lessened, and, the contrast between the two portions of the recoil being less sharply defined, the shoulder would be relieved from the effect of the kick to a greater extent than could be explained by mere difference of momentum.

It is probable, however, that the increase in the initial recoil, in consequence of the powder being of a rapidly-explosive character, or in consequence of the energy of the powder being enhanced by the increased weight of a heavy projectile as compared with a light one, may have a considerable effect in the accuracy with which a rifle will shoot. This initial recoil may in some measure account, perhaps, for the "jump" or muzzle disturbance in rifles.

Estimation of Recoil.

One frequently hears that—action and re-action being equal—the velocity of recoil and the velocity of the shot leaving the muzzle must be inversely proportionate to the weight of gun and shot, so that, if the gun be 100 times as heavy as the shot, it will move backward with a hundredth part of the speed with which the projectile moves forward. No doubt such might be the case if projectiles received their impulse at the muzzle of the gun, and started off, without any preliminary progression, like a champagne cork from the mouth of a bottle; but, inasmuch as projectiles have first to make their way through gun-barrels, we must take into consideration the circumstances which arise during the time that the shot is passing from breech to muzzle.

We do not nowadays accept the statement that the more a gun kicks the harder it must shoot, yet that would appear to be a logical sequence of the commonly-accepted doctrine that the momentum of the projectile is equal to the momentum of the gun from which it is fired. This definition appears to be much too limited; for the gun is not fired *in vacuo*, and the air offers resistance, first to the passage of the shot up the barrel, and afterwards to the escape of the gas. A correspondent in the *Field*, some time ago, added to the ordinary definition by saying, "the momentum of the gun is equal to the momentum of the shot, *plus* that of the powder gases as they leave the muzzle." This *plus* is a most necessary rider; for the state of tension of the gas at the instant the shot quits the barrel must have a material influence on the severity of the kick; and where there is a heavy charge of large-grain powder, that is giving off gas copiously up to the very muzzle, the final *kick* produced must be greater than when the chief part of the force is exerted at the breech.

One of the latest novelties in gunnery—a "marsupial gun," as it may be termed—recently brought out in America by Messrs. Lymann and Haskell, seems well adapted to furnish this condition of "giving off gas copiously up to the very muzzle." The gun has four "pouches" under the barrel, each containing powder. The first charge, which is in the ordinary position in the breech, consists of very slow-burning prismatic powder, which gradually sets the shot in motion. When it has thus got some way on, and passes the first pouch, a larger charge of powder, finer in grain, is ignited, and adds to the impetus of the moving shot; the same occurs at the second, third, and fourth pouches, each new supply of powder-gases adding to the speed of the projectile, which is said to leave the muzzle with a velocity of about 3500 feet per second, and to possess power of penetrating iron plates far beyond any Whitworth or Armstrong gun. Such a gun would doubtless give comparatively little strain upon the breech, but the powder-gases would have a very unusual amount of tension at the muzzle, and the amount of *kick* may be expected to be correspondingly large.

That the air has considerable effect in producing recoil appears evident from the fact that recoil takes place when there is no projectile, the gun being fired with blank cartridge.

Few persons appear to take the atmosphere into consideration in connection with recoil, yet air is a factor which ought not to be overlooked. It has already been shown, in page 65, that when bullets are passing through the open air, they encounter a resistance far beyond their own weight; and, with air inclosed in the gun-barrel, so that it cannot be pushed aside, but must be expelled from the muzzle, it may not unnaturally be supposed that the resistance it opposes to the passage of the bullet must greatly exceed that which it offers when it is free to move aside. If we attempt to thrust any close-fitting object rapidly through a long tube, the effect is very different from that of thrusting through unconfined air. We see, by the table just referred to, that, owing to the difference in shape, elongated bullets suffer much less obstruction from atmospheric resistance than is undergone by spherical balls; but when they are in the barrel, there appears to be no reason why they should have any such advantage—the amount of pressure would doubtless depend upon the area of the bore and the velocity of the bullet.

What is the extent of such resistance in the barrel under ordinary circumstances does not appear to be satisfactorily ascertained. The amount of atmospheric resistance to the bullet after it has left the gun has been worked out with great accuracy; but this is a very different matter from the action of the air in the barrel. In a paper by Professor G. Forbes, printed in the "Transactions of the Royal Society of Edinburgh" for 1879, it is calculated that, when a gun-barrel is choked by snow, dirt, or other obstructing matter, the pressure that would be set up by the advancing charge would be equal to about 7 tons per square inch, supposing the charge to have a velocity of 1000 feet a second, or about the velocity of sound, and the obstructing plug to have a density equal to that of water. It may be questionable, however, whether we should be justified in assuming that the charge would, under such circumstances, reach the plug with its full velocity; for the air in the barrel would be gradually driven forward from the instant the shot began to move, and would become more and more condensed as the shot advanced; and although under ordinary conditions it may be true that the velocity of sound is a measure of the rate of transmission of motion through the atmosphere, yet it is not proved that, under the extraordinary conditions of extremely high pressures, that rate of motion in the air will not be exceeded. We have, for example, projectiles driven through the atmosphere with about double the velocity of sound; and as an unusual amount of motion must be imparted to the air under those circumstances, may we not imagine that an unusual velocity may be imparted under the extreme pressure produced by the advancing shot in the barrel? If so, some amount of pressure may be transmitted to the obstructing plug in advance of the arrival of the shot; if not, the accumulating resistance of the compressed air in the barrel must be a considerable source of retardation to the shot, even when no obstructing plug interferes with its exit. At all events, it is not correct to assume that obstructions in the barrel invariably cause bursting, for there are many facts to prove the contrary. Some instances are mentioned at page 398 of the previous volume. Experiments have also been carried out on behalf of the United States Government, and it was found that of a large number of army rifles purposely choked with sand, &c., only a very small percentage were burst.

The effect of air-resistance in a gun-barrel was turned to account some twenty years ago by Mr. G. P. Harding in the production of what was called a "non-recoil gun." It was certainly a curiosity in its way, but apparently not of much practical value. It was simply a tube open at both ends, the charge being put in the centre, with a wad behind it, and a second wad placed further towards the end of the barrel, so as to shut in air between the two in much the same manner as it would be in a gun plugged by snow. When the charge was fired, the shot was driven out at one end of the barrel, but the wads still remained in at the other; and a gentleman who witnessed some of the experiments informed me that he saw the gun balanced on some support, and when the charge was fired the barrel remained unmoved. Doubtless the force exerted in driving out the shot was exactly counter-balanced by the compression of the air and shifting of the nearest wad as the pressure of the gases increased, and by a re-expansion and thrusting back of the wad as the pressure diminished.

A somewhat analogous experiment, carried out some years before by Colonel Parlby, is narrated in a work which he edited.* He took a musket barrel, made a new vent in the centre, and fired the charge therefrom with the hinder part of the barrel empty, and he found the penetration very little diminished from what it was when the powder was placed close to the breech; but the cushion of compressed air had so great an effect in diminishing recoil, that a 7lb. weight sufficed to keep the barrel in position in the one case, though a 50lb. weight was required in the other. That the recoil was only lessened, and not altogether removed in this case, may probably be owing to the fact that here there was a fixed breech, whereas in Mr. Harding's experiment there were two movable points, and in the compression and re-expansion of the air the second wad might be shifted to some extent, as well as that which was nearest the charge.

It is not impossible that, one of these days, some of our ingenious mechanicians may discover a means of introducing a reservoir of air behind the powder-charge, where it would probably have the effect, not only of lessening the initial

* Col. Anderson on "The Mode of Manufacturing Gunpowder at Ishapore Mills." Edited by Lieut.-Col. Parlby. London: Weale. 1862.

recoil, and thus preventing muzzle disturbance, but might also add to the safety of the gun by reducing the sudden strain, where quick burning powders are made use of.

Effect of Different Charges on Recoil.

It is not easy to find any comparative information about the recoil of rifles; but experiments that have been carried out with respect to shot guns will be serviceable, as showing the difference in recoil with the same charges of powder and varying weights of shot.

These particulars were ascertained by means of the *Field* machine-rest and recoil-gauge, an illustrated description of which is given at page 46 of the first volume of this work. The recoil of the gun, when fired, is registered on the scale of the Salter's spring attached to the machine, and thus shows when there is a difference of recoil by the difference in the number of pounds registered on this scale. I may frankly say I do not consider that these scale-numbers really give any idea of the actual pounds of pressure produced by the recoil; but they certainly give a means of comparison, and show most distinctly that there are considerable differences of recoil produced by alternating the weight either of powder or shot in the same gun, and also of firing the same charge from different guns. One defect which I conceive to exist in this apparatus is, that, owing to the effect of the spring, it underrates, rather than otherwise, the increase of recoil from heavier charges, and so makes them appear comparatively less severe than they really are. If, instead of relying on the ordinary Salter scale attached to the machine, a special scale were devised of a similar character to that attached to the *Field* force-gauge, and based upon the effect produced by falling weights, my belief is that a better means of comparison would be established. In like manner as the force-gauge admits of an estimate being formed of the actual velocity with which shot strike the target (as I have endeavoured to demonstrate at p. 343, vol. i.), so would a similar gauge applied to the recoil machine enable the velocity of recoil of the gun to be ascertained, supposing the weight to be known, and thus the energy of recoil in foot-pounds could be calculated. A heavy gun and a light gun might, on being fired with the same charge, show the same amount of recoil in one fashion, in consequence of their having equal momentum; nevertheless, the light gun would give a sharper blow to the shoulder by reason of its moving back with greater rapidity. This could be estimated in foot-pounds, if the velocity of recoil were known, but at present it cannot be ascertained. These remarks, however, are rather apart from my present purpose, which is to explain that, although, in my opinion, the pounds recorded on the Salter scale cannot be considered as true pounds, yet the figures about to be quoted show differences which really exist, and which would probably be accentuated to a greater extent if we could get the veritable results in foot-pounds.

The figures given opposite are obtained from the report of a long series of experiments carried out by Mr. R. W. S. Griffith, which were summarised and commented on in pp. 346 to 364 of the previous volume of this work. These experiments were carried out with the same gun, with varying charges of shot and powder, the shot being of different sizes and the powder of two kinds, viz., black (Curtis and Harvey) and Schultze. The mean velocities in a 40 yards range were taken with a Boulengé chronograph, and the recoil by means of the *Field* machine-rest. The record of each shot was originally published in the pages of the *Field*, but it will suffice here to give an abstract from the averages, from which there was, as a rule, but little variation. Where the charge of powder is given in drams, it means that such was the weight of the black powder, and that there was an equivalent charge of Schultze, viz., equal in measure or half in weight.

EQUAL CHARGES OF POWDER (3DRS.)

Size of Shot.	Charge of Shot.	Mean Velocity.		Recoil.	
		C & H	Schultze	C & H	Schultze
No. 2	1 oz.	913	914	82	75
,,	$1\frac{1}{4}$,,	891	896	89	82
,,	$1\frac{1}{2}$,,	845	847	90	83
No. 3	1 oz.	905	919	84	76
,,	$1\frac{1}{4}$,,	880	894	90	83
,,	$1\frac{1}{2}$,,	843	841	94	87
No. 4	1 oz.	890	893	85	76
,,	$1\frac{1}{4}$,,	870	864	89	84
,,	$1\frac{1}{2}$,,	832	837	94	87
No. 5	1 oz.	874	883	85	77
,,	$1\frac{1}{4}$,,	849	843	94	85
No. 6	1 oz.	860	858	86	79
,,	$1\frac{1}{4}$,,	849	841	94	86
No 7	1 oz	829	842	86	78
No. 8	1 oz.	816	823	86	79

The velocities are inserted as well as the recoil, in order to show that the former keep very close together with the two powders, whatever the change in the shot, so that the difference of recoil cannot be the result of the difference of velocity. If we are to accept the statements that are made, as to the recoil of the gun being proportionate to the weight and velocity of the shot, the recoil with the two powders ought to be as close together as the velocities are; yet we invariably find a considerable difference between the recoils, and the proportion keeps much the same throughout all the changes. We find, for example, with No. 2, that the recoil of black powder was 7 higher than Schultze when 1oz. of shot was used; with $1\frac{1}{4}$oz., both go up 7, and with $1\frac{1}{2}$oz. both increase 3 more. With No. 3 and smaller sizes a similar process goes on. Each reduction in the size of shot (the weight being unaltered) produces a greater amount of recoil, owing, no doubt, to the increased friction arising from a larger number of pellets pressing against the barrel; but whenever the recoil increases with the black powder, it increases also with Schultze, and the difference between them remains just about the same.

When the charge of shot remains stationary, but the powder varies in *quantity*, then we have similar differences of recoil between the two powders, except that there are wider intervals between successive steps:

VARYING CHARGES OF POWDER WITH EQUAL WEIGHT OF SHOT (1 oz.)

Size of Shot	Charge of Powder	Mean Velocity		Recoil	
		C & H	Schultze	C & H	Schultze
No. 2	2½ drs.	847	856	70	64
"	3 "	913	914	82	75
"	3½ "	988	985	90	83
No. 3	2½ drs.	818	810	73	65
"	3 "	905	919	84	76
"	3½ "	982	985	91	82
No. 4	2½ drs.	807	809	74	67
"	3 "	890	893	85	76
"	3½ "	965	963	92	84
No. 5	2½ drs.	816	817	75	67
"	3 "	874	883	85	77
"	3½ "	942	927	94	86
No. 6	2½ drs.	759	781	76	69
"	3 "	860	858	86	79
"	3½ "	900	905	95	87
No. 7	2½ drs.	761	766	76	69
"	3 "	829	842	86	78
"	3½ "	895	901	95	87
No. 8	2½ drs.	776	791	76	71
"	3 "	816	823	86	79
"	3½ "	828	831	96	88

The very great regularity in the gradations—the velocities keeping side by side with the two powders almost invariably, and the recoil always being from about 6 to 8 less with the Schultze, according the charge—makes it clear that the general belief of sportsmen in the lesser recoil of the nitro-compound has a better foundation than the conclusion which some adhere to, that you must have equal recoil if you have equal velocity and weight of projectile.

How, then, is the difference to be accounted for? My impression is that it is a natural result from the lower density of the powder. Schultze powder, in its unburnt state, is about half the weight of black powder; and when the powder is exploded, the products of combustion cannot be heavier than the material from which they were formed The gas from the Schultze powder may not be very different in weight from that of the black powder, but the nitro-compounds have scarcely any solid residue, whereas the black powder has nearly two-thirds of solid residue when it is cooled, although when first fired it is in a kind of liquid condition, the solid particles being intimately mixed up with the true gas.

When one body pushes against another, the momentum imparted depends upon the weight and velocity of the moving body as compared with the weight of that which is moved; and this applies, not only to solids, but to fluids also. The effect of atmospheric pressure is dependent upon the weight of the air as well as its velocity; and the effect of powder gases upon the projectile is, in like manner, dependent upon their weight and velocity. What is wanting in weight in the gases of the nitro-compounds must be made up for by the velocity of their expansion.

If the action of the two powders were similar throughout, it might be assumed that the velocity of Schultze gases at all points of the bore would be double those of black powder; but it is not likely that such would be the case.

It is more probable that the velocity of both is more nearly equal when the shot leaves the muzzle, and that that portion of the recoil which occurs after the expulsion of the shot would depend for its effect upon the weight of the gases in the barrel as well as the rapidity with which they rush into contact with the atmosphere; and as the black powder gases (or, rather, the mixture of gas and solid particles) would be doubly as heavy as the Schultze gases, the action of the former on the atmosphere, and their reaction on the gun, would necessarily be greater than those of the latter.

There is, too, another point for consideration. If the same amount of momentum be imparted by two bodies, one of which is half the weight of the other, but moving with double the velocity, the "energy" or rending power of the two is not equal, for the energy is proportionate to the square of the velocity. If, then, a certain amount of momentum is imparted to $1\frac{1}{8}$oz. of shot by 3drs. of black powder (a proportion of 1 powder to 6 lead), and equal momentum is imparted to $1\frac{1}{8}$oz. of shot by 42grs. of Schultze (a proportion of 1 powder to 12 lead), there must be a higher velocity of expansion to afford the necessary impulse; and the strain on the barrel would be proportionate to the square of the velocity multiplied by the weight. If the velocity of expansion of the nitro-compound were exactly double that of black powder, and the latter double the weight of the former, we should have $2 \times 2 \times 1$ as against $1 \times 1 \times 2$; that is to say, the strain would be double with the nitro-compound. The effect becomes more marked when the rapidity of combustion is increased by the drying of the powder. If black powder be dried, it burns more rapidly, and greater energy is developed with the higher velocity of expansion; but the increase of velocity is kept within comparatively narrow bounds by a clog on the movement of the gases. The solid residue is nearly double the weight of the true gases, and the latter must impart motion to the former; consequently a check is put on the rapidity of expansion. With the nitro-compounds it is not so, for there is scarcely any solid residue. When there is a certain amount of moisture, that checks the rapidity to some extent; but, on the moisture being wholly abstracted, there is practically no check, and the mass explodes almost simultaneously, or, to use another expression, it "detonates;" for detonation is merely rapid explosion. In like manner as the difference between a push and a blow is a question of velocity, so is the difference between explosion and detonation. You cannot draw a line as to where the one begins and the other ends: detonation is quick explosion—the difference is merely one of time. The effect of this seems to be, that if means be taken to lessen the strain on the breech by reducing the velocity of explosion of the nitro-compounds, the time may be so lengthened that a kind of "hang-fire" is produced, owing to the want of weight in the propelling gases. If, on the other hand, a stronger cap be used to remedy the hang-fire, the result, on a minor scale, is the same as that produced by firing a disk of compressed guncotton by a large quantity of fulminate. Guncotton is rendered so inert by extreme compression, that it will burn almost as slowly as a piece of wood; but if compelled to burn more rapidly by a very powerful cap, it explodes with such violence that a small mass will suffice to shatter a fortress.

It appears to be clearly established that there are vast differences in the amount of force exhibited by these nitro-compounds under varying conditions. With change of circumstances, the same powder gives results very similar in the wideness of their divergence to what is shown to exist between the Rifle Large Grain and the Russian Prismatic Powders alluded to on page 85. Under certain conditions, the E. C. powder burns so slowly that complaints have been made of its hanging fire badly; and in such case the strain in the chamber of the gun would be very small, for, as with the Russian prismatic powder, the gas would be chiefly developed further on in the barrel. Under other conditions there may be produced a medium amount of force, which will suffice to give good shooting without undue strain upon the gun. But with still further change of circumstances, as such great restraint on expansion, increase of fulminate in the caps, or abstraction of moisture from the powder—any circumstance, indeed, which favours extreme rapidity of combustion—the violence of explosion also becomes extreme. I have in my possession a crusher gauge which has been used in a Martini-Henry rifle under the same conditions as that represented in Fig. 13, page 120, except that, instead of 85 grs. of black powder, the charge was 42 grs. of the large-grained yellow E. C. rifle powder. The result of the resistance of the Martini bullet was to so considerably develope the force in the E. C. powder, that the gauge was crushed down to a greater extent even than that shown in Fig. 14.

These remarks have, however, wandered away somewhat from the question of recoil; but I may state, in connection therewith, my belief that great rapidity of explosion in the powder, whether black or otherwise, is not only accompanied by a great amount of strain on the breech, but that there is more *initial* recoil imparted to the gun when the shot is set in motion, and less *kick* produced as the shot leaves the barrel; and, further, that the greater the strain on the breech—whether produced by a quick-burning powder, or a heavier bullet, or resistance of any other kind—the greater is the probability of increased "jump" or "muzzle disturbance."

THE "JUMP."

The effect of the "jump" is nowadays a generally admitted fact, both with big guns and small arms; but if, as some persons contend, no motion is produced in the gun till barrel and shot part company, any subsequent movement of the one could scarcely affect the course of the other.

Professor Bashforth, in writing relative to a comparison of calculated and experimental ranges with cannon shot at high velocities, said: "It is probable that the experimental ranges will somewhat exceed the calculated ranges, because, when high charges are used, the 'jump' of the gun probably gives the initial direction of the shot an elevation sensibly greater than that for which the gun is laid." This would have the effect of causing the trajectory to appear to be flatter than it is in reality; for if, at the instant when the bullet leaves the rifle, the muzzle happens to be jerked slightly upwards, this additional elevation may cause a considerable difference in a long range, and the actual course of the bullet would be much higher than the apparent trajectory indicated by the sighting of the rifle.

Sir Joseph Whitworth, in his book on "Guns and Steel," has given the following interesting particulars of the increase in height of the projectile, and consequent extension of range, when shots were fired from one of his guns under different conditions:

"A $2\frac{1}{2}$-pounder Whitworth mountain gun was first placed in a tube, with its axis coincident with that of the tube. On firing, the gun could only recoil in the exact line of the axis of the tube. The shot left the tube in a horizontal line, and its range was 100 yards.

The same gun was then mounted on a field carriage of wood, and laid in a horizontal line. The elasticity of the carriage now came into play; the axis of the gun deflected upwards on recoiling, and the range was 204 yards. The projectile rose to a height of $10\frac{3}{4}$ inches above the horizontal line of fire.

The gun was finally mounted on a field carriage of Whitworth metal. Here its axis is brought much nearer to the axle of the carriage, and the leverage which assists the deflection is correspondingly reduced; also the rigid steel yields less than the wood.

The gun was laid, as before, in a horizontal line, and its axis deflected upwards, but to a less extent. The range was 190 yards, but the shot rose above the line of fire to a height of only 8 inches instead of $10\frac{3}{4}$ inches. The trajectory, with a nearly equal range, was, therefore, much flatter; and the experiment is most instructive as demonstrating the influence of the carriage upon the trajectory of the gun."

Evidently there must have been motion in the gun sufficient to throw up the muzzle before the departure of the projectile; and the plate accompanying the text affords particulars which enable us to form an estimate of the angle of elevation produced in each case by the motion of the barrel. The drop below the axis of the barrel was 10 inches, the diameter of the shot was 1·9 in., and the weight $2\frac{1}{2}$ lb.; and by means of the process already described, we are enabled to calculate approximately the velocity of the shot, and the amount of natural drop at the respective distances, and to see that the effects described are the natural consequence of the "jump."

The "jump" appears, however, to be by no means a definite quantity, and occasionally varies in the same rifle at different angles of elevation, besides differing at the same angle when there is an alteration in the charge. The latter result might be expected; but there seems to be no regularity of increase or diminution with increase or diminution of charge. In some artillery experiment carried out at Shoeburyness, and alluded to by Professor Bashforth, care was taken to measure the "jump" of the same gun at various angles of elevation from 5° up to 30°; but the figures show that there was not any uniformity of result corresponding with the increase of elevation; for in some instances the increase was large, and with others small, and in some cases the movement appears to have produced a negative instead of a positive result, and therefore to have thrown the shot lower instead of higher. In some cases, too, with the same gun, a small charge caused a greater "jump" than a larger one; and with a different elevation the opposite effect was produced. Possibly these differences of action may account for what appear to be occasional inequalities in the sighting of rifles, when the increasing height of the back sight does not follow the regularity of gradation which corresponds with the increase of range. The sighting of the rifle, not being a matter of calculation exclusively, has to stand the test of the target and to be regulated accordingly; and, if at one distance or one elevation, the "jump" happens to be greater than at another—if the bullet is high above the mark when the rifle has one angle of elevation, but strikes lower, or even under the mark, when the angle is different—alterations must be made to accommodate those variations, and there cannot, in such case, be the same regularity of gradation as if the "jump" had no existence.

With regard to differences of "jump" in rifles fired from the shoulder, it seems not at all improbable that something may be due to the difference of grasp and firmness of hold at different elevations, and also to difference of build in the shooter. One man is long in the neck and another short; and it is hardly to be expected that both will with equal ease align the sights for different distances. The long-necked man may look comfortably through the back-sight when raised to the height necessary for a long range; but, when it is lowered for a short range, he must either wrench his neck down awkwardly till it is in a line with the sight, or he must raise the butt of the stock to a higher part of the shoulder so as to bring the sight level with the eye. The short-necked man, on the contrary, may find the lower sights handy, but it being difficult to crane his neck up to the sights for long distances, he slips the stock a little lower down to the armpit. It is scarcely possible, under such circumstances, that either of these men will have an equally firm grip on his weapon at all elevations; and the "jump" may therefore take different proportions with variations in height of sight, and be different with the two men if they chanced to use the same rifle. With long-range rifles, fired from a prone position, any such cause does not, however, appear likely to hold good.

Mr. Metford's observations, both in his article (page 198) printed in the previous chapter, and in the chapter on sighting (page 225), are very pregnant, and throw light on various obscurities in the behaviour of rifles. It is well known that different guns will behave differently with the same charges of powder and shot, and that great changes may be produced in the performances of the same guns by varying the weight whether of powder or bullet. Some barrels, being made of more elastic metal than others, will expand more with equal charges of powder; while others differ considerably in their proportions of thickness at various parts of the barrel, as well as in length. Then there is the difference of construction between military and other rifles in the amount of woodwork, the bands that clasp the fore-end to the barrel, and other paraphernalia; and, on the other hand, where these are wanting, there are two barrels fixed side by side. All these things may produce differences of "flip," as Mr. Metford terms it, and more or less affect the aim in a way for which no general rule can provide, the only remedy being for the owner of the rifle to study its idiosyncracies and adapt himself thereto. Mr. Metford shows that one of his rifles is much more "tender" than another; and this would doubtless be acted on to a greater extent by the "waves of pressures" alluded to in page 81. He also shows the effect produced by a weight applied on one side of a barrel; and this, together with differences of "tenderness" in the material, may give a reason why the side-throw of some double-barrels is so much more difficult to regulate than that of others.

The effect of the "wave action" in a double-barrelled gun seemed well marked in one which recently came under my notice. The gun had been burst by E.C. powder, and the top rib had been driven completely out, in addition to a piece of the chamber. The rib, however, was not blown straight up and curled over, as sometimes happens, but seems to have been gradually removed by successive waves of motion proceeding down the barrel—the rib being bent into quite a serpentine form in its horizontal plane, as though action and re-action between the two barrels were going on throughout.

In artillery we have the "jump" looked upon as a regular thing, although it is anything but regular under change of conditions. In some cases it has been found that a certain increase of powder will give an increase of jump, and that a further increase in the charge will produce a "dip." A similar result may also happen from altering the weight of the projectile; and, on reflection, it does not seem very surprising that such should be the case, when read by the light of Mr. Metford's remarks. We have seen, by the table on page 85, at what different points of the barrel the maximum pressure will fall under different conditions in the powder charge; we have also seen, on page 120, how different is the amount of force exerted by the powder when it meets with greater resistance; and as there is likely to be a difference of expansion in the metal of the gun when the force acts upon a thicker or thinner part of the barrel, and also a difference of leverage according as the point of application is nearer or farther from the breech, we may thus account for many peculiarities of result with different guns. Possibly too, as we may not be able to provide a remedy for the idiosyncracies of particular weapons, we may arrive at the conclusion, that if we wish to obtain the best results, it will not be wise to take liberties with charges for which a rifle has been carefully regulated.

CHAPTER VIII.

SIGHTING.

THIS is so much a matter for the practical skill of the maker of the weapon, that little will be said upon it in this place. If there were nothing more to take into consideration than counteracting the drop of the bullet by the elevation of the muzzle of the gun, then the particulars given in previous chapters would indicate the lines upon which it would be necessary to go. Thus, with a drop of so many feet or inches, in a certain bullet and a certain range, an elevation of so many degrees or minutes of angle would give a rise equal to the extent of bullet-drop in such range. But this is only the mere threshold of the business. Two rifles made as a pair will not necessarily behave exactly alike, and they must be regulated according to their peculiarities. There has also to be provided for the difference of action of the same rifle according to the charge with which it is to be used. An elevation of so many minutes of angle may be required to compensate for the drop of a bullet in a given range; but it is found in practice that a less amount of elevation may suffice to enable the bullet to hit the mark. It is not that the drop is less and the trajectory really lower than was supposed, but that some movement in the barrel throws up the muzzle and gives it greater elevation than that produced by the sights alone. Under other conditions, too, if the barrel has a "dip," rather than a "jump" with a given charge, the sighting would have to be higher to counteract this effect. The build of the person who uses the weapon, and the means adopted by the gunmaker to fit it to the purchaser, may also in some cases affect the apparent though not the real amount of elevation.

If I am not mistaken, the course usually adopted by makers of match rifles nowadays is to sight for a very short range, such as a dozen yards, and, by studying the habits of the rifle with a given charge, so regulate it as to compensate for the idiosyncracies of the particular weapon within this short distance, and thus accommodate its jump. With the same charge of powder and lead, the jump may be assumed to be a constant quantity when once the quantity is known; and this being allowed for, a zero point is obtained, on which is based the elevation of angle required for the drop of the bullet at different ranges. The latter may be said to be a known quantity, although it will necessarily change with every variation in the charge; but the former is an unknown quantity, and the skill of the gunmaker is shown in the way he discovers and meets it. With any particular rifle, always used with the same charge, such as military weapons, the angles of elevation could be calculated; but with the infinite variety of sporting rifles, their differences of charges of powder and weight of bullets, it would be a hopeless task to attempt to give any useful tables.

Nevertheless, the tables of velocities and drop given at pages 143 to 153, may possibly be turned to account, as I will endeavour to show, by reference to the following interesting particulars supplied to me by a gentleman who carried out some experiments in order to ascertain the effect of altered charges on the drop of the bullet. He loaded with very great care three sets of ·450 cartridges containing charges of 105, 110, and 115 grains of powder and 280gr. bullet. He had the velocities of the bullets taken by chronograph, and found that 110grs. of powder gave about 40 ft.-sec. higher velocity than 105, while 115 gave about 30 ft. more than 110, the respective muzzle velocities being about 1820, 1860, and 1890 feet per second. He then tried at the target, at 100yds., cartridges from the three respective batches, and he found that those loaded with 115grs. placed the bullets about 3⅜in. higher than those of 110grs., and that the bullets from the 105gr. cartridges were 3⅝in. lower, making a difference of 7in. on the target for 10grs. difference of charge. It would be natural enough to assume that this 7in. difference in 100 yards was the result of about 70 ft.-sec. difference in muzzle velocity; but such is not the case. The mere reduction of velocity will scarcely account for 1-inch increase of drop, as will be seen by reference to the table given on page 146, where the drop of the 280grs. bullet is shown to be over 6in. with 1900 ft.-sec. and less than 7in. with 1800 ft.-sec. velocity in 100yds. We may therefore conclude that the rest of the difference is due to some other cause, and that that cause is most probably the variation of jump or flip produced by the alteration of the charge.

Assuming such to be the case, we may see that, with this rifle, there would be a difference of about 7′ of elevation required to compensate for the difference of effect produced by the alteration of 10grs. of powder in a range of 100 yards, whereas 1′ would suffice for the mere difference of drop produced by alteration of muzzle velocity. The remaining 6′ may be taken as a constant quantity applicable to all ranges, whereas the elevation for drop is a variable quantity increasing rapidly with length of range. At 200 yards there would be about 2′ increase of elevation required to compensate for the increased drop due to 100 ft.-sec. loss of velocity; and in 400 yards it would have grown so rapidly that about 12′ would be required to make up for the loss of speed; whereas the compensation for jump would continue as before.

We must not assume, then, that the mere variation in velocity of successive shots, fired with exactly the same charges of powder, will produce the same differences on the target as the alterations in velocity produced by increasing or diminishing the charge; but we may assume that if cartridges are so carelessly loaded by measure that one case contains several grains more powder than is put into another, the result may produce a very undesirable amount of irregularity in the shooting, not alone from the difference in speed, but from variation in jump. When, however, the powder is most accurately weighed, some degree of variation in successive shots cannot be prevented. The chronograph records of the rifles tried at Putney show that, in some instances, there was a variation of about 70 ft.-sec. in muzzle velocity in the course of the five successive shots. It is difficult to account for these variations, which no possible amount of care seems able wholly to eliminate; but the variations of velocity, in such cases appear to be as unimportant as the calculations would lead one to expect; for the same rifle which showed the 70 ft.-sec. difference of speed with the chronograph gave regular shooting at the target at Putney; and such is not surprising, if we take into consideration only the natural drop of the bullet. In the case of the experiments with the 280gr. bullets recently mentioned, we also find that the facts run on nearly parallel lines. The chronograph records from shot to shot vary, with the 105gr. cartridges, about 50 ft.-sec.; though with the other charges there was less variation. The difference between the highest of 105grs. and the lowest of 110grs. is, however, only about 20 ft.-sec. Accordingly, if speed alone had to be taken into consideration, the 105gr. cartridges ought, on the target, to be separated by more than double the space that would occur between the highest of the 105gr. batch and the lowest of 110grs. Such, however, does not appear to have been the case; and we may infer that when, with equal weights of powder and bullet, there are some differences in initial speed, but the other conditions remain unaltered, the effect produced is such as results merely from the difference of time of flight. But when the charge is altered, either in weight of bullet or of powder, or both, the conditions are no longer the same. The point of greatest strain in the barrel is changed, and complications are introduced by varying the nature of the jump or flip. The conclusions we may therefore draw from the observed facts are, that we should be chary of altering the charges of rifles which have been carefully regulated. Evenly-loaded cartridges will give fairly concordant results at moderate ranges, even if chronograph records do show a certain amount of variation in muzzle velocity; ill-loaded cartridges may, by the variation of charge, produce a greater amount of irregularity than mere difference of speed would suffice to account for: and if the sportsman deliberately alters his charge, and adopts one for which the rifle is not regulated, he must not blame the gunmaker if the results defeat his anticipations.

The following very interesting letter from Mr. Metford to Mr. Walsh has an important bearing on various matters connected with the sighting of rifles:

"*In re* of our Metford match rifle you speak of, and its sighting. There is a long and curiously interesting story attached to the sighting affair. You say your measurements "indicate a drop of $1\frac{1}{2}$in. at 12yds."

When I began scientific rifle work—now, I am sorry to say, over thirty years since—I felt that the proper thing would be to rig up a telescope sight, and that it would also be a proper thing to put its optical axis (in which line the cross-wires lay) absolutely parallel with the axis of bore. This I did with all the caution and skill I was master of (I was at that time able to make a theodolite, bar the dividing and optical glass work). With my telescope set to zero (or parallel with bore axis) I went to shoot at 25yds., speed 1400ft., therefore drop of bullet at 25yds. a trifle over $\frac{1}{2}$in. Telescope was 1in. above bar axis, therefore I expected the bullet to strike $1\frac{1}{2}$in. under centre of spot (rifle not rested). Nothing of the sort happened; the bullet struck a considerable distance under. I at once thought I had made some stupid blunder, and reset the whole work again, but still the rifle did the same.

I then fired the rifle laid flat to right, then the bullet struck nearly as much to left, and rather under. Again I laid the rifle flat to left, and this reversed the strike, the bullet going to right and a little under. I then came to the conclusion that the barrel was curved, and that I had overlooked it; but I could not, on examination, see it was at all curved.

I then found this peculiarity attended all rifles, but with variation, and had nothing whatever to do with the bore *in re* its straightness.

The point is, What is the cause?

Bidder, about twenty years since (now dead), who had also detected with Whitworth's rifle the peculiarity, proposed to me that it was some effect of gravity; that the nose of the long bullet began to fall before the heel could, and so it took a dive; but my sideways shooting annihilated this, as he admitted. He had not tried this.

My friend William Froude solved it, and showed clearly that it was entirely due to the mass of the stock being unsymmetrical with the mass of the barrel; and that the first thing the barrel would do, on explosion, would be that the muzzle would flip down, the barrel bending in a curve (this flip down would be dependent for its amount and velocity on the masses, and length, and stiffness, and charge of powder, &c.); and that eventually the whole motion would reverse itself, and the whole gun kick up; but that the bullet would be gone before the barrel had returned to its level and above it, unless the barrel was very stiff and short.

This matter was, I believe, first publicly treated of by me in an article on trajectory I wrote at the desire of one of the American sporting papers in 1878, and which was afterwards, I think, much discussed in that paper, or, anyhow, one of the American sporting papers, by men who had not seen my article, but had themselves come across the fact as a new and curious thing. I did not enter into the discussion myself.

I find, too, that if one puts a mass (say 2lb.) on either side of a rifle, if (say) left side the barrel it will throw left, and *vice versâ.*

Rifles differ in amount of flip—*e.g.*, that original explanation of mine gave 14′ angle = at 12yds. to $1\frac{3}{4}$in. about; and gave for side (telescope on left) 5′ to left. One of my match rifles is only $9\frac{1}{4}$′;

another equally stiff, apparently 22′. One of my rifles flips much the same amount whether I use quick or slow powder (initial speed being equal). Another rifle I know is, on the contrary, curiously tender, and so tender that I can actually tell which powder is being used.

Weights of powder and bullet affect it as well. You will see that there will be developed a lot of additions from the following cause: that the barrel, on the bullet passing muzzle, may either be progressing down, or at its lowest, or returning.

Only a fortnight since a friend "*announced*" a wonderful discovery of someone he knew; and, on inquiring, I found that the "someone" had just come across the flip as a brand new find, and the someone was going to stop it! Now the joke of it is, that it happens to be a convenient caper of the rifle, as it permits a much lower front sight for 100yds. ranges.

Look at a pistol which won't flip, on account of short stiff barrel, but kicks up straight off. What a bore is the high front sight.

Again, clearly a rifle with a very heavy muzzle, and other things being equal, behaves differently to a light muzzle in this matter. I inclose what I said in the American paper about it. [This extract forms part of Mr. Metford's article reprinted in the previous chapter, and the passage in question occurs on page 198.]

You will see now that the rifles are set, not to the constructive zero, but to the tangent of the barrel as curved by the joint, and at muzzle, or say parallel to the first foot of the bullet's flight.

My instruction to Gibbs for zero is, to put up a spot ⊙ at 12yds., and to so adjust the shoot that the bullet, when the slide is at zero, should cut a line below the spot $1\frac{1}{4}$in., the $1\frac{1}{4}$in. consisting of (1) the height of the eye-line above the bore-line $= 1\frac{1}{8}$in., and (2) $\frac{1}{8}$in. for the drop of bullet by gravity at the 12yds.

This method of setting zero enables one to entirely escape all bothers *in re* flip.

Still, as many rifles alter their flip, if the powder be changed in either amount or velocity of explosion, and if the weight of bullet be altered, it is necessary to ascertain again the zero on making such alterations, all or any of them, otherwise a man may be led into considerable error in statements as to his 1000yds. angles (say).

I have known a rifle shoot precisely identical angles apparently at 1000yds. with two entirely different charges, but, when zeroed, a difference of 6ft. or 7ft. would be found existing. I have known one man prove that an addition of 60grs. to his bullet did not alter the drop at 1000yds. at all, and so mislead another man, who would get desperate ricochets.

The fact is, even a match barrel, stiff as it looks, is really a very limp affair, for one can grossly chuck it out of line with one's fingers and thumbs. I trust all this rigmarole will be sufficiently clear to explain the zero anomaly.

The behaviour of a military rifle with its fore-end on, and then off, will give a very funny exposition of flip.

I hear there is some rumpus up about the non-cleaning rifles, as if it was any new matter. Why, it was my easy shallow rifle, first introduced by myself in the Whitworth times, which finished up all the rifles which had deep grooves, and drove Whitworth and his followers out of the field, simply because my rifles would not catch the dirt like the heavy Whitworth, Rigby, and Ingram and Henry rifles did.

Again, my military breechloader, which first appeared at Wimbledon in 1871, and which has only missed the Duke of Cambridge's 1000yds. prize (the great "any military" breechloader) twice since, has always shot dirty and with no lubrication; my friends have always said it shot better dirty than clean.

It is true I lost the Duke's in 1881, but the rifle which took it required a lot of tallow in the cartridge (Webley-Wyley's), which is not a military cartridge, as fat will run in hot climates, and is not, therefore, allowed in military work.

I began my breechloading experiments in 1870 (I think it was; I can't look at my experimental books now) by laying down the law that no lubrication should be allowed, as unmilitary; and last year my rifles at Wimbledon, I may say, swept the field; at least, my military rifle took *every first*, "any military" rifle prize, and about 75 per cent. of the rest. And my match rifle permitted no English, Scottish, or Irish rifles to take any first "any rifle" prize whatever. My only competitor was Sharp, and he did not hurt me much.

Again, ten out of the twelve rifles in the American and British match were mine, and the two not mine stood well down the lower half. All my rifles worked without lubrication, and in the great heat too. The other two rifles, I think, had lubrication. Considering all this, it appears to me that for any one to have promulgated the idea that for a rifle to run clean enough and shoot well was a new and great discovery at this late date is laughable.

The very last shoot I had but one (for Sir H. Halford) at 1000yds., no cleaning, was all bullets *but one* in a vertical ^ v of 18in. and the whole in 2ft. 4in. Fifteen shots, no lubrication. It looks like a mean vertical deviation of about 5in. to 6in. for the lot; but I did not work it out (see diagram, Fig. 19.).

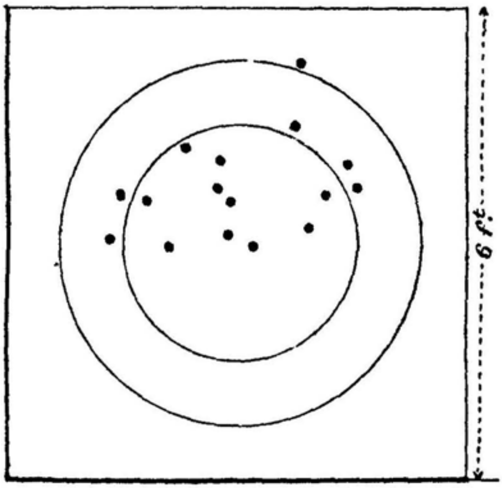

FIG 19.

You see, therefore, that I feel somewhat confounded at all this trumpet blowing, when the fact of my breechloader rifle shooting without cleaning for all these years with the greatest success, and with no lubrication, has been staring every one interested in this special work in the face.

I must now "trip and trail" up my unfortunate scrawling, and make it more possible to read, and so remain, yours faithfully,

W. E. METFORD.

P.S.—I suppose soon the shooting people will discover my hardened cylindrical bullet and announce it to the world as a new and excellent affair, not knowing that I introduced it in 1856, and that all our long-range rifle makers have used it ever since!"

CHAPTER IX.

INFLUENCE OF THE WIND.

THE drift of the bullet with the wind is more a matter for practical experience than theoretical explanation. It has already been briefly stated, under the head of Atmospheric Resistance (page 73), that the drop of the shot is increased or diminished by the retardation or enhancement of speed when the wind blows from front or rear; but the extent to which it will affect a bullet in a given range must depend upon the weight and shape of the projectile as well as length of range and force of wind; and here the sportsman's own judgment, based on the knowledge of his weapon and bullet, must be the chief guide. And if this be the case with head and rear winds, still more must it hold good of cross-winds blowing at different angles. The effect of these on light Express bullets is much greater than on heavy elongated projectiles; and this will scarcely seem surprising when we consider that many of these bullets are more or less hollow in front. Being thus light forward, a side wind would have most influence on that end of the projectile, and the effect would be much the same as that of the rudder of a ship being so applied as to turn the head of the vessel to leeward—it would run down-wind to a considerable extent. On the other hand, if a bullet were hollowed in the rear, so that the centre of gravity were thrown in the front, the effect would be the reverse of the above—it would be as if the helm turned the vessel's head to windward; it would "eat into the wind," and the drift would be comparatively small. Even with short Express bullets that are not hollow in front, there would be a tendency to drift more than the long projectiles used with military and match rifles, because the head forms a much larger proportion of the whole mass. If the bullet were a perfect cylinder, the side pressure would be equal throughout; but the head presents to a side-wind a larger area, in comparison with weight of metal, than the cylindrical portion of the bullet; consequently it gives way more to the side-pressure, and drifts down-wind more than the mere force of the breeze would otherwise account for.

For military and match-rifle shooting there are numerous handbooks which give instructions as to the use of the wind-gauge, and allowances to be made for the Martini and other bullets according to the "*state of the clock*," or *position* of the wind, supposing that the marksman uses his watch-face as a handy substitute for a compass. This practice is alluded to in the following observations from letters written by Sir Henry Halford and quoted by Lieut. Zalinski in the article from which an extract has already been made (page 180).

"I do not know the real angles of the rifles you used to make your calculations with, but you will see in Mr. Metford's paper, the angles of the rifles from which most of my experiments have been made. I have also shot much with Sharp's and Remington's rifles with practically the same speed and weight of projectile, and they agree with Mr. Metford's rifles in wind deflections, as they naturally should from having the same speed, form, and weight of projectile. I have also used a 380gr. bullet at very high speed, giving an angle of 2° 2′ at 1000 yards, but from its lightness it is deflected as 10 is to 7 compared with a 550gr. bullet. [The ratio of deflections in this instance is in the inverse ratio of the weights.--E. L. Z.]

The general angle of the rifles I have used with match charges of 90grs. Curtis & Harvey No. 6 is 2° 15′, with the thermometer at 50° Fahrenheit. On my card you will see that a wind which would give 30′ deflection if square across, would require a rise of 5′ if from 12 o'clock. A 430gr. bullet requires 8′ rise for head wind, a 570gr. only requires 3′! Mass tells.

I may mention that all our sighting is in degrees and minutes of angle, and the wind gauges are also cut to minutes. We find it the easiest way of working. The rifles are all shot for zero at 12 yards before the scale is cut, so that I can take up any of Mr. Metford's rifles and expect to get the sighting first shot, as well as with a rifle with which I am well acquainted.

I find the effect of temperature on angle is that, say from freezing point to 90° Fahrenheit, every $4\frac{1}{2}°$ of rise of temperature require a lowering of 1′ of angle. There is, too, some queer difference in winter and summer of angle, not entirely due to temperature, and I find winter angles raised more than summer. For instance, I have shot in winter with the thermometer at 48° and the same in summer, and in winter I require 2′ or 3′ higher angle, and this not due to wind. I cannot yet give a reason for this, but hope some day to find out. They are not due to difference of barometer, for I noted that point.

I see you have taken great pains with your tables. Ours are based on 20 years' hard shooting, with the wind taken with a Lind's gauge and with a spinning gauge; also a pocket spring gauge with a chronometer spring set to grains weight on centre of disk. I never now, or hardly ever, use a wind gauge, as I trust to feeling. I also, like you, make use of the smoke from the rifle. . . . .

It is almost impossible to lay down a law or make a table that will suit more than one projectile for effect of wind on trajectory. The card I sent you will suit bullets from 540grs. to 570grs. in weight. A 480gr. military bullet will require the head column to be nearly doubled when shot from the same barrel. Again, the old bluff-nosed bullet required more elevation for head winds, so I think one must be satisfied with getting practical results, for I don't see how one can lay down a law. And as to side wind, I think I told you than a 380gr. bullet with an angle of 2° at 1000 yards, requires as 10 : 7 over match bullet 560grs., with angle of 2° 10′.

American riflemen are very frightened at changes of light. For my own part I cannot see that they make a difference, provided one is careful not to take a fuller or finer sight, and with a match rifle I never heed changes of light. I have set carefully a theodolite and watched it for days, and could not detect any alterations of the object due to refraction. . . . .

Graduations. 5′ = 5in. roughly for every 100 yards, is very easy to see and easy to calculate. I have these spaces on my military rifle, and one can set sights very accurately with it.

Some years since Mr. Metford and I got up some half-inch calibre rifles weighing 15lb. for 2000 yards, with telescope sights and did very good work with them. I could reckon on hitting 12ft. by 12ft., but it was felt that two sorts of small arms ammunition would not be practical; so the matter was dropped. And, moreover, it would have been difficult to get a soldier to stand the recoil of 150grs. of quick powder and 700grs. of lead. We used percussion shell, and very nice they were"

With regard to "minutes of angle," it may perhaps be worth mention that one minute (1′) is equal to about an inch in 100 yards; and it would apply equally if it were an angle of elevation to compensate for the drop of the bullet, or an angle of side, to compensate for its drift. An angle of one degree (1°) is very nearly equal to a slope of 1 in 60, or 1 inch in 5 feet, or half an inch in a 30in. barrel. As there are 60 minutes in a degree, a minute of angle is equal to a slope of about 1 in 3600; and there are 3600 inches in 100 yards. Accordingly, an elevation of 1′ is equal to a rise of about 1 inch for every 100 yards; an elevation of 1° equals a rise of about 5 feet per 100 yards; and so on. The Government angle for the Martini-Henry at 1000 yards is near about 3½°. This angle would consequently be equal to about 17½ feet in 100 yards, and to about 175 feet in 1000 yards. The drop of the Martini, with 1350 ft.-sec. muzzle velocity, is shown at page 153 to be 186 feet; so that, supposing the angle of elevation to be just as stated, there would be about a dozen feet to account for. The minute of angle is, however, a fraction more than an inch in 100 yards; besides which there is the "jump." Air-resistance, too, would tend to check descent in the bullet, as its drop velocity would exceed 100 ft.-sec. in 1000 yards, and resistance be proportionate to the square of velocity; but with sporting rifles the effect would be practically *nil*, the drop velocity of Express bullets in 150 yards being only about 10 ft.-sec.

CHAPTER X.

RETENTION OF ENERGY AND PENETRATION.

THE muzzle velocity of the bullet is not the only thing that concerns the sportsman in choosing his rifle and projectile. This speed is but a means to the end he has in view. He wants to kill his game at a greater or less distance, and not at the muzzle of the gun. According to the nature of the bullet, so will the velocity dwindle away; and one bullet which has the greatest initial speed may, by reason of its lightness, have lost that advantage by the time it has gone a hundred yards, and it will consequently not only strike with less force than another which had a smaller nominal power at first, but, by reason of the loss of speed, it will have a higher trajectory at all longer ranges.

Some tables have already been given showing the diminution of velocity and the amount of drop of eight typical bullets of ·450 bore at different ranges; and these tables also apply to forty-eight other bullets of different calibre, whose weights are stated on page 142. But although certain particulars have been given relative to these fifty-six bullets, nothing has been said to indicate what is the amount of "energy" or working power that they respectively possess; and the energy is, in some respects, a better gauge of their merits than the muzzle velocity, which merely tells the speed with which the shot leaves the barrel.

The energy of a moving body is ascertained from its weight and its rate of motion, and the unit of work is, in this country, usually denominated a "foot-pound." The most simple example of this unit of work is when a pound weight is lifted 1 foot. An amount of force equal to 1 ft.-lb. would be generated by dropping 1lb. a space of 1 foot; and 1 ft.-lb. of energy would be required to project the same weight the same distance upwards. The number of foot-pounds is estimated, in one way, by multiplying the weight of the body by the number of feet of fall, so that 1lb. dropped 100ft., and 20lb. dropped 5ft., or any other multiples that produce the same result, will give an equal number of foot-pounds; and, in another way, it is estimated by multiplying the weight by the square of the velocity and dividing the product by 64.

The figures on page 51 show that a weight falling for a certain time acquires a velocity equal to 32 feet per second; that the space passed through in a given time is equal to the mean velocity during that time; and that the square of the time, multiplied by the half of 32 ft.-sec. (16) gives the total drop. On the other hand, if the final velocity be squared, and the product divided by twice 32 ft.-sec. (64), we also get the total drop. Applying these facts to the ascertainment of foot-pounds, we find that 1lb. weight acquires 8 ft.-sec. velocity in dropping 1 foot, and, conversely, that if 1lb. be projected upwards with 8 ft.-sec. velocity, its rise would equal 8 × 8 (64) divided by 2 × 32 (64), so that the height would be 1 foot and the result 1 ft.-lb. If the velocity were 800 ft.-sec. the result would be 800 × 800 (640,000) divided by 64, which would give 10,000 as the number of foot-pounds of energy; and, were it not for the resistance of the atmosphere, a 1lb. shot projected upwards with 800 ft.-sec. velocity would rise 10,000 feet before its energy was exhausted in raising its own mass against the force of gravity. When fired horizontally, the shot would have the same original amount of energy as when fired vertically; and such portion as is not expended in overcoming atmospheric resistance would be available against any object with which it comes into contact. Accordingly, if we take the velocity of any of the bullets mentioned in previous tables, square that velocity, multiply by the number of grains the bullet weighs, and divide by 64 (twice 32 ft.-sec.) and by 7000 (the number of grains in a pound), we get the number of foot-pounds of energy there is in the bullet at the particular point.

The energy of all the ·450 bullets mentioned in tables from pp. 143 to 153 are thus calculated in the table on p. 237; and as it would be inconvenient to refer to and fro to ascertain the velocities of the respective bullets, these also are collected together for facility of comparison. The amount of energy applies only to the eight bullets of ·450 calibre, because the weight of the other bullets alter more or less according to the size of the bore; but the velocities apply to the bullets of all calibres. If the energy of the larger or smaller bullets is required, it may be ascertained by the process just described; but a less troublesome method is to take from the table of energy the number of foot-pounds given for the ·450 bullet, and multiply this number by such one of the following factors as applies to the calibre of the bullet whose energy is to be ascertained:

Bore	Multiple	Bore	Multiple
·360	64	·420	·87
·380	·71	·500	1·23
·400	79	577	1·64

Thus, if we take the energy of the ·450 bore bullet of 360grs. at 100 yards, with 1700 ft.-sec. muzzle velocity (1650 ft.-lb.), multiply by 79 and cut off the last two figures or decimals, we get 1094 ft.-lb. as the energy of the ·400 bore bullet of the same type, which the table on page 142 shows to weigh 284grs. In some cases an error of a pound or so may arise from the decimals in the multiple not being carried further, but this slight difference is immaterial.

REMAINING VELOCITIES OF THE TYPICAL BULLETS AT DIFFERENT RANGES.

Weight of Bullet and Muzzle Velocity	Yards Distance from Muzzle of Rifle.									
	50	100	150	200	250	300	30	400	450	500
Grs.	Ft.-sec	Ft.-sec	Ft.-sec.	Ft.-sec	Ft.-sec.	Ft.-sec.	Ft.-sec.	Ft.-sec.	Ft.-sec.	Ft.-sec.
260										
2000	1787	1592	1413	1257	1130	1036	974	919	870	826
1900	1696	1508	1338	1195	1081	1006	948	896	849	807
1800	1604	1423	1266	1137	1040	977	922	873	828	788
280										
1900	1710	1534	1372	1233	1118	1034	976	925	876	837
1800	1617	1448	1297	1171	1069	1003	949	900	856	816
300										
1900	1722	1556	1403	1267	1154	1062	1002	951	906	864
1800	1629	1470	1325	1202	1100	1027	973	926	882	843
1700	1536	1384	1252	1141	1053	995	945	900	859	822
330										
1800	1645	1498	1363	1244	1144	1062	1007	960	917	878
1700	1550	1411	1286	1179	1089	1025	977	933	892	855
360										
1800	1657	1522	1395	1282	1184	1100	1036	991	949	911
1700	1563	1433	1315	1212	1124	1052	1004	961	922	885
1600	1468	1347	1240	1148	1070	1017	973	933	896	862
400										
1600	1481	1370	1270	1183	1107	1046	1003	965	929	896
1500	1387	1286	1196	1118	1054	1010	971	935	896	870
440										
1500	1397	1303	1219	1145	1081	1033	995	961	928	898
1400	1306	1222	1147	1083	1034	996	962	929	899	870
480										
1350	1268	1195	1115	1072	1038	996	964	934	906	879

On comparing these tables, it will be observed that the higher the velocity and the lighter the bullet, the greater is the loss of speed; and that a 260gr. bullet which starts with 2000 ft.-sec. velocity loses more than 400ft. of that velocity in the first 100 yards. At the end of that distance, a bullet 20grs. heavier, and starting with 100ft. less speed, already equals it as regards energy, and in longer ranges surpasses it in velocity. The same thing goes on with each increase of weight; 20 or 30grs. addition to the bullet soon compensating for 100ft. less muzzle velocity.

ENERGY OF ·450 TYPICAL BULLETS AT DIFFERENT RANGES.

Weight of Bullet and Muzzle Velocity	Yards Distance from Muzzle of Rifle										
	0	50	100	150	200	250	300	350	400	450	500
Grs.	Ft-lb	Ft-lb	Ft-lb	Ft-lb	Ft-lb	Ft-lb	Ft lb	Ft.-lb	Ft lb	Ft.-lb.	Ft.-lb
260											
2000	2321	1853	1471	1159	917	741	623	551	490	439	396
1900	2095	1669	1320	1039	829	678	587	522	466	418	378
1800	1880	1493	1175	930	750	628	554	494	442	398	362
280											
1900	2204	1828	1471	1176	950	781	668	595	535	482	438
1800	2025	1634	1310	1051	857	714	629	564	506	458	416
300											
1900	2417	1986	1621	1318	1075	892	755	672	606	550	500
1800	2170	1777	1447	1176	967	810	706	634	575	521	476
1700	1935	1580	1283	1050	872	743	663	598	543	494	452
330											
1800	2387	1993	1653	1369	1140	964	831	747	679	619	568
1700	2152	1770	1466	1218	1024	873	774	703	641	586	539
360											
1800	2603	2206	1862	1564	1321	1127	972	862	789	724	667
1700	2322	1963	1650	1390	1180	1015	889	810	742	683	630
1600	2057	1732	1458	1236	1059	920	831	761	699	645	597
400											
1600	2286	1959	1676	1440	1250	1096	977	898	831	771	717
1500	2009	1718	1477	1277	1116	991	911	842	781	717	676
440											
1500	2210	1917	1668	1459	1288	1148	1048	972	907	846	792
1400	1925	1675	1467	1292	1152	1050	974	909	848	794	743
480											
1350	1953	1723	1529	1332	1240	1154	1063	996	935	880	828

It may be said, with regard to the comparative effects of speed and weight, that higher muzzle velocity gives a lower trajectory. So it does, for short ranges; and it is entirely a matter for the sportsman's consideration whether the flatness of trajectory is sufficient compensation for the loss of power within the range for which he chiefly intends to use his rifle. By comparing the three tables of trajectories on pages 145, 149, and 151, it will be seen that, in a range of 150 yards, the trajectory of the 260gr. bullet is about two-tenths of an inch lower than the 300gr. bullet with

100ft. less initial speed, and half an inch lower than the 360gr. bullet with 200ft. less velocity; at 200 yards the trajectories of the three bullets are about equalised; and, after 300 yards, the lightest bullet, despite its high muzzle velocity, has not so flat a trajectory as either of the other two, while in striking force it is much inferior.

Upon its striking force of course depends the power of penetration of the bullet. And here another question for the sportsman's consideration is the nature of the penetration he wishes to obtain. A long and slow bullet will drill through a thin-skinned animal without expending its force, and, by giving little shock to the system, will leave the beast with nearly all its vigour to escape pursuit, or perpetrate mischief for the time being, although it may have received a mortal wound and eventually die a lingering death. On the other hand, a light hollow-fronted bullet may be smashed up on a tough hide, without ever penetrating at all.

So much depends upon the nature of the projectile and of the substance against which it is impelled, that it is difficult to give any general idea as to the penetration of bullets. We can here only proceed on the assumption that the target at which they are fired admits of penetration, and gives equality of resistance, and that the bullet does not change its form on impact. In such case, the penetration of bullets of the same calibre and the same shape would be proportionate to the square of their velocity multiplied by their weight.

Bullets having the same energy, but differing in calibre, would not, however, have the same power of penetration, for they would be met with an amount of resistance proportionate to the square of their diameter. Hence, if two bullets, of ·500 and ·400 bore respectively, and of the same weight, struck with the same velocity, their energy would be equal, but the resistance to the larger bullet would be as 25, and to the smaller as 16, so that the former would only penetrate about two-thirds as far as the latter. With some kinds of game the extra penetration would be an advantage; with others it would be better to have less penetration and greater local shock. Accordingly, in the choice of projectiles, the means must be adapted to the end.

In the case of the bullets to which the foregoing table of energy is applicable, all that are of the same type would have equal power of penetration, because their weight increases or diminishes at the same rate as the area of resistance. But between bullets of different types this would not hold good. Those of the same calibre would increase in penetration with increase of weight, supposing their velocity to be equal; but where the area of the bore increases more rapidly than the increase of weight, the penetration would diminish; and *vice versâ*. Thus, with 100 ft.-sec. difference in initial speed, the energy of the 260gr. bullet and of the 280gr. bullet of ·450-bore are equal at 100 yards (see p. 237), and we may therefore expect the penetration to be equal; but if a ·400 or other bullet had the same velocity as a ·450 bullet of the same weight, the energy would be equal, but the penetration would be greatest with the smallest bore. The amount of difference may be estimated by means of the multiples on page 235. Supposing, for example, it were known that a bullet of ·450 calibre, with a given energy, penetrated twenty boards of a particular kind, the proportionate penetration of a ·500-bore bullet, with the same amount of energy, would be $20 \div 1·23$, or about sixteen boards. The proportionate penetration of a ·400-bore, with the same energy, would be $20 \div ·79$, or twenty-five boards. If we know the penetration of a ·500 bore, and want to get that of a ·400 of equal energy, we multiply by 1·23, which brings the ·500 to the ·450 standard, and then divide by ·79, which gives the ·400 equivalent.

In Messrs. Holland's trial in 1879, the penetration of

1in. yellow pine boards by ·577-bore solid Express bullets, hardened by 1 part of tin to 9 of lead, was, in round numbers, at the rate of one board to about every 120 ft.-lb. of energy. With a ·450 bullet, owing to the smaller area of resistance, we might estimate the proportion as 120 — 1·64, or about 73 ft.-lb. per board; if it were a ·400 bullet, the corresponding proportion would be 73 × ·79, or one board for about 58 ft.-lb. of energy. But in all practical experiments, the actual penetration would necessarily depend upon the relative softness in the wood and its freedom from knots.

Concluding Remarks.

The main purpose of the writer of the previous chapters has been, while treating of theoretical matters, to endeavour to render them of some little practical value to those for whom the book is chiefly intended; and recourse has therefore been had to such available facts as would best illustrate the questions under discussion. If a more ample supply of facts about sporting rifles had been forthcoming, the result might have been more satisfactory; and any further records of comparative trials with different weights of powder and lead will be gladly accepted, as such records are valuable in forming a basis for more definite conclusions.

These notes have been expanded far beyond the writer's original intention, and yet he is sensible that various points have been passed over with little or no notice. Some, no doubt, are topics of more interest to the artillerist than to the sportsman, whose projectiles are in motion for very brief periods of time, and have comparatively small amounts of rise and fall. But the theme is almost boundless in its scope; and the anticipation expressed in the first of these chapters is fully verified on arriving at the last, viz., that the subject would not be exhausted here.

T.

BOOK V.

THE MECHANICAL CONSTRUCTION OF THE SPORTING RIFLE AND ITS AMMUNITION.

CHAPTER I.

GENERAL PRINCIPLES OF CONSTRUCTION.

THE main difference between a shot gun and a rifle lies in the barrels, those of the latter being so much the heavier and stronger. The breech action and stock of a rifle also require greater strength than the similar parts of a shot gun, but to a less marked extent. The rifle also has almost invariably the pistol hand grip instead of the straight hand of the shot gun. Most of the breech actions described in Volume I. can be applied to double rifles for sporting purposes, as in fact many are, but single rifles require somewhat different treatment, as we shall hereafter see. I propose, therefore, to confine myself to the consideration of the barrels, ammunition, and trials of shooting of the modern sportsman's rifle, occasionally noticing the external details of some typical rifle in each group.

BARRELS.

Most rifle barrels are now made of steel of a specially tough and tenacious quality. Until a few years ago welded barrels were largely used for this purpose, partly on account of their beautiful figure, but mainly because the steel then obtainable was of an uneven, unreliable quality, with varying degrees of hardness, and occasionally so brittle as to fracture under a moderate bursting strain in a most alarming manner. This is now a thing of the past, as steel manufacturers (stimulated, no doubt, by Sir J. Whitworth's great success with his excellent fluid compressed steel) now constantly turn out steel as tough and reliable as can possibly be wished for by any rifle maker. The welded barrels, damascus or other figure, were always subject to imperfections or "greys," defects that seem inseparable from their manufacture, and quite inadmissible in a high-class rifle barrel. The great difficulty also experienced in obtaining a welded barrel of small calibre "clear" in the bore adds no little to the cost of figured rifle barrels. With regard to the double barrelled rifles, the manufacturing processes to which a pair of these barrels are subjected differ in no essential point from those described in Chap. IV. of my first volume in treating upon shot gun barrels, though in the "putting together" process some extra care is required in determining to what extent the tubes shall incline towards each other from breech to muzzle, taking care that each tube be truly straight during its whole length. There is no process upon which the ultimate perfection of the weapon so much depends as this one of "putting together." The angle of inclination towards each other for each particular calibre and weight of barrel, taken with due regard to the charge of powder and weight of bullet to be used—having been previously ascertained by careful experiment—every precaution should be taken by the workman, so that when the operation is completed each tube of the pair should be as straight as when single, and the determined point of impact of each tube when fired with its proper charge be as nearly as possible coincident. We all know that an expert "regulator' can so alter and manipulate a pair of badly put together rifle barrels as to obtain fair, and sometimes good results, but, apart from the question of unequal wear, &c., upon a "sprung" tube, the result can be but a compromise, some of the best points of the rifle being sure to suffer more or less.

Rifling.

In approaching the question of rifling or grooving the barrels for the purpose of spinning the bullet, and thereby insuring its approximately true flight through the air, I am aware that I touch upon a vexed question, nearly every rifle maker of note having a particular shape of groove, and some also a special kind of twist, for which they each claim some marked superiority in results over all other methods. My investigations into this matter, both by experiment and inquiry, have resulted in a rather satisfactory conclusion for the practical sportsmen, that is, that equal quality of workmanship and finish give very nearly equal results with most methods of riflings now in vogue; though in some slight degree, in certain special cases, one method may be superior to others. But this superiority is sometimes counterbalanced by some other slight disadvantage. Any method of rifling barrels must be largely influenced by the ammunition to be used and the conditions of using; and as, for sporting purposes, the rule is to employ, in proportion to calibre, rather light bullets and heavy powder charges (for all but small game rifles), we must expect quite a different style of groove from that of the highly-accurate target rifle, whose ammunition is constructed upon opposite proportions: *i.e.*, heavy bullets and moderately light powder charges. We must also take into consideration the conditions under which the sporting rifle is likely to be used, and the necessity of providing for a "rough-and-tumble" life as compared with the carefully-used target rifle. Upon this view of the question, we find most makers of sporting rifles using moderately deep grooves and a comparatively slow twist; in fact, it is generally recognised that, for the purpose of reducing recoil and obtaining a high muzzle velocity, the twist should be as slow as is compatible with accuracy at sporting ranges, while the groove should not be so shallow as to be rendered ineffective by any slight amount of accumulated fouling, or some unavoidable moderate variation in the hardness of the bullets. The groove should, of course, be easily cleaned, and not likely to be seriously damaged by ordinary treatment. In proceeding to examine the leading methods upon which sporting weapons are rifled, I must refer my readers to the accompanying illustrations, which give a fairly accurate idea of each variety, though it is necessary where such small values are dealt with as enter into the grooving of a rifle barrel, to somewhat exaggerate some of the details, so as to enable the eye to sufficiently appreciate them, and hence they do not pretend to indicate the depth of the cut. In all cases the dotted lines represent the original bore. The following plans are selected as those which are now in general use, and are given in the order in which they have been brought out. The sketches are about four times the real size, and in all cases represent the barrel as viewed from the breech end.

The Enfield Rifling.

This was originally made with three or five grooves, but is now more frequently employed in a seven-grooved form, with flat sides and concentric bottoms to each, as in the annexed plan. It has been adopted for many years by Mr. Turner, Messrs. Tolly, of Birmingham, and others, and until lately by Messrs. Holland, of London. When used with the special ammunition of the last-named firm it gave very satisfactory results, though they now adopt a different method, to be presently described; but, as might be expected upon an examination of this method of grooving, a slight loss most probably occurs in the matter of recoil and trajectory. This plan of grooving, in its essential feature, has been largely before the public for the last twenty years, it being identical in principle with that used in the Government Enfield and Snider rifles—the chief peculiarity being what is called a "progressive cut," or a gradual increase in depth of groove from muzzle to breech—not, as in the "Henry," for a short distance near the breech only, but for the entire length of the barrel. The variation of depth of groove at breech and muzzle respectively can be regulated to suit the requirements of the ammunition or the fancy of the maker, who, by allowing a moderate depth of groove at breech to die out, as it were, towards the muzzle,

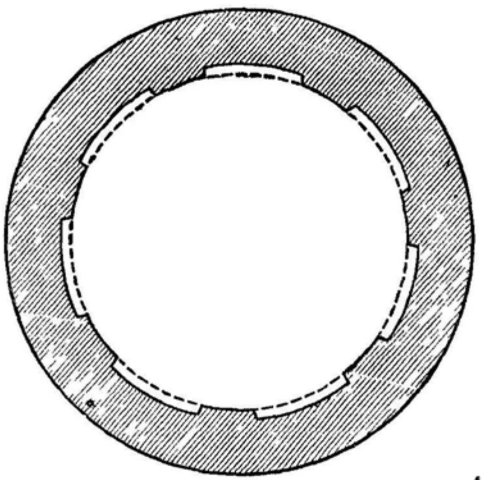

FIG. 20. ENFIELD RIFLING, AS NOW USED FOR SPORTING RIFLES.

thereby produces the "semi-smooth" style of rifling. As might be expected from our experience of the shooting made by the Snider rifle, especially at sporting ranges, this method of rifling gives very satisfactory results, provided a projectile resembling the Snider bullet be used, that is, a short, more or less hollow bullet, unpatched, and cannelured, with its exterior well lubricated with grease or wax, or some compound containing these anti-frictional substances. With a solid projectile, if of any length, we may expect that the increasing friction met with in passing every inch of the entire length of the barrel would have a detrimental effect; neither would a similar paper covered bullet work well under such exacting circumstances. The manufacturing details employed in this system of grooving are rather more complicated than usual, and it is found difficult to correct or modify any small defect in the grooving (such as a slight bruise, scratch, or rust spot) inflicted subsequent to the cutting of the barrel in the rifling process, which may account for the system not being generally popular among sporting rifle makers.

THE LANCASTER OVAL BORE.

The so-called "oval bore," introduced some thirty years ago by Mr. C. Lancaster as a suitable groove for the ·500 calibre muzzle loader, has been adapted to sporting rifles mainly by his successors in business, and, judging from report, with a fair amount of success. I have described in the *Field* some good results in point of accuracy from a ·500 calibre Express single rifle, but I am unable to verify any performances made with other calibres rifled on this system, which was largely used by the Government for military arms at one time, but has been discontinued by them for a number of years. The peculiarity of this rifling is that the interior of the barrel has two bold grooves cut opposite to each other and formed without any rib or edge, so that the barrel has obviously an oval appearance (see Fig. 21). This absence of corners, such as exist in other styles of groove, certainly facilitates cleaning, and reduces the liability to injury from bruising, &c., when that operation is carelessly performed. On the other hand, the great obliquity of the bearing side of the groove used in imparting rotation to the bullet during its passage, seems to me to be calculated to set up unnecessary friction, resulting in diminished muzzle speed and increase in trajectory curve.

There is also an objection of some weight against all methods of rifling that have an *equal* or even number of grooves, thus throwing two grooves opposite each other; this objection is not of much moment in a rifle in which the conditions permit a shallow groove; but in the Lancaster system the grooves cannot be shallow. Thus a bullet to give accurate results must quite fill up the entire depth of both grooves the instant of firing; and to insure this an amount of forcing is resorted to by increased diameter of bullet as compared with the calibre of barrel not in accordance with modern axioms received by rifle makers. This plan is most usually rifled upon an

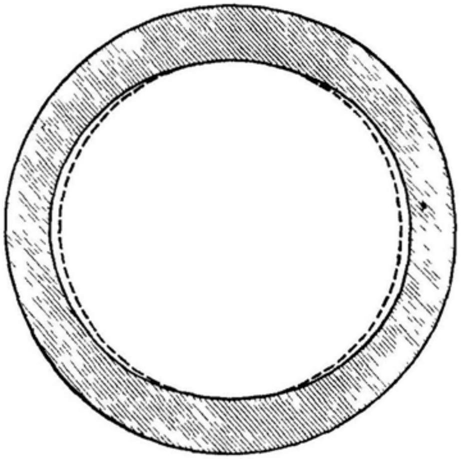

FIG. 21. C. LANCASTER'S OVAL BORE RIFLING.

increasing pitch of spiral gaining in rapidity towards the muzzle and combined with a more or less progressive depth of groove from muzzle to breech.

I have already observed that in my opinion there is little advantage in any of the various methods of rifling now in use as compared with their rivals, but as "Mr. C. Lancaster" claims a good deal, and as his claims have been endorsed by many of the correspondents of *The Field*, I insert his description *in extenso,* with the obvious conclusion that, according to the above statement, I do not endorse them as fully as he could wish.

CHARLES LANCASTER'S NON-FOULING ELLIPTIC OR SMOOTH OVAL-BORE RIFLING.

The Lancaster oval-bore is a modification (as far as the principle is concerned) of the 2-grooved, but at the same time a modification that obviates all the objections to which that system was open. The method of construction is as follows: The barrel is bored perfectly cylindrical, ready to receive the frame that carries the cutter, by which the bore is increased on two sides, so giving a major and minor axis in one and the same tube, and making the barrel oval in the bore instead of cylindrical, which oval form turns spirally the whole length of the barrel, and the bullet, when forced through the barrel, necessarily gets a rotatory motion on its own axis. The great object to be obtained in a rifle is accuracy with the flattest possible trajectory. This is only to be obtained by a high velocity for the ball during its passage over a given distance. The initial velocity of the ball depends upon the burning of so much powder in the barrels. The accuracy of the ball's flight depends upon its rotatory motion, that rotatory motion is imparted by the grooving of the rifle in most cases, and by the oval-bore in the Lancaster system.

With a given amount of powder, the smaller the resistance to the ball in passing through the barrel, the greater will be its initial velocity on leaving it The grooves on the inside of a barrel naturally prove a greater resistance than a smooth surface, therefore the smooth surface of a Lancaster barrel gives less resistance than any grooved barrel, and for a given amount of powder, the initial velocity of the ball must be greater and the recoil less.

The ball having left the rifle, the great object is to keep up its velocity to the highest possible pitch for the sake of a flat trajectory, and to keep up its rotatory motion for the sake of accuracy. The etarding forces opposed to the attainment of this object, are the resistance of the air and the friction of the air on the rotating ball therefore, the smoother the ball the less friction or retardation there will be.

In the case of the Lancaster oval-bore, the ball leaves the barrel with a smooth surface, while in grooved rifles, it is more or less jagged and indented by the grooves, therefore, with a given amount of rotary motion on leaving the barrel, the Lancaster ball will keep up that motion longer than a ball from a grooved barrel, and would, therefore, give greater accuracy along the whole length of its flight.

But, having shown that for a given amount of powder the initial velocity of the Lancaster ball must be greater than that from a grooved rifle, and also that after leaving the barrel it meets with less resistance than a ball from a grooved rifle, therefore it has a flatter trajectory, greater accuracy and less recoil, hence its superiority.

I append herewith a trial of a Lancaster smooth oval-bore Express rifle which took place before the Editor of the *Field* on Feb. 12 at Wormwood Scrubbs, report of which appeared in the *Field* of the 17th Feb. 1883:—

"On Monday morning last, after several adjournments owing to the weather, we proceeded to Mr. C. Lancaster's ground at Wormwood Scrubs, with a view to witness a trial of one of his oval bores, which we have been requested to do by several correspondents. The morning was by no means favourable to good shooting; indeed, the wind was so high as to tax the strength of the shooter in keeping the barrel steady. It blew from the right front of the range, and occasionally with great force, with a few drops of rain, which necessitated an umbrella being held over the front sight.

"The rifle was a single ·500 oval bore, with Mr. Field's action, weight 10lb. 6oz., length of barrel 26in. We began with a series of ten shots, with 160 gr. C. and H. No. 6, and 600gr. pure lead bullet, having a cavity in front, $\frac{1}{16}$in. in diameter, and half the bullet; distance 100 yards.

"First eight shots were grouped in a space of 5in. × 4in., the ninth $1\frac{1}{2}$in., and the tenth 4in. to leeward of the group.

"Second series.—Powder, 160gr.; lead, 440gr. pure soft lead, with a cavity in front filled with wax Eight shots were fired, of which the first six were in a group $3\frac{1}{2}$in. square; the seventh was 6in. from the centre of this group to the top right. Mr. C. Lancaster, having previously stated that he was hitherto making no allowance for wind, now declared to make a bull ($1\frac{1}{2}$in.) by allowing for wind, and did so, the barrel not being wiped out during the trial.

"This performance even without taking into consideration the gusts of wind which were blowing, is a very good one, but making allowance for this drawback, our readers will, we think, agree with us that it was highly satisfactory to Mr. C. Lancaster, who, besides being the maker, shot the rifle himself.

"The initial velocity of the heavy bullet was about 1620 feet per second, and that of the lighter one 1750ft., as taken by the chronograph belonging to Messrs Curtis and Harvey; consequently, there should be a difference of about 1in. in the elevation of the two at 100 yards on this calculation, yet in practice, though Mr. C. Lancaster took the same sight throughout, they were as nearly as possible alike, which can only be accounted for by the greater 'jump' given by the heavier ball. This is a very interesting fact in support of the 'jump' theory."

The introduction of the breech system of loading a rifle has done more to perfect the oval-bore and its performances than perhaps any other system of rifling, because, when used with a muzzle-loading rifle a certain amount of windage had to be allowed to facilitate the passing of the bullet down the barrel on to the wad over powder charge; consequently a wild shot was sometimes obtained owing to the stripping of the bullet, which bullet was in those days of an ovoid form, and care had to be taken to get the bullet into the oval or major axis of the barrel in loading. The introduction of breech-loading arms has enabled the major axis or oval to be very much nearer in size to the minor axis or cylindrical portion of barrel, thereby considerably reducing the friction and possibility of a jam, which sometimes occurred in the rifles where both the barrel and the bullet were ovoid. The bullets are now perfectly cylindrical and conical at the front, and made on the very best principles of Express patterns, so as to obtain the very best results. Their diameter is regulated to that of the bore of the rifles which is made in all sizes from ·230 to ·577, and also from 20 to 4 bore for large game. In either case its lateral expansion at the moment the rifle is fired, is enough to compel it to fill the barrel perfectly; in fact, to seal the tube hermetically till the projectile has left the muzzle, and so obtain its rotatory motion from the spiral ovoid. The bore being as smooth as that of a shot gun, it can be more easily cleaned than a grooved barrel, also as there are no grooves, shot can be used from rook rifles, thereby making them useful for collecting small birds abroad, and also from the larger bores in cases of emergency, where the "pot" has sometimes to be filled in hunting expeditions.

Bullets may be made either of soft pure lead, or may be hardened down to $\frac{1}{10}$th of tin.

It will be seen in the above description that "Mr. C. Lancaster" *claims a greater muzzle velocity in proportion to the powder used than can be obtained from other forms of* grooving. According to the Enfield trials of the military arm this has not been shown, and even taking Messrs. Curtis and Harvey's report of the velocity of the ·500 bore, as recorded at page 250, a muzzle velocity of 1750 feet per second only was obtained with 160 grs. powder to 440 grs. lead, rather more than 1 to 3, which is as nearly as may be the same as that given at the *Field* trials of 1883 by other rifles.

THE HENRY RIFLING.

Fig. 22 represents a ·450 express rifle barrel grooved on the "Henry" system. Certainly more sporting rifles in this country have been grooved on this system than any other,

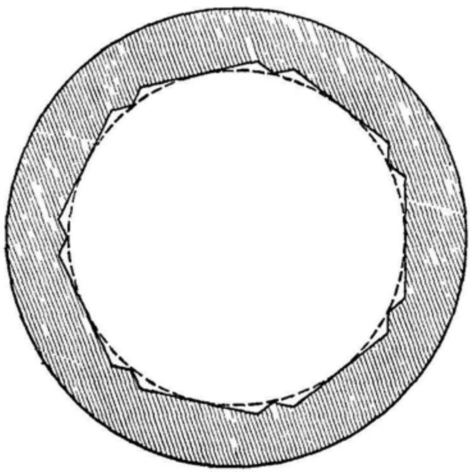

FIG. 22. HENRY'S RIFLING.

especially the small and medium calibres, probably on account of its adoption by the Government in 1868, though this pattern groove was then selected on account of its suitability for a long-range military weapon carrying a heavy bullet and moderate powder charge. As will be seen, there are seven grooves, each with a rib or "re-entering angle" filling up what would otherwise be the deepest part of the cut. Sometimes this pattern is made with nine grooves, especially in larger calibres than the ·450. Since its first introduction an important practical modification has been incorporated with this system, which is somewhat difficult to describe; that is, for some inches from the breech end the groove gradually deepens toward the breech, so that the calibre is widest at that end of the barrel, the effect being, that on firing the cartridge the bullet expands to the wide part, and gradually tightens as it passes onwards until it gets about one-quarter way up the barrel, whence up to the muzzle the depth of cut is uniform. This rather difficult mechanical process seems to be so necessary to the correct performance of the "Henry" barrel, that few are made otherwise, though in his original specification the patentee seems unaware of its importance. In a patent for "rifling barrels," dated 1860, by Mr. Turner, of Birmingham, we find this identical improvement described, also the tools, &c., necessary to carry it out. The twist of this rifling in a ·450 Express is uniform in spiral, and a complete revolution, in all the specimens I have examined, is made in from 30 to 35 inches. It appears necessary in this method of grooving to keep the calibre of the barrel *small* in comparison to the diameter of the bullet, showing that neither expansion, or what is termed "upset," is entirely relied on for securing the complete engagement of the groovings by the bullet.

THE METFORD RIFLING.

Fig. 23 represents a barrel, ·450 Express, rifled on the Metford principle. This method is chiefly used by the firms of Gibbs, of Bristol, and Westley-Richards and Co., of Birmingham, and has not as yet come into very general use. Though various forms of groove have been sanctioned from time to time by the inventor, the annexed figure gives a fair representation of the latest pattern or one of them. As far as shape goes it will remind old sportsmen of the cut recommended by Forsyth for 12-bore rifles some fifteen years or more ago. The great distinguishing feature of the Metford system is the varying curve of its spiral, starting slowly at the breech end of barrel (say one turn in six feet) and increasing according to a definite law based on the increasing effect produced by the powder gas, which law the inventor claims to have dis-

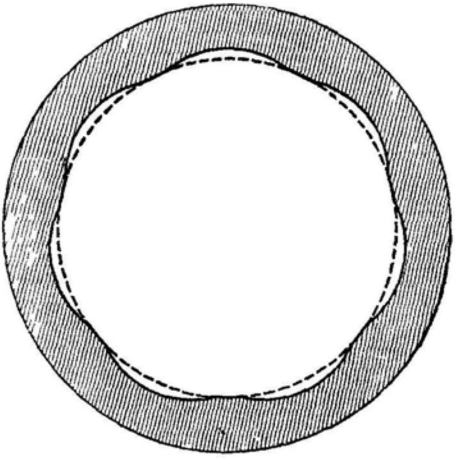

FIG. 23. METFORD RIFLING.

covered; so that at the muzzle the terminal twist in a ·450 Express will be about one turn in 25 or 30 inches. This constantly varying curve necessitates a patched or paper covered bullet, as the friction on a naked projectile would be considerable from its constant change of form; and in a properly proportioned barrel and its relative bullet, the inventor claims that the effect of the changes of pitch are but just enough to fully shear the paper envelope of bullet without permitting any material injury to its actual surface. Whether any real actual advantage exists in rifling sporting arms on this system has not as yet been made manifest, though, as will be shown under its proper division, there can be no doubt that the Metford system applied to long range target rifles has done good work.

The Rigby Rifling.

Mr. Rigby adopts a groove of the annexed shape (see Fig. 24), but with a very shallow cut, varying from ·005 inch to ·003—and of the same spiral throughout. In his sporting

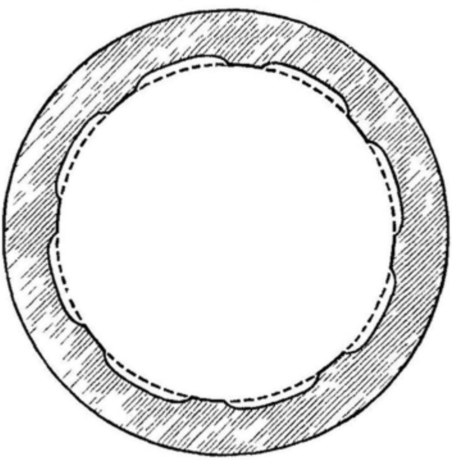

Fig 24 The Rigby Rifling.

rifles the cut is even more shallow than in his match rifling, which will hereafter be described. In the Rigby sporting rifles the groove is three times the width of the lands.

Hollands' Present Rifling.

Messrs. Holland have handed me the annexed section (Fig. 25) of the rifling they now use, with which they employ the same smooth plan as to depth, alluded to at page 244.

It will be seen that it closely resembles Mr. Rigby's, and it is also very nearly allied to that adopted by Messrs. Webley, of Birmingham, described below.

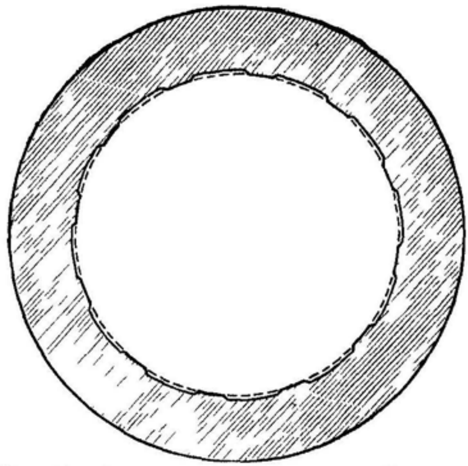

FIG 25 RIFLING OF HOLLAND'S 450 EXPRESS

MESSRS. WEBLEY'S RIFLING.

This plan has for some time been adopted by Messrs. Webley and Son, who are well known as large wholesale rifle

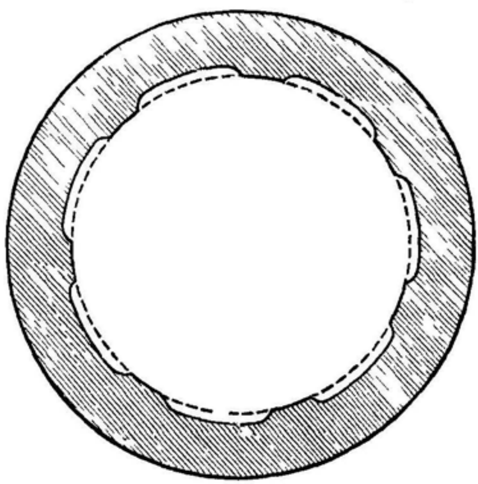

FIG 26 WEBLEY'S RIFLING

makers, and whose target rifles I shall hereafter notice in the section devoted to that class of weapon. This rifling is cut with an uniform twist of spiral, the pitch or amount of turn in a given length of barrel varying in different calibres in accordance with the diameter and length of bullet. The noticeable feature in this plan of grooving, is, that not only is the groove a little deeper at the breech end than at the point several inches nearer the muzzle, but, from the shape of cutting tool it is also a little wider, the object being, no doubt, to insure the grip or engagement of the rifling upon the bullet without any undue forcing of the latter. This is obtained, I am informed, to a most satisfactory extent, as is shown by the use of a calibre of barrel very much nearer the actual diameter of the patched bullet than is usually practicable with some other methods of grooving.

There are numerous other methods of grooving rifle barrels used by different rifle makers, but the examples I have given illustrate the main features of nearly every important type. In large bore rifles, such as 12, 10, 8 and 4 bores, generally used with spherical bullets only, a number of grooves (from 9 to 15, as the case may be), similar in shape somewhat to Fig. 20, with narrow lands, but cut of uniform depth from breech to muzzle, are generally preferred, so as to insure a reliable grip on the periphery of the spherical ball which can only take the rifling by a narrow zone, unless much upset and disfigured by the explosion.

It will be seen by my readers that each plan of grooving I have described displays nearly in every case the anxiety of the maker to insure the bullet "taking" the rifling, as it is called, immediately on leaving the cartridge. There is also apparent a general desire to cause the bullet to tighten its fit in the barrel during its passage outwards, thus continuing to seal the joint, as it were, and prevent the powder gas, at its exceedingly high pressure, from passing it, until it is discharged from the weapon. In some instances an endeavour is made to lessen the recoil by reducing the pitch of spiral toward the point at which the bullet enters the grooving; and, in fact, it will be seen that considerable mechanical ingenuity and research have been brought to bear on this apparently simple, but most important detail of rifle construction.

CHAPTER II.

SPORTING DOUBLE EXPRESS RIFLES.

In the present day Express rifles have almost completely superseded all other rifles for general sporting purposes, many good sportsmen considering that they are fully equal to bringing down the elephant and rhinoceros if fairly aimed at the brain of either of these animals, which their great accuracy enables the hunter to do with almost absolute certainty. From the enormous velocity given to the ball, and its hollow shape, the lead is made to spread out on striking a hard body such as bone, and, continuing to rotate with velocity, it tears a large hole in the interior of the chest if aimed at that part, or in the brain, as the case may be, and thus destroys life instantaneously. In this power it resembles the shell, which was relied on by Capt. Forsyth for the same purpose; and not being liable to the accidental bursting in the barrel—to which the shell is sometimes prone—it is by so much the superior, and consequently it has superseded the shell in India and Africa, where this was formerly in general use. With the aid of the gentlemen mentioned at page 10, I have been enabled to define the limit within which an Express may be said to exist, and it is therefore needless to return to the subject here. It is now necessary to describe the bores in general use, the length of barrel best suited to each, and the weight of the whole weapon when put into the sportsman's hands.

Express Bores.

The bores now almost universally adopted are ·400, specially recommended by Sir H. Halford for deerstalking; ·450, in general use for that purpose; ·500, more especially adapted for dangerous game; and ·577, which is only suited to those who can bear a very heavy recoil, but in their hands is no doubt a still more fatal weapon than the ·500 bore.

Length of Barrel.

The length of double-barrelled Expresses is on the average 27 inches, but different makers adopt slight variations in this length.

Weight.

The total weight for ·400 bores is usually about from 7lb. to 8lb.; ·450, 8lb. to 9lb.; ·500, 9lb. to 10lb.; and ·577, 10lb. to 12lb.; but, as in the length, so here some variations occur in the hands of different makers.

Charges used with the Various Bores.

For Express velocities the general rule may be laid down that at least 1 of powder to 4 of lead must be employed. This proportion is sometimes increased up to 1 powder to 2 of lead—or nearly so. Those actually in use will be found given in a table of loads under the head of Ammunition.

Though, as I have previously remarked, nearly every kind of breech action described in Vol. I. may be used in the construction of a double Express rifle, still as a rule, for some considerable time, rifle-makers have almost unanimously preferred the kind of action known as the "double grip," illustrated and described at p. 144, Vol. I. This preference has been justified by the undoubted soundness and capacity for resisting wear and tear shown by this kind of breech action, besides its great advantages for rifle purposes over most styles of snap actions in the matter of the "draw" or screw-like action of the grip lever in firmly closing the barrels down to their place upon the breech, even against the resistance of a cartridge that is moderately refractory. When this breech action is made with the extended rib or "doll's head," as described in pp. 156 to 160 in Vol. I., it displays, in addition to the advantages there enumerated as belonging to this mode of construction, the additional feature of affording a point of resistance to the "twist," or lateral tendency the barrels have to move in the breech, in consequence of first one barrel being fired and then the other. The value of the extension in thus steadying the side strain in a rifle that fires very heavy charges is not to be over-estimated. The accompanying illustration (Fig. 27) shows a double rifle

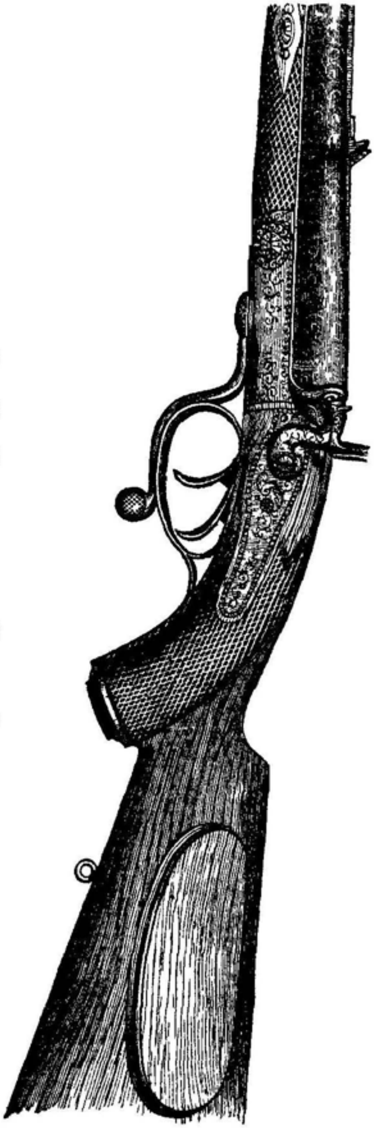

FIG. 27. MODERN DOUBLE EXPRESS RIFLE.

having this breech action, together with those almost invariable features *in such weapons as the "pistol grip"* and "cheek piece," both being modifications of the usual shape of the ordinary gun stocks, and supposed to be peculiarly suitable to rifles for sporting purposes. The utility of the pistol grip is very generally admitted, as it not only allows the firer the better to sustain the recoil of the piece by firmly drawing it to his shoulder, but it brings the finger into a good position for using the triggers. As to the utility of the cheek piece, opinions are somewhat divided. Probably for rifles firing moderate or light charges this form of stock would offer some slight advantage; but with rifles that recoil sharply the stock must be "cast off" to an undue extent to permit the introduction of the cheek piece, and too much cast off is a fault in a rifle stock for obvious reasons. The extra workmanship involved in this rather ornamental excrescence upon a gun stock has probably led to its continued use as a quality mark, or an indication that a rifle is of a rather superior style of finish.

Since Chap. VII., Vol. I., was written, sundry novelties in hammerless gun actions have been introduced, one of the most noticeable here being Messrs. Webley's "positively safe" hammerless action, as it is called, which, when used in combination with that firm's "screw grip" holding-down arrangement shown at p. 224E, in Vol. I., is calculated to be peculiarly suitable for double rifles, though it is also applicable to shot guns. As will be guessed from the name applied, the distinguishing feature in this breech action is the arrangement for insuring safety, which my readers will be able fully understand from the following description and illustrations.

All the safety contrivances hitherto brought forward are on one main general principle, namely—given a tumbler urged forward by a mainspring, and held by a scear, to

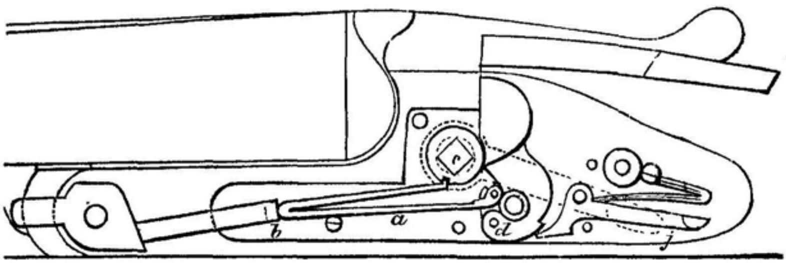

FIG. 28.

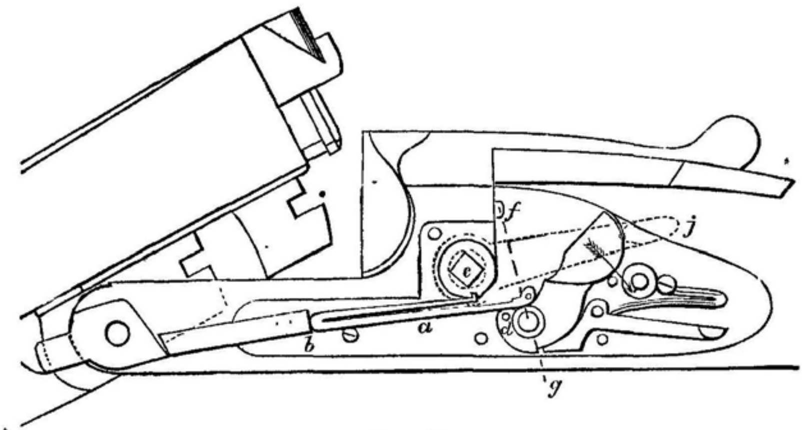

FIG. 29.

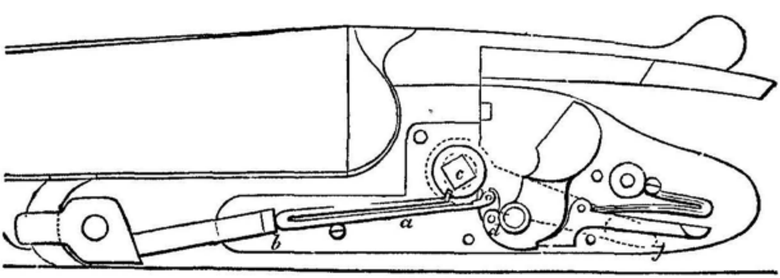

FIG. 30.

MESSRS. P. WEBLEY & SON'S "POSITIVELY SAFE" HAMMERLESS BREECH ACTION.

interpose some safeguard against the firing action of the tumbler, in case of its accidental release from the scear. To no one has it seemed to occur that it was possible to construct a hammerless action that should be safe *per se*, irrespective of any safety catches, until intended to be fired. In the arrangement under our notice this desirable result is obtained in a most simple manner, the mechanism being so arranged that, until the user wishes to fire the weapon, the pressure of the mainspring is forcing the tumbler hammer *backwards*, in a direction contrary to that needful for firing; thus, the arm is "positively" safe, and not "negatively" so, by reason of the interposition of extraneous stops and catches. A reference to the annexed figures will show how simply this is carried out. Figs. 28, 29, and 30, show the firing mechanism in three positions. Fig. 28 showing the mainspring released, and the tumbler in the "fired" position. Fig. 29 shows the mechanism "cocked" by the opening of the breech action. Fig. 30 shows the same ready for firing.

The mechanism being in the position shown in Fig. 28, the dropping of the barrels brings it into the position shown in Fig. 29, where the mainspring is shown thrust backward from its abutment at (*b*) pushing before it at its swivel end (*d*), the tumbler, until the latter is at full cock.

The force exerted now by the mainspring is very slight, and is applied to the tumbler *behind* the dotted line (*f g*), thus forcing the tumbler in the direction of the arrow.

While the lock is in this state the scear may be removed from contact with the tumbler with perfect safety. Therefore, while in other breech-action locks the pressure of the mainspring upon the tumbler at full cock is the primary source of danger, needing the check of safety appliances, this very pressure affords the most positive means of safety in this arrangement, because the tendency of the tumbler is *from*, not *towards* the firing pin or striker. *It is impossible* for this gun to be fired in the act of closing.

It will be noticed that the mainspring engages with the disc (*c*) by the small projection at one end of its shorter side; thus, as it slides it causes the disc to turn on its centre, and the outside lever or thumb-piece (*j*), being attached to the disc, moves with it. This lever gives the user control over the mainspring, and also acts as an indicator. To fire the gun, the disc (*c*) is turned by depressing the outside lever (*j*), thus placing the lock in the position shown in Fig. 30. Here *it will be seen that the mainspring* has *thus* been returned so as to bear upon its abutment (*b*), the swivel (*d*) has assumed a line at right angles to the mainspring, this latter having thus become fully compressed, and its force, exerted upon the tumbler at a point *in front* of the dotted line (*f g*), being in the direction proper for firing, when the trigger is pulled in the usual course. An important feature in this lock is that, except at the actual time of firing, the mainspring is in a permanent condition of "*ease*," there being no appreciable strain upon it, whereas the opposite is the case in all bolted or checked safety arrangement.

The squared axis of the outside lever (*j*) passes through and so operates on the disc (*c*) of each lock; thus, after firing one barrel, the other lock can be put back into the position of safety shown in Fig. 29 by raising the lever. In the same way if, after preparing to fire, the intention be changed, the locks can be at once restored to the safe position.

I think the simplicity and effectiveness obtained by this mode of constructing lock work, will thoroughly recommend this breech action to the notice of my readers, though I may state that I have not actually tried it.

CHAPTER III.

LARGE-BORE RIFLES FOR ELEPHANT SHOOTING.

THESE rifles, which extend from the 12-bore to the 4-bore, are almost invariably used with spherical balls, and are rifled with polygrooves, the shape of which varies a good deal, but is really of little consequence. Some sportsmen still consider these small cannon necessary to insure the bringing down of big game; but the smashing power of the ·577 Express is so great that the majority now rely upon it as perfectly serviceable when properly handled. Still it is necessary here to describe them, for the benefit of those who continue to prefer their use.

No modern sportsmen, however, attempts to dispense altogether with the Express rifle—he only demands a bigger bore in addition to it; and, if he can afford it, the elephant hunter makes up a complete battery of these weapons, from a 4-bore down to a ·450, or even to a ·400 bore. I am not now pretending to give any opinion on this subject, and confine myself to a description of the various rifles in use by the modern sportsman, merely alluding *en passant* to what are the general opinions on it. The 12-bore double rifle usually weighs 11lb. to 13lb., has barrels 26 inches long, and is accurate up to 50 or even 100 yards, but is seldom relied on beyond the former distance. The balls used with it are described under the chapter on ammunition. The 10-bore weighs 12lb. to 14lb., with barrels 26 inches long, and its shooting is similar to that of the 12-bore.

The 8-bore double rifle usually weighs 16lb. to 18lb., and has barrels 24in. long. It is used with a spherical ball, and is not to be relied on for accuracy much beyond 50 yards.

The 4-bore double rifle weighs from 20lb. to 24lb., with barrels about 22in. long, and, like the 8-bore, is only used for spherical balls. It also is only sighted for 50 yards.