object againft which it is intended to any other, as fuch defultory operations are generally inefficacious towards the reduction of the place. The common rate of firing from batteries at a fiege is at moft 9 rounds an hour from each gun.

In richochet firing, the guns are elevated between 8° and 12°; and fired with very fmall charges, juft fufficient to throw the fhot over the parapet or into the covered-way; that it may afterwards make feveral bounds: the proper charge having been afcertained, is put into flannel cartridges; that the powder being always collected together in the fame manner the inflammation may be uniform; and fince the firing is to be continued day and night, the coins and platforms fhould be marked that the elevation and direction may remain the fame.

In batteries for throwing red-hot fhot, a large iron grate is fixed behind the battery; the fhot are laid in it and a ftrong fire kindled: the proper charge for throwing the fhot 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 fpunges it out with a wet fpunge, and with a pair of pincers puts the red-hot fhot into the gun, and another gunner inftantly fets fire to the priming with a match. Thefe batteries likewife fire night and day; but as the guns are foon heated, the firing ceafes at proper intervals to allow them time to cool.

60. The mortars intended to enfilade the works in order to difmount

dismount the artillery and harrass 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 enfiladed, 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. Seldom 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.

CHAP. VI.

Of the Second and Third Batteries.

63. It 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

to but lower than the works, whence they can be battered with effect, as in the cafe of the place being built on an eminence and much expofed; then the batteries in breach fhould be erected on thefe points and collateral batteries eftablifhed to deftroy the defences.

Each battery fhould be erected oppofite to that part of the fortification which it is intended to batter; and the breach will fooner be rendered practicable, if fome guns can be brought to bear upon it obliquely. The fervice of the mortars will be moft exact, when their batteries are perpendicular to the faces produced of the works that are to be bombarded; thofe for the ftone-mortars fhould be eftablifhed in the moft advanced lodgements, taking care that the ftones from their fpreading can do no injury to the befiegers.

65. The third batteries are conftructed on the outworks of the place: when there are two lines of out-works, the befieger after reducing the firft, muft erect a fourth fet of batteries in the outworks moft contiguous to the body of the place; he will alfo be under the neceffity of doing this, whenever the body of the place is conftructed on a *fyftem of demolition*, or with double baftions: he muft determine on the fpot from actual obfervation, whether there be any readier or furer method of reducing them than by opening breaches.

66. In the fecond plate thefe directions (63, 64) are exemplified: the battery in breach A is oppofite to the part M M of the face of the ravelin in which a breach is to be made, and fome guns might if neceffary be placed at I to bear on it obliquely; the collateral battery B is directly oppofite to the part Q that flanks the face M M. The battery in breach C is oppofite to the part N N of the face of the baftion in which a breach is to be made, and if the ground at C does not admit of a fufficient 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 fappers within it; thefe two batteries will be fupported by the collateral battery D oppofed to the flank R.

The face M M of the ravelin and the flank R are enfiladed from the mortar battery G; and fome ftone-mortars are placed at F and E, to project ftones 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

MM: 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-braie, 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 C C correſponding to the part K K of the face of the ravelin; and other batteries at D, E to open a breach at F F correſponding to the part L L 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 K K and another at P to ruin the defences Q of the breach L L, and the counter-guards are ſo narrow that the guns cannot be brought up through the breaches C C, F F 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

of the traverſes of which there ſhould be ſeveral to prevent the batteries being enfiladed. The interior width of the embrazures 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 embrazures 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 narrownefs and fteepnefs is a very troublefome and tedious operation, fince they muft be dragged by men.

CHAP. VII.

OF THE ATTACK OF COUNTERMINES.

71. HITHERTO the befieger has been fuppofed to conftruct his batteries on the glacis and the other parts of the outworks, without any moleftation from the countermines of the befieged: but if the place be well countermined and under the direction of fkilful officers, the eftablifhment of the batteries will be a very arduous undertaking; fince in this fubterraneous war the advantage lies on the fide of the befieged. That the fecond and third batteries may be erected in proper fituations, and the fubfequent operations of the fiege not retarded by the fpringing of the countermines, one of the firft objects of the befieger is to render them of no effect; either by filling them with water by means of a canal made for that purpofe; by rendering the air unfit for refpiration, by throwing into them various compofitions that emit an infupportable ftench and fmoke of a fetid and poifonous nature; by making a few fougaffes to cut off the communications between them and the body of the place; by overfetting on the principle of compreffion, the galleries and branches intended to blow up the batteries; or finally, by feizing poffeffion of the countermines along the front of the attack and preventing the befieged from entering into them. But the befieger not having it always in his option to adopt the moft convenient method, even when provided with an exact plan of the countermines; and being, when he has no plan, under the neceffity of feeling his way with extreme caution and at great hazard; here follows a general idea of each mode of attack, that the befieger may judge which is beft fuited to the particular exigency.

72. When the level of the countermines is lower than the ditch, fo that a ftream of water may be made to flow into them, this expedient will be the moft eafy and effectual. To this end, the pioneers are employed in digging a proper canal; while the miners divided into fquads are fearching

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 overset 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 ſubteraneous 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 wherever 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 empoiſoning 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 4½ feet. The galleries are 6 feet high, and about 3½ feet wide. The branches 4½ 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	$18\frac{1}{2}$
$13\frac{1}{2}$	—	1	7	—	2	0	$1\frac{1}{2}$
$16\frac{4}{5}$	—	2	1	—	3	3	$10\frac{1}{2}$
20	—	2	4	—	6	2	10
$23\frac{2}{5}$	—	2	9	—	10	2	13
$26\frac{4}{5}$	—	3	2	—	15	2	27
$30\frac{1}{5}$	—	3	6	—	22	2	$1\frac{1}{2}$
$33\frac{3}{5}$	—	3	11	—	30	1	16
$36\frac{4}{5}$	—	4	4	—	41	0	0
40	—	4	9	—	53	1	22
$43\frac{1}{5}$	—	5	1	—	67	3	$17\frac{1}{2}$
$46\frac{2}{5}$	—	5	6	—	84	2	$27\frac{1}{2}$
$49\frac{3}{5}$	—	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 countermines 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 $10\frac{1}{2}$ cwt., to which add $5\frac{1}{4}$ cwt. or the half; then $15\frac{3}{4}$ 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 $15\frac{1}{2}$ 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 countermines 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 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, diftant from each other about 50 or 60 feet, fhould be made near the foot of the revetement by the battering guns; floping even for that purpofe, if neceffary, the embrazures and the top of the counterfcarp: the wall being thus pierced and the defcent and paffage acrofs the ditch completed by the fappers, the miners fhould be introduced into each hole, to drive a fhaft into the terreplein, equal in length to the height of the wall; and having made branches to the right and left, they fhould make a chamber at the extremity of each, to deftroy the furrounding countermines. If they meet with a branch or gallery, they fhould endeavour to chafe the befieged from it by throwing in fetid combuftibles; and in the mean time prepare and charge a chamber or two to deftroy thefe countermines and fhake down the cafemates: while one party of miners is thus employed, another fhould explore the communications leading to the countermines under the glacis from the attacked outworks, in order to drive the befieged from thence by force or other means.

Thefe operations are carried on under cover of an inceffant fire of mufquetry from all the lodgements that bear upon the ditch, to check the befieged in any attempt to deftroy the epaulment, or difturb the miners.

81. If the attacked work be very fpacious and the befieger under the neceffity of erecting batteries at the gorge; after having deftroyed the countermines under the breach (80), he muft effect a lodgment in the gorge by affault; and then by finking fhafts endeavour to cut off the communications between the countermines and the body of the place: for this purpofe the direction given (73) for the attack of the countermines under the glacis may be fuccefsfully applied. While this is going forward, he fhould endeavour by means of the fhafts funk upon the capital, or of the countermines he has got poffeffion of, to penetrate into the galleries under the gorge of the work, and totally expel the befieged, afcertaining by thefe means the fecurity of his batteries.

82. From thefe premifes it may be inferred;

1. That to attack a place with two ftages of countermines, there muft 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.

CHAP. VIII.

Of the Surrender of the Place.

83. THE artillery will continue firing after the chamade 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.

CHAP. 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 palliſadoes. 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 embrazures, 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 mattraſſes.

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 fiege to a fpeedy termination.

4. When from bad roads, or other circumftances, the artillery is infufficient to profecute the fiege with vigour.

92. In the firft and fecond cafe, the engineers make trenches of communication from different parts of the line of circumvallation, at the diftance 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 inclofed in a redoubt of refpectable profile, and fpacious enough to contain a guard fufficient to fecure it againft any attempts of the garrifon. Guards are likewife pofted 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 fuftain the redoubts, and give time to the troops at the camp to come to their affiftance in cafe of a general fally: but if the batteries be covered by a river, canal, morafs, precipice, or defile, a ftrong guard in each redoubt will be fufficient for their fecurity.

93. In the third cafe, (91), the befieger muft exert himfelf to turn every acceffible point, whence the town can be annoyed either with fhot or fhells, to the greateft advantage, by planting on them a proper quantity of artillery of large calibre.

The proportion of ordnance for this kind of fiege is greater than for regular fieges, particularly when the blockaded town is very large; unlefs in regular fieges, a fire is directed from every fide on the moft populous quarters of the town, in order to excite confternation and terror among the inhabitants.

94. In the fourth cafe, the lines or trenches judged neceffary on the occafion, ought to be conftructed with a view to their being ufeful, when an adequate quantity of artillery arrives, to convert the blockade into a regular fiege; the vivacity of which muft depend on the knowledge the befieger has acquired concerning the ftrength of the garrifon, the ftate of the fortifications, and the nature of the adjacent country.

An army fometimes fits down before a place of great importance, in hopes of inducing the enemy to abandon an advantageous poft in order to relieve the place, and perhaps hazard a general engagement. The moft 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.

CHAP. X.

Directions for demolishing the Fortifications of a City.

96. It is generally deemed ſufficient to demoliſh the revetements of the works, and blow up the magazines, caſemates, &c.; the deſtruction ſeldom extends to the terre-plein, 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 *Trebia*, 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 $\frac{2}{7}$ 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,

 O, P, where

O, P, where the walls interfect, and under the pilafters Q which fupport the fronts A B, C D, and on which the roof refts (97, No. 4). The chambers in the wall F F which is without any break, are diftant from each other, and from the principal mines, 12 or 15 times the lenght of the fide or diameter (97, No. 5); and if in the faces A B, C D, the chambers A, H, I, be too far diftant 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 fize of the principal chambers K, L, M, fhould be increafed by about ¼. The mines thus difpofed may be divided into two claffes; viz. thofe made in fingle walls, as Q R, S, and thofe made in crofs walls, as A H, &c.

100. In this profile P P reprefents the plane of the ground furrounding a building: (Pl. 4, Fig. 5) the walls are fingle, 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 ½ of the thicknefs of the wall D E in depth as D B, and 3½ feet in width as C D. Let the chamber G of a cubical form, be made ⅓ of B D diftant from the bottom B F, and a wooden box of proper dimenfions for containing the quantity of powder afcertained by preceding experiments (98) placed in it; and if there be any reafon to apprehend that the powder may be damaged by the moifture 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 fize of the planks that are to clofe the opening. Any projections or cavities in the wall where the trench is dug, fhould be fmoothed or filled up with well worked plaifter. The planks for blocking up the chamber fhould 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 efcape of the inflamed fluid) prepared. The box being filled with powder, and a faucifton laid in a pitched wooden trough, communicating with it, the opening is exactly clofed; 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 interftices filled with clay and dung well rammed.

101. To

101. To make mines of a cubical form in a crofs wall A B; let C, D, E, F reprefent a fquare pit hollowed in the adjoining ground; (Pl. 4, Fig. 6) the fide of which is 4½ feet, and the depth 1 ½ of the thicknefs of the ftrongeft wall. At about ⅓ from the bottom, hollow out in the wall B a branch F N G H 3 ½ feet high, 2 ½ feet wide, and ½ of the thicknefs of the wall B in length; then in K B the centre line of the wall B make the chamber K of a proper fize: 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 fauciffon applied, and the opening I clofed and blocked up with beams laid horizontally to L G: let the opening F N be clofed in the fame manner as I; and difpofing the mantlets around the fides of the pit, drive in horizontal layers of beams croffing each other alternately at right angles, till they reach the furface of the ground, always filling the interftices with dung and clay, and taking care to bring out the fauciffon. It fhould be remarked here, that though in this cafe, where it is intended to blow up a greater extent of wall, the fame charge is ufed as in the preceding paragraph; yet greater refiftance being oppofed to the explofion 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 fhould be hollowed in a hemifpherical form, in the following manner: A A is the profile of a fingle wall; dig a fquare pit B D C F the fide of which is 4 ½ feet; then make the branch B L G E 3 ½ feet high, and of fuch 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 fide of which is equal to the diameter of the hemifphere would contain: at the mouth of the chamber make the ledge H H, and fmooth the roof and bottom of the branch with well worked plaifter. Having charged the mine, applied the fauciffon, clofed 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 ftrong beams R; then clofe the entrance B E, and placing other mantlets againft the wall and the oppofite fide C F, lay rows of beams horizontally between them, filling all interftices with clay and dung, and carefully bringing out the fauciffon.

103. The figure reprefents the plan of two walls which interfect each other, and exceed 7 feet in thicknefs: (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 with

with the powder, the great refiftance oppofed by the earth upon the upper floor, prevents the powder from acting upwards, and directs its force againft the walls of the tower, which being of no great folidity, eafily yield and fall down.

SECOND PART.

Of the Service of Artillery in the Defence of Places.

105. THE fcience of defence conftitutes one of the moft effential branches of the military art, fince a few troops are thereby frequently enabled to make head againft a very fuperior army, to the prefervation of a whole country: and as in the profecution of this fyftem, the inferior army is often compelled to fuftain a fiege, the defence of places forms one of the moft important parts of this fcience. Now the defenfive fyftem may either be the refult of a premeditated plan; or a nation may be unexpectedly forced into it by the fudden invafion of a foreign enemy, or by a train of unfortunate events, that oblige an army which began the war with the faireft hopes of conqueft, to change its fyftem and act on the defenfive.

106. When a defenfive war is forefeen, fome of the fenior officers of artillery are fent to infpect the quality and number of arms and ftores of all forts in the different garrifons; examine the condition of the magazines, works, and countermines; and take notes of every thing that may be wanting in cafe of a fiege.

After the infpection, each officer makes a report in writing of the number and nature of artillery and carriages, with his propofed arrangement of them; and alfo of the proportion of tools, machines, arms, and ammunition, which in his opinion may be adequate in proportion to the ftrength of the garrifon, for making a vigorous defence;

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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.

CHAP.

CHAP. I.

OF THE DISPOSITIONS FOR THE REGULAR DEFENCE OF A PLACE PREVIOUS TO ITS INVESTITURE.

108. THE 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 violents 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

of

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 embrazures 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 embrazures. 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 embrazures, 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 embrazures, the merlons would be ſoon deſtroyed by the enemy's artillery: the ſame rule ſhould be obſerved in opening embrazures 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 embrazures; but in the ravelin on the front of the attack, a greater ſpace is left from the ſaliant 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 ſaliant angle for the barbette, 2, 3, and embrazures 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 lodgements 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 unſerviceable; 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

be

be tripled; the refult will give the proper ftrength of the garrifon for a regular fiege.

In mountainous fituations, where there is no covered-way, two men are allowed for every 10 feet along the magiftral line of the front attacked, including the outworks; to this add the neceffary guards, and the fum tripled will give the number of the garrifon.

119. For example; fuppofe a regular pentagon, of which the line of defence is 134 toifes; this gives 56 toifes for the faces of the baftion, and 25 toifes for the flanks; let the profiles of the ravelins, which are fuppofed to be the only outworks, admit cannon. The following will be the difpofition of artillery.

	No. of Guns.	
	Brafs.	*Iron.*
On the two faces of the baftion on the front attacked	20	—
On the two faces of the collateral ravelins	12	
On the two faces of the ravelin between the baftions	12	—
On the barbette batteries and flanks	—	18
Total	44	18

This number, defigned for the firft part of the direct defence, will be more than adequate for the fecond part; two or three light 4 prs. may be added for fallies or counter-approaches, when this mode of defence is practicable.

If the place be hexagonal with a line of defence of 134 toifes, and the flanks a little longer, two pieces of brafs and two of iron fhould be added to the above proportion.

Suppofing the befieger can carry on his approaches upon the capitals of the baftions and ravelin, and erect batteries in breach on the creft of the glacis; the number of mortars will be at leaft

6	Stone-mortars
6	Royal ditto
4	10 inch ditto
4	13 inch ditto
Total 20	

If

If the garrison [illegible] constantly on duty, and [illegible] stant fire; there [illegible] in reserve; [illegible] reconnoitring parties.

120. This [illegible] of a place in a [illegible] transported [illegible] so uneven [illegible] tion and [illegible] without making use of [illegible] each attack [illegible] artillery; and that there may not be a [illegible] the quantity of [illegible] of the same nature [illegible] that means the ammunition [illegible] swer equally well for all [illegible].

If in the vicinity of a place situated [illegible] tainous country, there be any [illegible] cannon of the ramparts [illegible] himself to the great annoyance of the garrison, a proper number of [illegible] vided for firing into them.

121. The number of rounds for each gun depends on the quantity of the besiegers artillery, and the [illegible]. 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 [illegible] 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 lodgments 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 up against the embrazures of the place.

The

The mortars always being placed under cover of the ramparts cannot be affected by direct firing: the interruption from curvelinear projections may be reckoned at about $\frac{1}{6}$ 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 soldier 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 sorties. 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.

	Days.
From the opening of the trenches till the lodgment is compleated 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, blunderbuſſes 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 palliſadoes, 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 N N, (119).

Proportion of Guns, Carriages, Ammunition and Stores.
Ordnance, Carriages, and Side-arms.

	Nature. Pr.	No.
Braſs guns	32	12
	16	18
	8	12
Iron ditto	8	18
Braſs ſhort ditto	4	4
Total of guns		64

Carriages

Carriages of different natures for the above guns			96
Setts of fide-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 fide-arms for ditto			40

Spare Arms for Carriages and Side-arms.

Wheels with iron ftreaks for carriages of different calibres		36
Iron axle-trees for ditto		36
Cheeks for carriages		24
Spokes for wheels		200
Staves for fpunges		100
Rammers for ditto		200
Sheepfkins for ditto		100
Wad-hooks		12
Plates of copper for ladles		60
Copper nails for ditto	lbs.	20
Iron nails for fide-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 brafs gun and 200 ditto for each iron ditto	10800	
— 4 — At 200 rounds	800	
Cafe-fhot for 32 and 16 prs.		2000
Ditto for 4 prs.		400

Shells.

		Number.
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 rounds each	cart loads	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-waggons	3
Limbers	12
Block-waggons	6
Common ditto	30

Cordage.

Ropes for guns	10		
Spare ropes for gins	6		
Ditto for windlaſſes and capſtans	2		
Double ſlings	10		
	cwt.	qrs.	lbs.
Ropes of various ſizes	18	—	—
Packthread	1	—	—
	Number.		
Drag ropes	50		

Armoury

Amoury.

	Numbers
Long wall-pieces	12
Wall-pieces	600
Mufquets	600
Piftols	20
Spare rammers for mufquets	600
Efpontoons	400
Scythes with handles	400
Cuiraffes with cafques	50

Ammunition.

Flints			40000
Bullets for wall-pieces			3000
	cwt.	qrs.	lbs.
Lead for mufquet balls at 20000 rounds a day, including forties	274	—	—
Match	109	—	—
			Number
Powder ... whole barrels			3600
	cwt.	qrs.	lbs.
viz. For 10800 rounds from 32 prs. at 10¼ lb. each	988	—	—
For 10800 rounds from 16 prs. at 5⅛ lb. each	494	—	—
For 10800 rounds from 8 prs. at 3 lb. 4½ oz. each	316	—	—
For 800 rounds from 4 prs. at 1lb. 10 oz. 4dr.	11	—	—
For 3600 ditto from 13 inch mortars at 12 lb. 4¼ oz.	395	—	—
For 1200 ditto to roll upon the breach at 8lb. 3¼ 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 ftone ditto at 4lb. 1 oz. 9 dr.	263	—	—
For 12000 hand grenades at 3 oz. 4 dr.	22	—	—

	cwt.	qrs.	lbs.
For 600000 cartridges for the infantry	182	—	—
For 3000 cartridges for wall-pieces	300	—	—
For artificial fire-works and combuſtibles	91	—	—
Add $\frac{1}{10}$ for accidents	360	—	—

Combuſtibles.

	Number.
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

	cwt.	qrs.	lbs.
Port-fire compoſition to be put into the ſhells	54	—	—

Articles of different kinds.

	Number.
Oaken planks for platforms	1000
Sleepers for ditto	500
Ballaſt-baſkets	1000
Hand barrows	100
Spare helves for intrenching tools	2000
Sand bags	20000
Large oil-cloths	100
Small ditto	100

	cwt.	qrs.	lbs.
Greaſe	36	—	—
Flannel for cartridges	yards		300

Iron-work and Nails.

	cwt.	qrs.	lbs.
Iron-work of ſorts 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 Compofitions of various kinds.

Powder; pulverized faltpetre; flowered-fulphur; powdered charcoal; crude antimony; rofin; tar; pitch; turpentine; fpirits; fpirits of wine rectified; oil of olives and lintfeed; vinegar; yellow wax; fuet; greafe; affa-fœtida; glue; thread; fine and coarfe tow; linen and cotton cloth and barras; fewing thread; old linen and match; faggots; iron wire; thin cord; fmall iron chambers and piftols for the carcafes. The quantity of thefe articles depends on the number and kind of fire-works, and the nature of the compofitions, which may be eafily known from the laboratory books.

Articles for the Laboratory for making up Fire-works.

		Number
Cheft of drawers		1
Steel-yard		1
Balance with fcales		1
Tables		3
Ditto for mealing powder and mixing compofitions		2
Large copper cauldrons		3
Medium and fmall ditto		5
Iron trivets for ditto		6
Large peftle and mortar of bronze		1
Common hammers		3
Pincers	pairs	3
Large and fmall axes		3
Rafps for wood		10
Files		10
Drawing knives		10
Common ditto		6
Large and fmall fciffars	pairs	6
Iron punches		10
Straight and crooked awls		10
Packing needles		12
Sewing ditto		100
Common and fine faws		8
Augres and gimblets		30
Common fieves		6
Fine filk ditto		3

		Number.
Small wooden bowls for holding compofitions		10
Benches for driving fufes		10
Drifts for ditto		24
Tin funnels of fizes		10
Tin meafures ditto		50
Wooden fetters for fufes		10
Small ditto		20
Oaken planks with holes for loading the hand grenades and fufes		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
Brafs fcales		2
Wooden ditto		12
Large and fmall oil cloths		20
Common compaffes	pairs	4
Calibres	pairs	2
Glue brufhes		12
Royal and common paper	reams	10
Pafteboard	ditto	2
Flints, fteels, tinder-box and matches		

	cwt.	qrs.	lbs.
Tacks and large nails	1	—	—
Wax candles	3	—	—

Intrenching Tools.

	Number.
Pick-axes	1000
Mattocks	1500
Shovels	400
Large and fmall axes	200
Hand bills	500

Tools

Tools for 12 Carpenters.

	Number.
Broad axes	12
Small ditto	12
Crofs-cut faws	4
Common ditto of forts	12
Triangular files for faws	24
Planes	30
Mortaife chiffels	24
Hatchets	12
Square and round gouges	16
Chiffels of fizes	36
Large and fmall compaffes	8
Large gimblets	16
Small ditto	80
Drawing knives	12
Sledge hammers	4
Pincers ... pairs	12
Whetftones	4
Hand-vices	8
Iron crows	4
Working benches	8

Tools for 6 Blackfmiths.

Large bellows with anvils and ftocks	2
Forge tongs ... pairs	16
Nail borers	6
Forge hammers	12
Sledge ditto	6
Files of fizes	24
Benches with beak irons, one large one fmall	4
Small vices	6
Small anvils	4
Iron prefs for binding and ftreaking wheels	1

Tools for 12 Armourers.

Forge bellows	4
Anvils with ftocks	4
Small anvils	6

		Number.
Forge hammers of fizes		24
Forge tongs	pairs	16
Benches with iron and wooden beaks		12
Files of fizes		200
Rafps		50
Planes		24
Large and fmall gouges		48
Inftruments for making fcrews of fizes		16
Drills with bows		12
Augres		12
Gimblets		60
Drawing knives		12
Hand vices		12

With a proper quantity of coals for the black-fmith and armourers.

If the place be countermined, there fhould be the fame proportion of miner's tools as in the former inventory; taking care to increafe 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 occafional works, and for boxes to contain the powder; beams for making the frames of the occafional works; pitched wooden troughs; fauciffons made of coarfe cloth; large oil-cloths; fand-bags; petards of fizes; fhells; piftols; blunderbuffes; tin chandeliers. Lanterns; olive-oil; candles; nails of 40 to the lb.; powder; clay; old dung; inflammable and fœtid compofitions. The quantity of each of thefe articles muft be apportioned to the manner in which the mines are charged, and to the method of carrying on the fubterranean war, which will be enlarged on in the 4th chapter.

126. The number of artillery-men for the daily fervice of the guns and mortars contained in this inventory, may be eafily inferred from the former remarks on that fubject (57): three times that number will be the proper compliment for the defence of the place; one part is on duty on the batteries, and the fecond is preparing and providing the batteries with ftores, while the third is repofing. If the corps of artillery be not fufficiently numerous for all thefe duties, the line muft furnifh a certain number of additional gunners: four men at leaft, fhould 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 laying, 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 N N.

127. THE 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 embrazures 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 œconomy 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 $\frac{2}{3}$ of the weight of the ball for muſquets, &c. $\frac{1}{2}$ 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 troncated cone.

Point

		Point Blank.	Longeſt Range.
		Yards.	*Yards.*
Muſquet		270	1348
Wall-piece		303	1550
Long wall-pieces		438	2360
Guns	4 pr.	438	3035
	8	540	3372
	16		3541
	32		4046
Mortars	Royal		1348
	10 inch		1686
	13 ditto		2192
	17 ditto		2697
	Stone		337

CHAP. III.

OF THE DISPOSITIONS FOR THE ACTUAL DEFENCE.

130. WHEN 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 additionals 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 countermines.* The whole front of the attack is lighted during the night, that the artilleriſts 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 countermines 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 embrazures 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 embrazures 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 manoeuvre 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 saliant 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 lodgements on the creſt of it; and every embrazure 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 intention, 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-commençe.

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 gla[illegible] by ſap, all the mortars ſhould play on the. con[illegible]ni[illegible] that will be made along the faces; and while the [illegible] is [illegible]rying on, it ſhould be enfiladed by the guns [illegible] m[illegible] that bear on it. If the guns in any of t[illegible] at[illegible] can plunge into the enemy's lodgments on [illegible]

embrazures 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 embrazures 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 embrazures 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.

CHAP. IV.

Of the Defence of the Countermines.

142. IN 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 fundamental

damental 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 sauciffon 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 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 diſ-

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 enterprizes 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.

PART V.

OF THE USE OF PERMANENT COUNTERMINES IN THE DEFENCE OF PLACES.

155. FOUGASSES 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 confideration, (as the number and difpofition of the enemy will be difcovered by means of light balls, &c.) whether it will be more advifeable inftantly to fpring the fougaffes, or wait till their lodgments are completed: This muft depend on the garrifon, and the circumftances of the fiege. Suppofing the attack to be fo vigorous that the garrifon is compelled entirely to abandon the covered-way, a ftrong detachment fhould under cover of a heavy fire from all the works that command the places of arms force their way into them again, and fet fire to the fauciffons that lead to the fougaffes; and immediately after the explofion, retire to their former poft, and pour in a very heavy fire of mufquetry.

157. If the befieger attempt to get poffeffion of the covered way by fap, the fougaffes fhould be fprung fucceffively, accordingly as he makes his lodgments; taking care to fpring them before the enemy can difcover and render them ufelefs.

158. The befieger having re-eftablifhed his lodgments on the creft of the glacis, and begun to conftruct his batteries in breach, the chambers of the countermines of the firft ftage beneath the batteries are charged: the quantity of powder fhould not be too great for the following reafons.

1. Left the befieger lodge himfelf in the excavation or *entonnoir*; the ground fhould only be fhaken enough to overfet the batteries and bury the guns.

2. Not to damage the contiguous countermines by too violent an explofion; which might render them of no effect in oppofing the enemy in making his defcent into the ditch.

3. Not ufelefsly to expend powder, which may before the conclufion of the fiege be wanted for fome effential purpofe.

159. That the charge may act only on the fide of the line of leaft refiftance, the paffage to the chamber fhould be very folidly filled up for a length and half of the line of leaft refiftance. For example, fuppofe 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 leaft refiftance: 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 fize to contain the powder: having filled it and applied the fauciffon, cover it with planks; and in cafe 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.

CHAP.

CHAP. VI.

Of the Defence of Places constructed on a System of Demolition.

164. THE 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.

CHAP. VII.

Dispositions for Defence of a Place irregularly besieged.

169. THE subject of this chapter applies to all fortifications constructed on the modern system; to those thrown up on the spurt 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 situation,

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 fuperabundance of powder, fireworks, and combuftibles, 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 fupplied with fuel till the whole be expended.

One of the moft effential points towards prolonging the defence in this cafe, is not to expofe the garrifon to unneceffarily hard duty. Every avenue by which the enemy can get accefs to the place through the ditch, as canals, aqueducts, &c. ought to be effectually blocked up, and every precaution taken to guard againft furprize: no more men fhould mount guard during the night than are abfolutely neceffary; and even this number fhould be diminifhed during the day: the garrifon ought to be well fed, and for the fake of exciting emulation, any foldiers diftinguifhed for activity or intrepidity, fhould be handfomely rewarded. But if the troops, though fufficiently numerous, be from want of experience or fufpicion of their fidelity, unfit to be intrufted with the defence of the covered way; the governor and the principal officers fhould endeavour to inftruct them in the moft fimple and material parts of their duty, and fet them examples of indefatigable zeal and exertion: they ought to be particularly careful to prevent their being feized with a panic, check all irregularity, and be on their guard againft mutinies, which frequently happen in regiments compofed principally of deferters.

175. The four cafes in which a fortrefs is blockaded, have been already mentioned. To render the blockade of no effect in the firft cafe (91, No. 1), the magazines and barracks are made bomb-proof, and proper precautions taken to prevent and extinguifh fire: in large cities expofed on every fide to bombardment, where the houfes cannot be fecured from fhells and red-hot fhot, the governor to cover the inhabitants as much as poffible, fhould endeavour by the moft prompt and vigorous meafures to keep the enemy at a diftance; by making powerful fallies, throwing up lines of counter-approach, and feizing and fortifying with artillery every ftrong poft in the vicinity of the city.

176. When a blockaded city has not the moft diftant profpect of fuccour, the garrifon fhould keep up a very heavy fire from their artillery, and frequently make large fallies, that they may compel the enemy to raife the fiege: by thefe 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.

CHAP. VIII.

Of Counter-approaches.

177. COUNTER-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 invariable 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 fortreſs, 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.

THIRD PART.

OF THE SERVICE OF ARTILLERY IN THE FIELD.

183. THE 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 propofed fyftem of operations fhould be confidered: fince the army ought according to the nature of the country to be compofed either of infantry folely; or of infantry and artillery; or of infantry, cavalry, and artillery. The proportion of each fpecies of troops varies alfo, accordingly as the country is level or mountainous; interfected by rivers, ravines, and moraffes; or covered with woods: the number and quality of the enemy's troops is likewife another point effential to be afcertained.

CHAP. I.

OF THE SEVERAL SPECIES OF TROOPS THAT COMPOSE AN ARMY.

186. UNIVERSAL experience proves that the fuccefs of an army depends on its compofition, and the manner in which its marches and difpofitions in the day of action are regulated.

There are certain judicious combinations founded, in the opinion of the beft military writers, on the different fervices of the feveral fpecies of troops, and on the manner in which each can act; relatively to the nature of the country and the method in which the foldier is armed.

187. The mufquet with the bayonet is an arm which the foot-foldier carries with eafe: with it he can march through narrow paths, and over mountainous and difficult roads; and a bridge of flight conftruction ferves for his paffage over rivers, canals, or broad ditches.

In common marches that continue about 6 hours, a foldier walks with a free and natural ftep 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 flower, according to circumftances: in the flow movement, calculating each ftep at 24 inches, and 60 fteps in a minute, a regiment of infantry paffes over 40 yards in a minute: and when it moves with an accelerated pace, it paffes over twice this fpace or 80 yards in a minute.

188. From the conftitution of infantry, the fmall fpace that each foldier takes up, and the arm he carries, this fpe-

 cies

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 carabine, 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

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 $\frac{1}{4}$ 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-

To give an idea of the advantage that the artillery has in this cafe; let us fuppofe the enemy to advance in quick time or at the rate of 80 yds. in a minute; the guns will eafily (196) make three difcharges in a minute without being annoyed by the enemy, whofe firing has ceafed; fo that while the infantry is marching the diftance of 170 yds. to attack the cannon, they will be expofed to fix rounds of cafe-fhot from each gun, which will be more deftructive the nearer they approach.

201. Artillery when oppofed to cavalry, and covered in front by a broad and deep ditch, and fecured in the rear by chevaux-de-frize, &c. has greatly the advantage; but when from the nature of the ground they are entirely expofed, the flanks and rear fhould be covered by detachments of infantry or in fome other manner. Each gun fhould be fired twice in half a minute, being the time that cavalry takes to gallop at full fpeed over a fpace of 170 yards, which is the greateft velocity that cavalry can charge with.

Guns of the largeft calibre fhould be oppofed to cavalry, as they project a greater number of fmall balls, and with round fhot do more execution in enfilading (194).

202. Thefe feveral fpecies of troops compofe the bulk of armies; and from their folidity and mutual fupport when properly combined together, are deftined for all great military operations.

There are other troops, which differ much from the former in their fervice and method of fighting: they are diftinguifhed into light-infantry and light-cavalry, and are defigned to act by detachment; for fecuring the tranquility of the camp; covering convoys; beating up the enemy's quarters; and harraffing them on marches. On them devolve all the more minute duties; but as they are never accompanied by artillery, it is needlefs to examine their conftitution more particularly. The neceffity of being acquainted with the method in which the feveral fpecies of troops that compofe armies can act, and be combined together on marches and in action, according to the nature of the ground and the difpofition of the enemy, will from the perufal of this chapter be obvious to every officer.

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 dimiſhes 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 palliſadoe 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

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 harrass 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 $\frac{1}{5}$ or $\frac{1}{20}$ 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.

CHAP. III.

OF THE FIELD TRAIN OF ARTILLERY.

210. THE 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 champaign 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 champaign 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 manœuvreing

vreing 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 dimished.

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 inlisted (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 5½ cwt. to each pair of horses beside the weight of the carriage; that they may not be worn out before the end of the champaign. 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 oppofing very powerful attacks of infantry: the particular deftination depends on the ground and difpofitions of the enemy.

213. The following is a return of horfes, &c. for one brigade of 8 prs.

	Horfes.
Five 8 prs. mounted on travelling carriages, with limbers, fide-arms, coins, and hand-fpikes, with 4 horfes to each	20
Two fpare carriages, with limbers, carrying 4 fpare wheels, 4 fpare axle-trees, 4 fets of fide-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 $4\frac{1}{2}$ cwt. of iron-work for gun carriages, 2 cwt. of fpare rope, 1 cwt. of greafe, carpenters tools, lanterns and 1 cwt. of candles	4
Six powder waggons carrying 60000 mufquet cartridges, 30000 flints for mufquets, 2000 flints for piftols, $3\frac{1}{2}$ cwt. of powder, $5\frac{1}{2}$ cwt. of mufquet and piftol ball, and 10 reams of cartridge paper	24
Two waggons carrying oats for the horfes with fpare harnefs	8
Horfes for one officer, two non-commiffioned officers and a farrier	4
Number of horfes for one brigade	84

Befide 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 confifts of 4 prs. two horfes are allotted for each gun, and four tumbrils for the ammunition; the reft as above. Should the army move to a diftance from the arfenals or fortified towns, a large depôt of ammunition both for infantry and artillery ought to be brought forward and lodged in fome caftle or walled town under the care of a detachment of infantry.

214. The

214. The detachment of artillery for the fervice of each brigade confifts of a captain and two or three fubalterns; fix or eight non-commiffioned officers; ten or twelve artificers; with eight or ten gunners to each gun, according to its calibre, and a conductor of ftores for taking care of the ammunition, &c. All the brigades are commanded by a field officer, who has under him an adjutant and two affiftants. The commiffary general of artillery detaches a commiffary, to make the iffues and purchafes during the campaign.

215. When a broad river runs through the country in which the army is to act, a fufficient number of large boats are provided for making bridges, and are left in the water till wanted.

When there are feveral fmaller rivers, a number of pontoons accompany the army, carried on proper carriages, with baulks, cheffes, cordage and every thing requifite for conftructing 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 neceffity of making, and by the breadth of the rivers: the common calculation is a pontoon for every 16 feet of breadth, befide the two for the centre; if the river be navigable. The conftruction of thefe 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.

	Pairs of Oxen.
Twenty pontoons mounted on carriages	60
Twenty-four carts carrying 360 cheffes 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, fheer-lines, 6 capftans, artificers tools	8
Number of pairs of oxen	107

Inftead of pontoons, boats made of leather are fometimes carried in waggons folded up; when wanted for ufe, they are ftretched out with crofs pieces of wood, and 4 axle-trees fixed

fixed to the bottom furnifhed with fmall wheels, that they may run into the water without being damaged; upon them is laid a kind of ftage, and over that the bridge is conftructed.

In mountainous countries, fmall leather boats are carried on the backs of mules; each mule carries two. Bridges made of thefe boats will not fupport a weight exceeding 10 cwt.

In laying bridges of all kinds, whenever the river is fo fhallow that a heavy weight would fink the boat till it touch the bottom of the river, treftles fhould be fubftituted in their room, for reafons too obvious to need mentioning.

CHAP. IV.

OF THE ENCAMPMENT OF AN ARMY, AND OF THE PARK OF ARTILLERY.

217. THE troops that are to compofe an army are drawn out of their cantonments and quarters at the beginning of the war or of each campaign, and march to fome particular place where they encamp in order of battle (209). As the place of rendezvous is always at a diftance from the enemy, it is fufficient if it be dry and abounding with wood, water, hay, and ftraw: but the other camps that the army may occupy in the courfe of the campaign, independent of thefe requifites, muft in other refpects correfpond with the views of the general: the firft object is the fecurity of the troops; wherefore,

1. There fhould be in the front of the encampment a fpot fpacious enough to draw up the whole army in two lines, and to engage without being embarraffed by the tents.

2. The front and flanks fhould be covered by houfes, villages, rivulets, ditches, ponds or ravines, which the enemy cannot pafs in order of battle.

3. Above all, the rear of the encampment fhould be fecured, and a free communication eftablifhed between the magazines.

4. Any villages, houfes, or high-grounds near the camp, fhould be occupied by ftrong detachments.

5. If

5. If the camp be interfected by canals, ditches, rivulets, or other obftacles to a free communication between every part of it, bridges fhould be laid and paffages opened, that the whole may eafily move to the fupport of any part that is attacked.

218. In nothing is the ability of a general more confpicuous than in the choice of his encampments; and few circumftances have conduced more than this to gaining the moft brilliant victories; but as the full difcuffion of this interefting part of tactics would be foreign to the purpofe, our obfervations will be confined to a few points.

(Fig. 10, Pl. 6) The fixth plate reprefents a common encampment of 40 battalions and 40 fquadrons; A, the encampment of the firft line; B, that of the fecond, diftant from the firft 6 or 800 paces; C, brigades of infantry of five battalions each; D, brigades of cavalry and dragoons of 10 fquadrons each; E, the park of artillery; F, head quarters; G, the village whence the camp takes its name; H, ground for the firft line to draw up in order of battle, diftant from A at leaft 600 paces; I, ground for the fecond line to draw up in order of battle; K, houfes or barns occupied by the advanced guards of infantry; L, advanced guards of cavalry, as pofted 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 battallion as it contains files; and an interval of at leaft 20 paces is left between every two battalions of the firft line, that thofe of the fecond line may, if neceffary, pafs through them and form at I.

As many paces as there are files in each fquadron and one half more are allowed for the front of each fquadron; with an interval between every two of at leaft half the front of a fquadron, that thofe of the fecond line may pafs without interruption, and form at I. This difpofition is nearly regular when the ground is level and open; but is deviated from, if fuperior advantages can be gained by a different pofition, or the fafety of the camp better fecured. When one flank is covered by a ravine, river, lake or impaffable morafs; 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 practifed for thefe two laft centuries; but in the defenfive fyftem,

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 antients, 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

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.

CHAP. V.

OF THE MARCH OF AN ARMY, AND OF THE DISPOSITION OF THE TRAIN OF ARTILLERY.

223. LONG 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 artilery 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 appoined 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-colour-men 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 it's 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

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 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.

CHAP. VI.

Of Battles and general Engagements.

228. An 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 par-

 ticular

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 defendants 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 crouding 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 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 [illegible] infantry four deep [illegible]

The artillery is [illegible] ture of the ground and [illegible] most execution.

234. The [illegible] receive battle, [illegible] and the commanding [illegible] do their utmost [illegible] of artillery [illegible] action labour [illegible] ral necessary manœuvres [illegible] number of additional [illegible] to assist in working the guns [illegible] ditches; or laying down [illegible] they should be under the command [illegible] non-commissioned officers.

It is sometimes impossible [illegible] connoitre the country [illegible] artillery ought to be [illegible] in this case ride along [illegible] come to close action [illegible] commander in chief [illegible] as appear the most advantageous [illegible] orders he receives.

When the armies engage [illegible] quently the whole front [illegible] manding officer of artillery [illegible] tended by some subaltern officers [illegible] send orders to the several brigades [illegible] he should never quit the commander [illegible] mission; and then [illegible] or transport himself [illegible] absolutely requisite [illegible] nary reinforcements [illegible] enemy, or for [illegible]

235. The officers of the several brigades [illegible] their orders, distribute the artillery [illegible] the guns, and immediately open [illegible] flank, that they may be able to move [illegible]

When the army advances [illegible] horses to the place of action; [illegible] action, the spare carriages and waggons [illegible] 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 additionals 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 t the depôt (222) for more ammunition, and informs the commanding officer of his loſſes and expenditure.

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 aukwardneſs; 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 additionals practised in dragging them.

3. The officer should ever preserve an air of coolness and tranquillity, 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 flurried 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 waggons 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.

CHAP. VII.

Of the Attack and Defence of Field Fortifications.

239. TO 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, mortrass, 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 banquette: this is thrown up in places which the enemy cannot approach without being obliged to defile; 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 inftant they force the intrenchment.

3. In the third kind of intrenchment, the difpofition of the troops depends upon the mode of attack: when the enemy makes regular approaches, the fame regulations are to be adopted as in the defence of fortreffes. If the enemy attempt to carry the work by affault, the troops fhould be drawn up 3 or 4 deep on the banquette to throw in a very heavy fire, in order to make him repent of his temerity.

248. The difpofition of artillery in the two firft fpecies of field fortifications depends on the nature of the ground, and the order in which the enemy approaches. The general rule is,

1. To poft the artillery at the parts where the moft ferious 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, cafe-fhot is fired from all the guns that bear directly on his front: fome others are brought to bear obliquely with round fhot. An inceffant firing is kept up, till he is obliged to retire out of gun-fhot to rally: then the firing is fufpended; and every thing prepared for giving him a warm reception when he returns to the attack.

3. When the ground is fo favourable to the enemy, that he can by manœuvreing alter his difpofition at pleafure and keep the defendants in doubt which part he intends to attack; fome guns are kept limbered and loaded, that they may be inftantly drawn to the point of the greateft danger.

249. In attacking an intrenched camp with a profile of the firft or fecond kind, the flanks fhould be firft attempted; but if their profile is, as it fhould be, of the third kind, the troops muft 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 prefent the whole front to the fire of the intrenchment, unlefs the enemy weaken fome part not attacked in order to reinforce thofe againft which the attack feems directed.

When any defect in the works, or the interior of the camp, that embarraffes the troops in their manœuvres is perceptible, the weight of the attack fhould be directed againft that part; otherwife 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.

250. 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 cafes the diftance of the guns from the works fhould be from 240 to 340 yards; and when very much expofed to the enemy's mufquetry, they may be in fome meafure fheltered by cafks filled with earth, or with the doors and windows of the neighbouring houfes: Some officers from an abfurd and falfe principle of honour have difregarded this mode of covering the artillery; but thofe who confult the real honour of a foldier will know, that it confifts in advancing the interefts of their country in the moft certain and expeditious manner; it is therefore the firft duty of an officer to cover his men as effectually as poffible. Some guns ought to march in the rear of the column to feize any opportunity of acting to advantage.

251. Artillery is alfo employed in the attack of intrenched pofts, in the following cafes:

1. When the intrenchment is of great extent; as lines of circumvallation, and expofed to infult: fome guns are fent with a body of infantry to make a falfe attack during the night, in order to caufe a diverfion of the enemy's troops: the falfe attack is made at a diftance from the real one, and commences fome hours before it with a very heavy fire.

2. When the profile of the intrenchment fecures it from infult, a kind of irregular fiege is carried on with batteries and trenches: thefe attacks are generally directed againft the flanks of the intrenched camp, or fome faliant point.

3. In battering bridges built of boats, and covered by redoubts or intrenchments, fome guns are brought to the edge of the river, whence they can bear on the bridge; and if the oppofite fhore be lined with mufquetry or artillery, a fuperior fire muft be directed againft it, to cover the guns: when the intrenchment is injudicioufly conftructed, the infantry after the fire of the artillery has continued for fome time, fhould advance and ftorm it.

4. When the enemy having laid a bridge of boats, endeavour to pafs the river; the troops and artillery that are to difpute the paffage, form oppofite to the bridge, to enfilade the enemy, who having croffed the bridge in column, will endeavour to deploy in order

of

of battle; fome guns are alfo planted on the bank to cannonade the bridge: and if the enemy cover his paffage by a fire from the oppofite fide, a fuperior fire muft be eftablifhed. It may be remarked here, that whenever a bridge is to be attacked, or the paffage of it difputed, and there are guns on both fides of the river, if the two banks be not on the fame level, the troops on the higheft bank will have the advantage, when the river is not lefs than a mufquet fhot acrofs.

CHAP. VIII.

OF THE QUARTERS OF AN ARMY.

252. IT is cuftomary to put the troops into winter quarters towards the end of autumn; and in fome countries, into fummer cantonments during the great heats of that feafon. They are lodged in the towns and villages, and diftributed according to the order of battle in which they are encamped; that is to fay, the troops that compofe the firft line are quartered in the houfes neareft to the enemy, and thofe of the fecond in the towns in the rear; regard is alfo paid to the pofition of the wings and centre, fo that the troops may on occafion march forward to the ground that is fixed on for their general rendezvous, without confufion or danger of croffing each other in the march. The quarters are more or lefs extended in proportion to the diftance between the two armies, and there is generally a river or defile in front.

253. The brigades of artillery are generally quartered together in fome city or town in the fecond line, with a body of infantry to cover them.

At every halt during the campaign, the damages were repaired as far as circumftances would admit; and advantage is now taken of the fummer cantonments, to examine and put every article in a complete ftate of repair, that on any emergency the brigades may be inftantly ready: the ammunition, &c. is left in the waggons, and the park formed in the proper order, that the horfes may be harneffed without confufion. When the ammunition is carried on beafts of burthen, it is unloaded and lodged in fome building not expofed to fire, and fpacious enough to contain it without

mixing

mixing the feveral fpecies together. The officers, non-commiffioned officers, artillery-men, drivers, conductors, and horfes are quartered in the houfes contiguous to the park, with a proper guard; particularly in conquered countries. The commanding officer of artillery having been previoufly advertifed by the commander in chief, of the pofition each brigade is to take up in the field of battle, and of the route by which they are refpectively to march, examines the roads and ground attended by his captains, and orders the neceffary 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 exprefs or concerted fignal; in the latter cafe, fome attentive men are pofted day and night to obferve the fignals.

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 poft or commanding fituation; it fhould be occupied by a detachment of infantry, fupported by one or two brigades of artillery, that it may be able to hold out for fome days, and give time to the army to affemble and march to its relief. The officer who commands thefe brigades will confider attentively the nature of the poft, and the adjacent country, and judge whether it be expofed to a coup-de-main; and whether it can be ftrengthened by any additional works: he will communicate to the commanding officer of the poft, his ideas upon the plan of defence, and poft his guns at the moft important points, with a proportion of ammunition in cafe of attack.

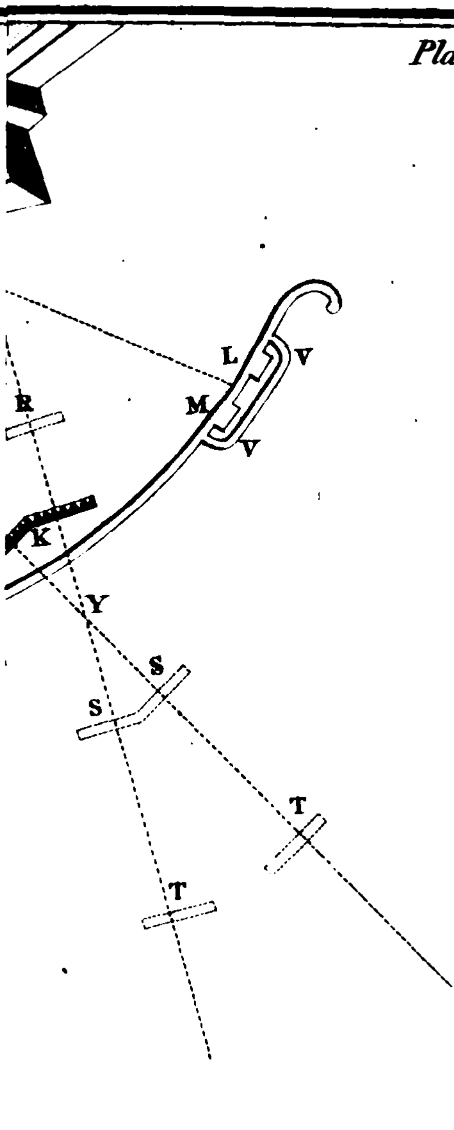
255. At length, the feafon for military operations being over, and the commander in chief having ordered the army into winter quarters in the moft convenient and plentiful country, that they may recover themfelves from the fatigues of the campaign; the brigades of the artillery move towards the place of their deftination under the efcort of a body of infantry or cavalry, marching and parking as before directed. Being arrived at their quarters, which fhould be covered from every attempt of the enemy, the ammunition is lodged in the magazines, the carriages put under cover, and the neceffary repairs inftantly begun: during the winter, attention fhould be paid to the comfort of the men, and the forage of the horfes, that the whole may be able to take the field in the enfuing fpring with recruited ftrength and vigour.

F I N I S.

E R R A T A.

Page	xiv	Line	25, *for* d'Oil *read* d'Œil
——	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* ×
	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

Plate 1.st



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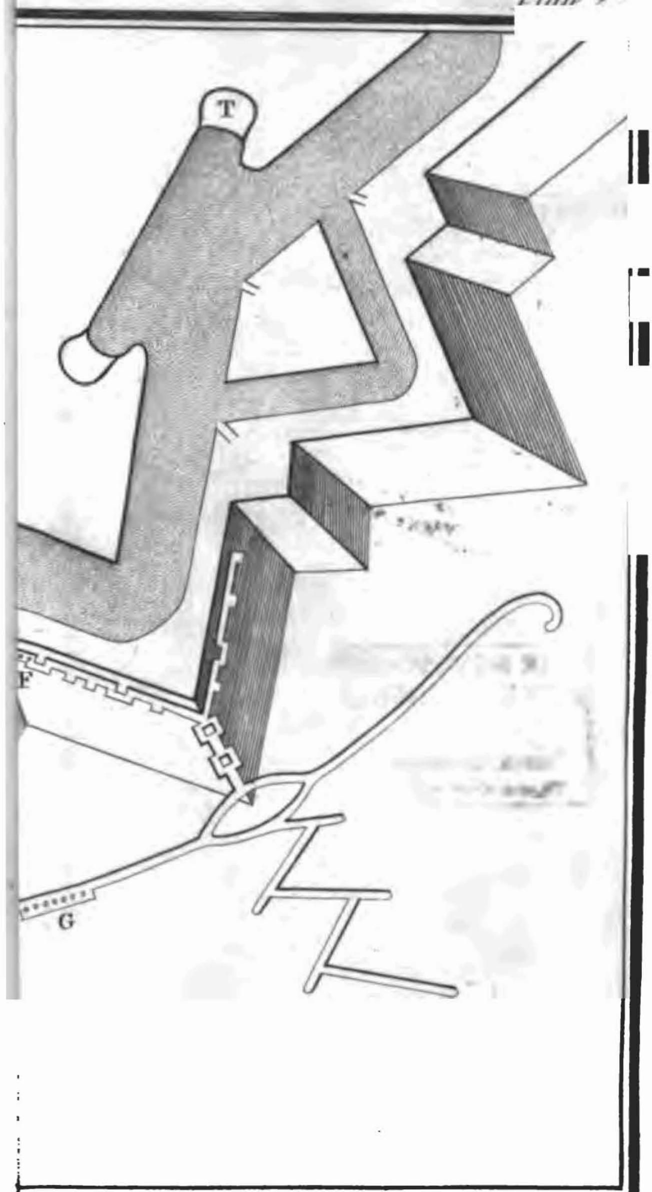

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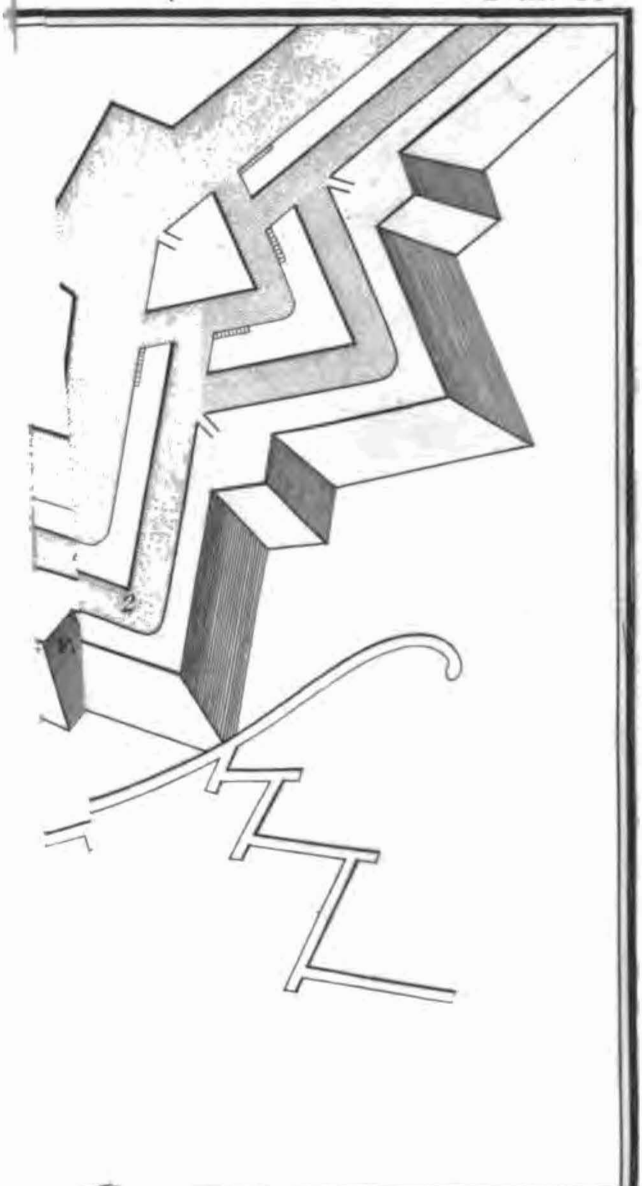
Plate 3.d



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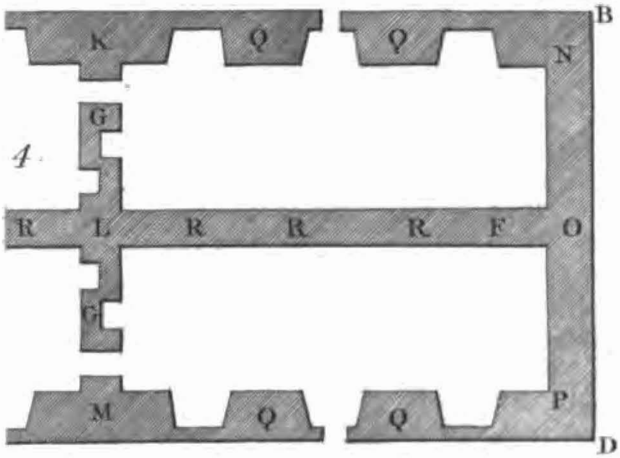
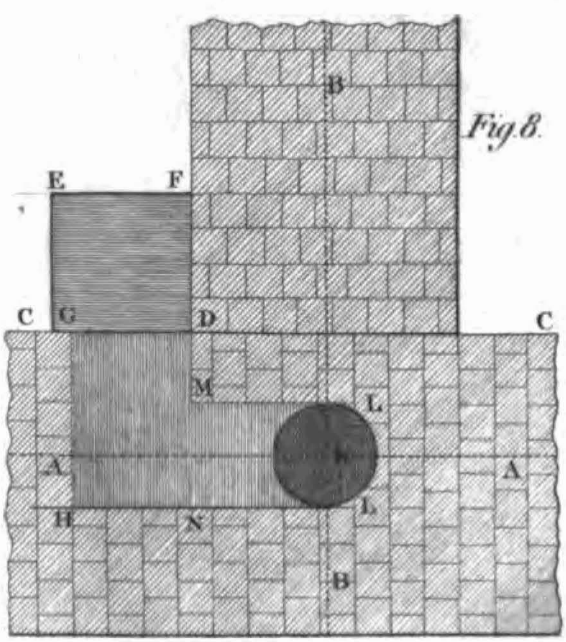


Fig. 8.



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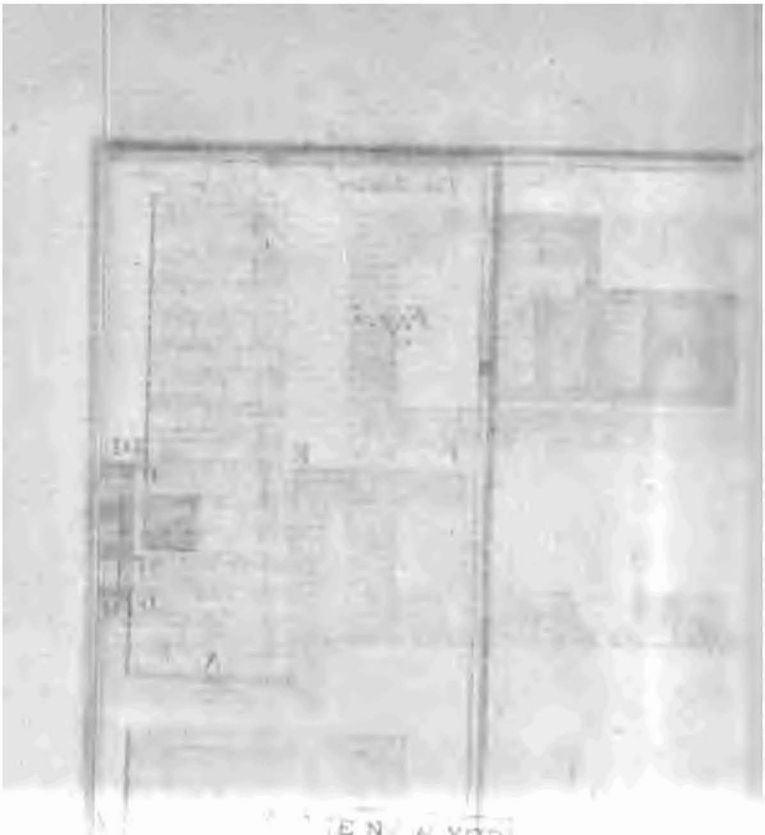

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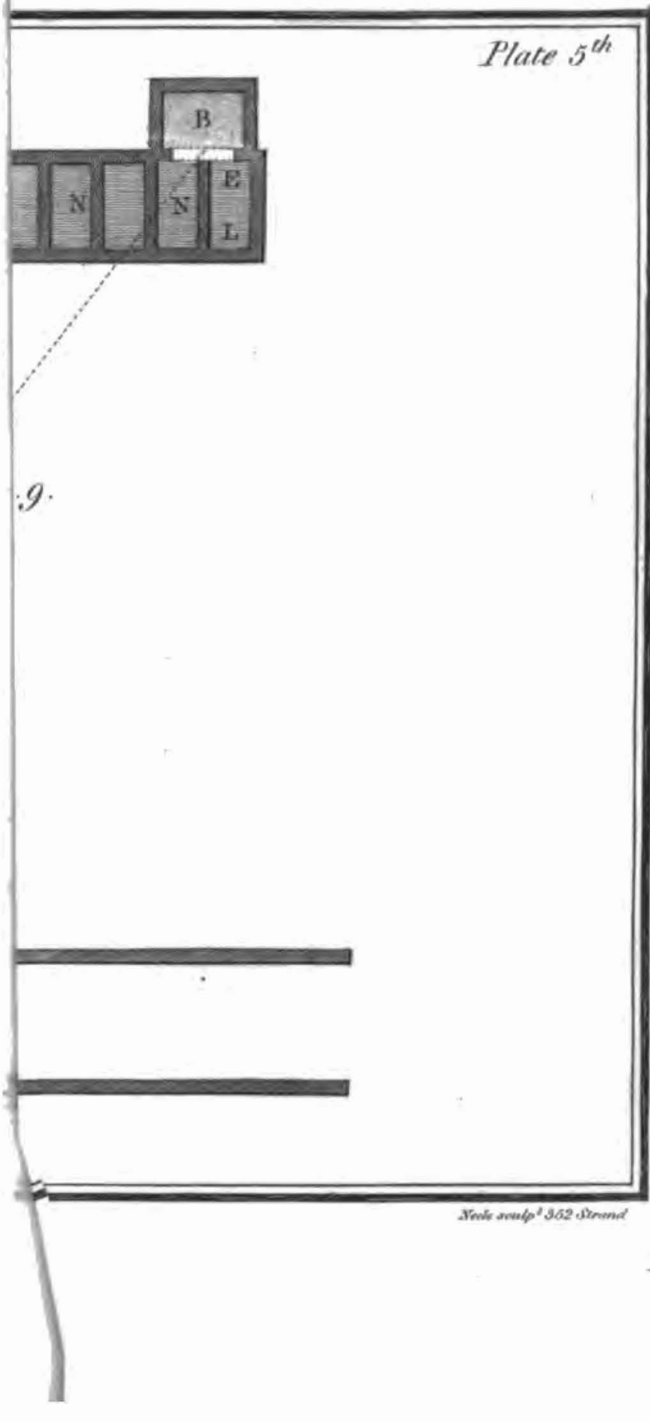

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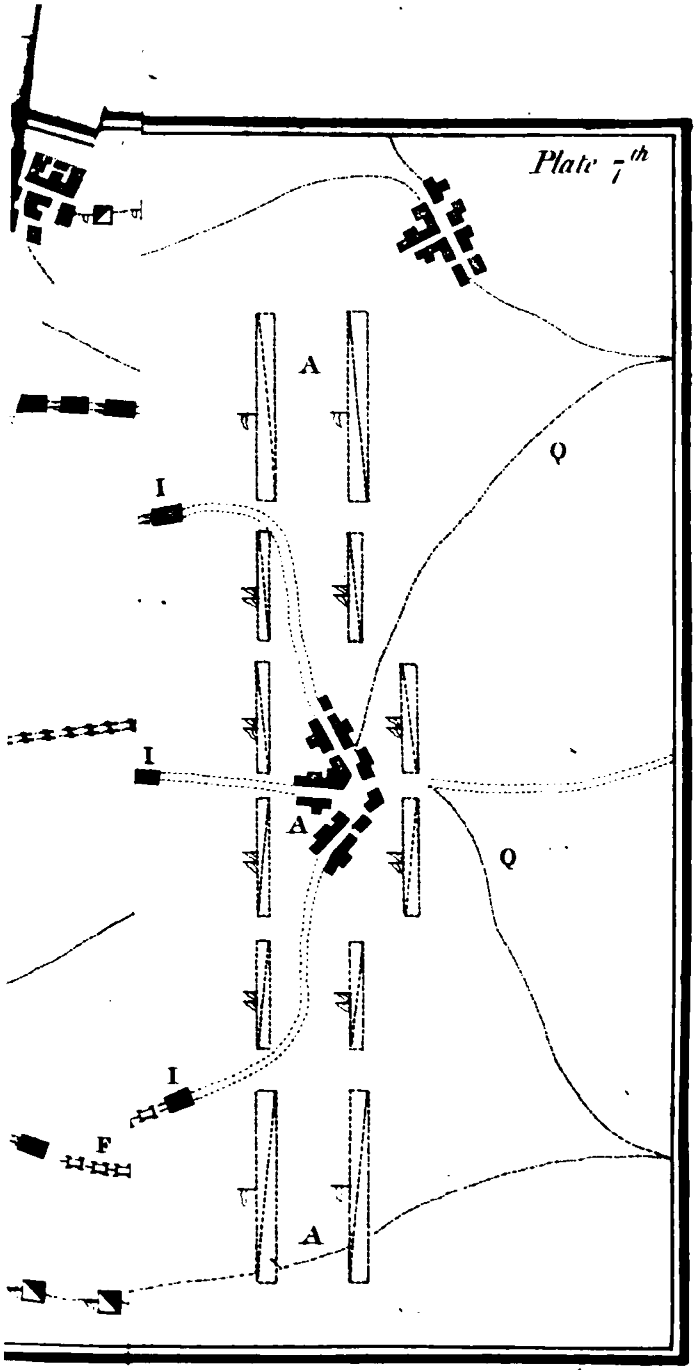

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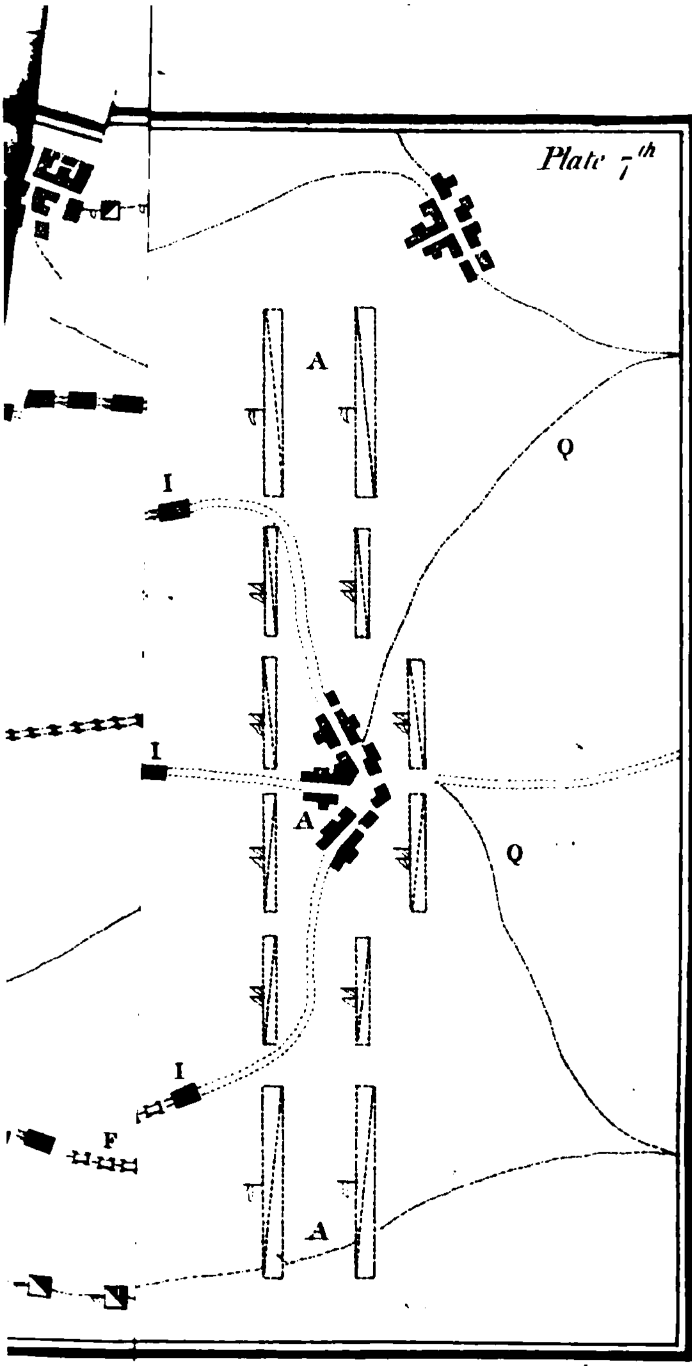

Plate 7th

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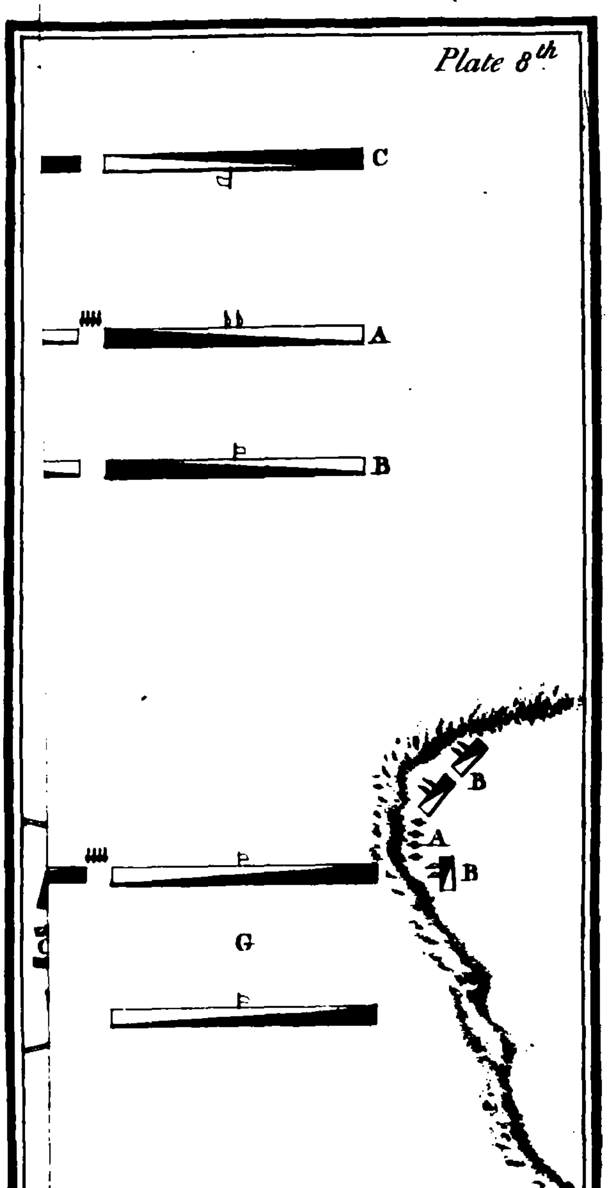
Plate 8th
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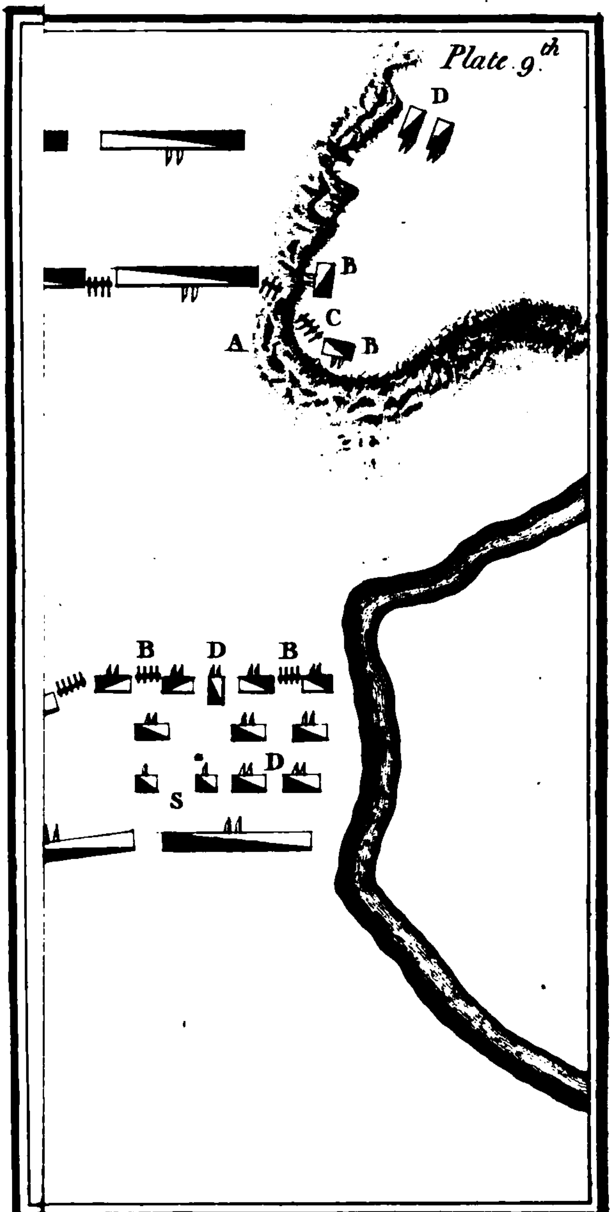
Plate 9th
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