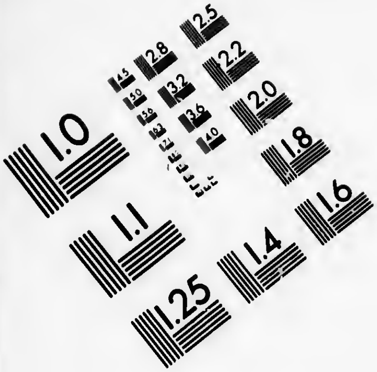

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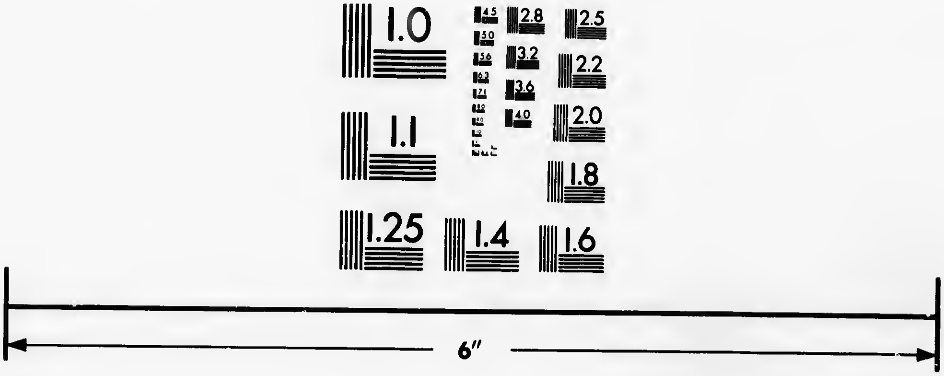

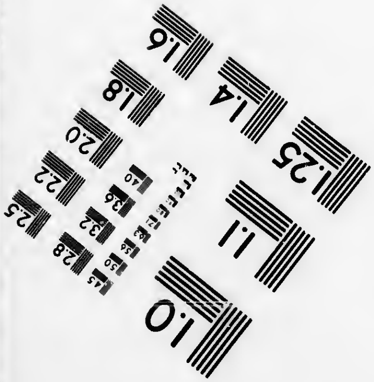

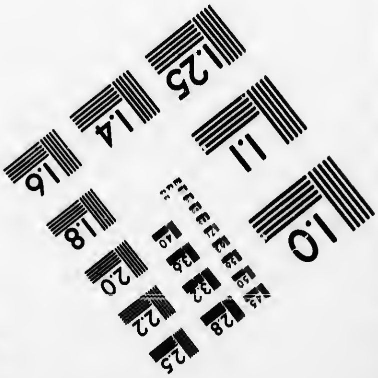

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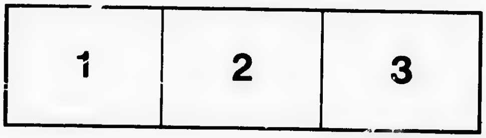

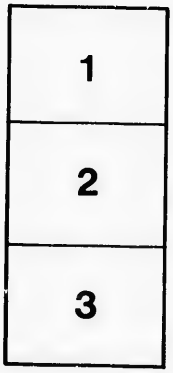

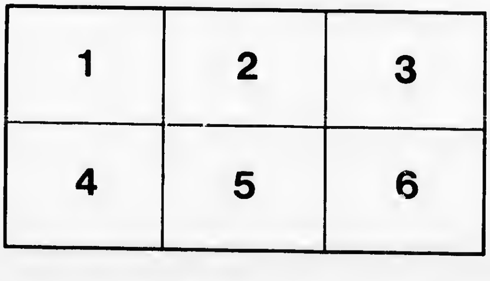

EXTRACT FROM THE MANUAL

FOR THE

MILITIA ARTILLERY OF CANADA.

PART III.

SCIENTIFIC.

SECTION I.

PRINCIPLES OF GUNNERY.

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PART III.

SECTION I.

PRINCIPLES OF GUNNERY.

DEFINITIONS.

Matter.—The substance of which bodies are composed, may be solid liquid or gaseous and imponderable.

Body.—Any definite portion of matter perceptible by our senses, or which may act or be acted upon by other bodies.

Particle.—An atom or a point so minute as to be indivisible.

Mass.—The quantity of matter in a body, it is estimated by weight.

Cohesion.—The force which holds together the particles of a body; without cohesion a stone would be dust.

Volume or Bulk.—The space a body occupies.

Figure.—The form or shape of a body, thus a round shot and a cylindro-conoidal rifle projectile may have the same volume, but have entirely different figures.

Density.—The closeness of the particles of any body, or the quantity of matter in any given bulk.

Elasticity.—An inherent property in bodies by which they recover wholly or partially their former figure or state, after the removal of external pressure tension or distortion.

Inertia.—A property of matter by which it cannot of itself put itself in motion, or if in motion, has no power within itself to alter the direction or extent of its motion.

Motion.--The passing of a body from one place to another.

Velocity.—The degree of swiftness with which a body moves over a certain space in a certain time, it is uniform when moving over equal spaces in equal periods of time, variable when moving over unequal spaces in equal time, it is accelerated when moving over greater spaces in each equal successive portion of time, retarded when moving over a less space in each equal successive portion of time.

Initial Velocity.—The velocity at the instant of departure of the projectile from the bore.

Terminal Velocity.—If a body be allowed to fall in the atmosphere there is a certain limit to the velocity it will acquire, this is attained theoretically when the resistance of the air has become equal to the accelerating force of gravity; the motion of the body will then be uniform, and is called its *terminal velocity*.

Final Velocity.—The velocity of the projectile at the end of a given range.

Velocity of Rotation.—The number of turns of a projectile on its centre or axis of rotation during a given time.

Centre or Axis of Rotation.—The point or axis about which a body revolves.

Momentum.—The quantity of power in a moving body, this is always equal to the mass of the body multiplied by its velocity.

A 7 por. shell moving at the rate of 1,300 ft. per second has more momentum than a 9 por. projectile moving at the rate of 1,000 ft. per second.

Force.—Any power which moves or stops, or tends to move or stop a body. It is measured by weight, a force which bends a spring into the same position as a 4 lb. weight would do is called a 4 lb. force.

Friction.—The resistance which a body meets from the surface on, or the medium through which it moves.

Force of Gravity.—The tendency of everything to fall in a straight line towards the centre of the earth, the measure of it is weight.

Specific Gravity.—The weight of a body compared to that of another body of equal bulk. Air is the standard for gases, water for other bodies. A cubic foot of water weighs

1,000 ozs.=62½ lbs. { 1 gallon weighs 10 lbs., at average temperature.
6¼ " " 1 cubic foot.

Centre of Gravity.—The point on which, if supported, the whole body would balance in any position.

A Concentric Body.—A body whose centre of gravity and centre of figure coincide, if they do not coincide the body is eccentric

Resistance of the Air.—The resistance a body encounters in its flight through the air, which is due to its displacing from its path a greater or smaller number of particles of air according to the velocity with which it moves, these resistances will be as the cube of the velocity at ordinary gun velocities, *i. e.*, from 1,100 to 1,400 ft. per second, and is the chief cause of the irregularities in the flight of rifled projectiles.*

Approximately for low velocities resistances vary as V^6
" " high " " " V^2

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* It is said by some that the particles of air cannot move among themselves faster than the rate at which waves of sound are transmitted through the air, 1,150 ft. per second. When the projectile has attained about this velocity the rate of burning of time fuzes is affected, it is thought, by the increased pressure due to the creation of a vacuum behind the shot which the particles of air cannot move fast enough to fill until the speed of the shot slackens when there is a relief of pressure on the head of the projectile. Opinions are divided on the above theory.

II.

PROPELLING FORCE.

Propelling Force.—Motion as previously defined is the passing of a body, viz., a shot or shell from one place to another, *i. e.*, from the gun to the object aimed at; but as the projectile, because of its inertia, can no more than any other inanimate body move itself. It requires a force or power to propel it from the gun to the object.

Propelling Power.—Is produced in artillery by placing at the bottom of the bore of the gun and behind the projectile a certain quantity of gunpowder and inflaming it, the powder burns and produces a great volume of gas (about 4,000 times the bulk of powder) which expanding in the bore, and finding a resistance on every side except on that of the projectile, forces it out of the gun with more or less velocity.

The force thus produced by the inflammation of the charge will be as the density of the powder used in the charge, as the heat produced by the burning of the powder and as the rapidity of its inflammation.

The estimated force produced by the explosion of gunpowder has been ascertained by experiment. It can produce a pressure of nearly 30 tons to a square inch of surface, that is to say that each square inch of the bore and base of the projectile against which this pressure was exerted, was submitted to a force equal to nearly 30 tons.

III.

RESISTING FORCES.

The propelling force is not the only one which acts on a projectile, there are others which also affect its motion, but it is by resisting or modifying it, some whilst the projectile moves inside the gun, others after the projectile has left the bore.

A. *Those forces which act on the projectile whilst in the bore*, are:—

1. The force produced by the resistance of the column of condensed air in front of the projectile in the bore of the gun; which force increases rapidly as the projectile acquires its velocity.

2. The force produced by the resistance due to friction between the projectile and the bore.—In smooth bore guns it is not considerable as the projectile simply rolls on its natural axis and rebounds along the bore. In rifled guns the artificial rotation imparted by grooves and lead coated or studded projectiles causes considerable resistance, which has been determined by experiment to be equal for a 12 pr. rifled gun to a weight varying from 3 to 20 tons.—The following conclusions may be accepted.

The resistance opposed to the motion of a projectile in the bore of a gun depends upon the form and weight of the projectile, upon the circumstance of the piece being smooth-bored or rifled, and upon the system of rifling adopted.

The projectile will commence to move when the force of the gas has become equal to the resistance offered to motion.

The time necessary for the conversion into gas of the quantity of the powder required to move the projectile will depend upon the nature of the gunpowder used, the form of the cartridge, and the point of ignition of the latter.

The maximum strain upon the metal of the gun will mainly depend upon the rapidity of the conversion of the powder into gas.

The initial velocity of the projectile may not, however, be in proportion to the maximum strain, but its square varies as the work done on the shot, or as the pressures into the spaces through which they act, or :

$$P.\ s. = \frac{W\ V^2}{2\,g}$$

Where P = pressure of gas in pounds.
s = space in feet through which P acts,
W = weight of projectile in pounds.
v = velocity of projectile in feet per second.
* g = accelerating force of gravity.

and if s. be a very small interval a fair approximation to the mean strain exerted through it in the bore of a S. B. gun may be calculated by this formula.

Recoil. $\frac{W\ V2}{2\,g}$ = Energy of recoil if W = weight of gun
V = velocity of gun.

Momentum $\frac{W\ V}{g}$ of gun = momentum of projectile.

Distance of recoil depends on the friction opposing the recoil, &c.

B. *Forces affecting the projectile after leaving the bore of the gun.* The projectile on leaving the muzzle of the gun is submitted to the influence of 2 forces which affect its motion. The forces are :—1, gravity; 2 resistance of the air. - If these forces did not exist a projectile fired from a gun, would travel indefinitely in a straight line through equal spaces in equal times. Thus it would travel from A to B (fig. 1) during say the first second of time, from B to C equal space during the second second of time, from C to D in the third, and so on.

Force of Gravity.—But as the force of gravity acts on the projectile in motion it will, as it proceeds onward, fall 16 feet, B, E, in the first second of time, and at the second second it will have fallen 64 feet, C, E, and at the third second of time 144 feet, D, C, (or as 16 mul-

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* If 1 foot and 1 second are the units, as usual.
$g = 32.2$ approximative.
This value differs at different points of the earth's surface. For the purposes of this Manual, the number 32 is sufficiently accurate.

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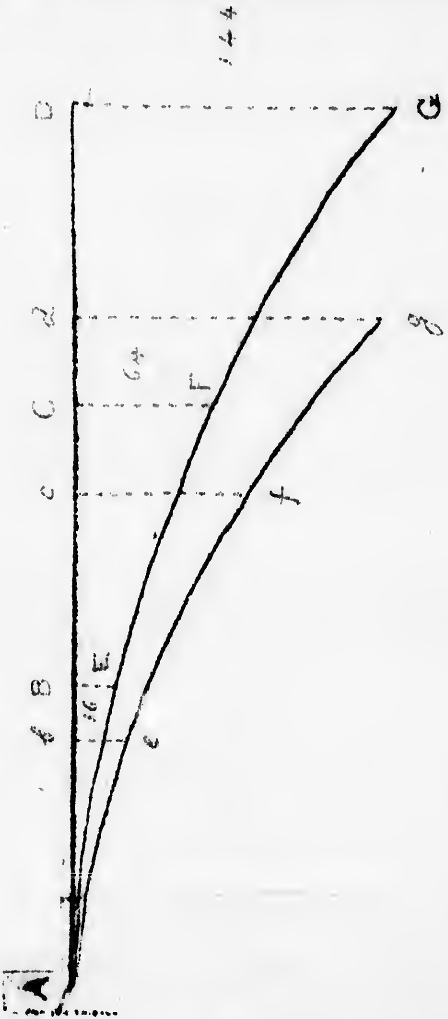

Fig. 1.

tiplied by the square of the time $= 16 \times 9$), being at the end of each of these seconds at the points E, F, G, respectively, describing a curved line A, E, F, G, which will continue curving until the projectile strikes an obstacle or reaches the ground and its motion is partially or entirely stopped.*

This curve A, E, F, G, is the one which would be described by the projectile if it was fired through vacuum, that is to say if there was no air. But the air itself, as already said, offers resistance to the projectile's motion and tends to limit it; because the projectile to pass through the air must push apart all the particles of air which are in its way and some of the propelling force which the projectile has received from the explosion of the charge of powder in the gun is expended in doing so. A 24 pr. shot fired from a gun with the usual service charge, met it is stated with a resistance from the air equal to 400 pounds at least and did not in consequence reach 1-5 of the distance it would have done if the resistance of the air had not prevented it, thus again a rifle bullet which would have ranged up to 3,674 yards if there had been no air to oppose its motion, reached only 640 yards † scarcely 1-6 the distance. Referring to Fig. 1, the projectile instead of describing a curve A E F G of Fig. 1, as we supposed it to do when acted upon only by the force of gravity would therefore when acted upon by the resistance of the air describe a curve A E F G entirely different from the first, and would reach the earth at a point much nearer to the gun A, than if the force of gravity was the only force affecting its motion.

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* This curve in vacuo would be a parabola, *i. e.* [illegible]tion of a right cone cut by a plane parallel to the side, with lo[illegible]ocities of 200 or 300 feet per second the parabolic theory gives t[illegible]ably accurate results; the following formula may therefore be found useful in certain cases of practical gunnery, such as high angle fire with mortars and small charges.

Let V = initial velocity.
R = range.
T = time of flight.
a = angle of projection.
g = gravity.
x and y = horizontal and vertical co-ordinates.

The equation of the trajectory or path of shot.

$$\text{Is } y = x \tan a - \frac{g\,x^2}{2\,V^2 \cos^2 a} \quad (1)$$

$$R = \frac{V^2 \sin 2a}{g} \quad (2)$$

$$T = \tfrac{1}{4} \sqrt{R \tan a} \quad (3)$$

† Experiments in France.

Means of reducing the effect of the force of gravity and resistance of the air.—If the gun be placed on a high hill or if elevation is given it by raising its muzzle at an angle to the plane, the projectile will not fall to the ground so soon as if the gun had been laid without elevation, also by increasing the propelling power the curve described by the projectile will be flatter. Referring to figures 1 and 2, if the projectile during the 1st second moves a horizontal distance from A to R instead of moving to B and if in the 2nd second it moved a horizontal distance from R to S instead of up to C, and in the 3rd second from S to T instead of up to D, then it will reach further horizontal distances from A, than as previously mentioned. But whatever may be the charge of the gun or the velocity with which the projectile is moving, the latter will invariably fall to the ground one second after having left the gun if fired horizontally at a height of 16 feet from the ground, or it will fall to the ground two seconds after having left the gun if fired horizontally at a height of 64 feet from the ground *i. e.* as the distance it falls in the 1st second multiplied by the square of the time.

IV.

AIR RESISTANCE.

Though gravity is an accelerating force and the spaces through which a body under its influence will fall in successive seconds are as the squares of the times, yet it is constant and uniform in its action—not so with the resistance of the air. The effect of it varies and consequently the distance through which a projectile travels may be more or less diminished by it, its contents, its surface, its density and its form, cause the resistance of the air to affect the velocity with which a projectile moves in a greater or less degree. We will first consider the effect of the resistance of the air on spherical projectiles and afterwards its effect on elongated projectiles.

Effect of the air resistance on spherical projectiles.—It has been found by experiment that with two spherical shot of the same diameter, one of lead, the other of iron, leaving the gun with equal velocities the *retardation* or effect of the resistance of the air would be less on the leaden shot than on the iron one, and that the difference between the two will be proportional to the differences of their densities which are about in the ratio of 11 to 8, that is to say as to their respective densities; again with a spherical solid shot of 6″ diameter and another of 3″, both made of iron equally dense and naturally of different weights, starting with the same velocity, the effect of the resistance of the air would be as the squares of their diameters, that is to say, as 9 is to 36, and inversely as their weights or as the cubes of their diameters. Again compare two 24 pr. shots moving, the first at the rate of 900 feet, and the second at the rate of 950 feet per second of time, the first would meet a resistance of 78 lbs. and the second a resistance equal to 92 lbs. These numbers are very nearly as the cubes of the velocities, viz: 900 and 950, showing that in this

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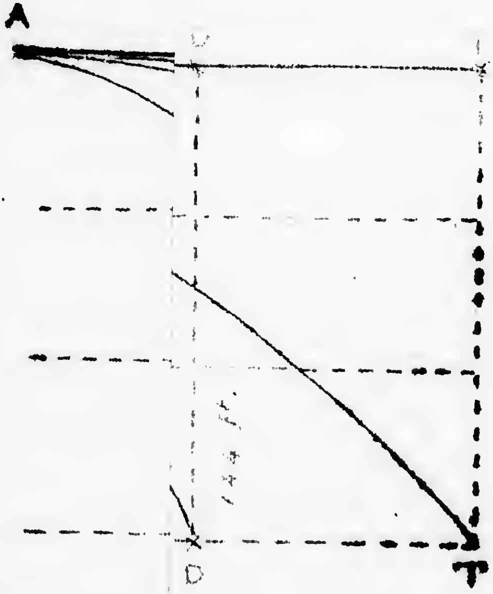


Fig. 2.

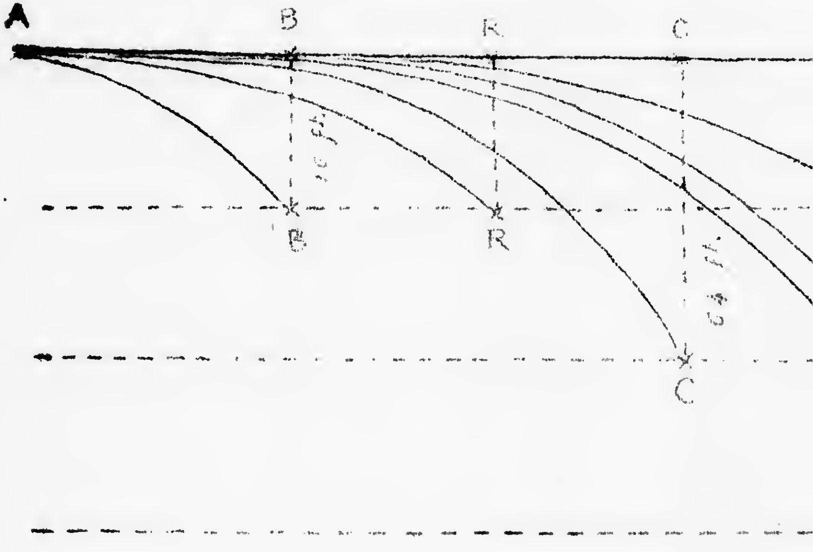
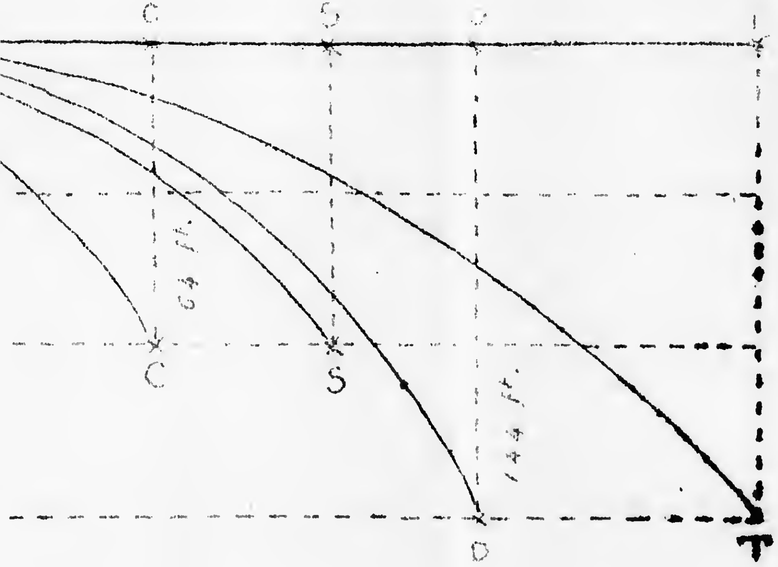


Fig. 2.



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instance the resistance of the air to motion of projectiles varies as the velocity with which they move, with spherical projectiles, it is said to be as the cube of the velocity, &c., &c.*

We have hitherto considered the resistance of the air only as tending to limit of range of projectiles, that is to say to make them fall to the ground at points nearer to the gun than they would have done if the air offered no resistance. We have now to consider how the resistance of the air may cause spherical projectiles to deviate to the right or left. The principal cause of these deviations with spherical shot or shell is the rotation which the shot or shell receives before or just at the moment it leaves the gun and which is caused either, 1st by windage or the difference between the diameter of the bore and of the projectile, 2nd by the shot's eccentricity.

First cause: Windage.--A shot rebounds in the bore of a gun because the projectile does not fit accurately in the bore, and it generally leaves the gun taking an accidental direction to the opposite side to that from which the last rebound took place. Such rebounds give it also a rotary motion (see Fig. 4), because no spherical body can strike an opposing surface at a less angle than a right angle without receiving rotation and if at its last rebound the projectile has struck the left side of the bore, it will have a rotation from right to left, and incline to the left finally, if the right side, it will have a rotation from left to right and finally curve away to the right.

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* Therefore if—d = diameter of ball,
v = velocity.
R = resistance which varies as $d^2 \; v^3$

The experimental resistance to a ball with a given velocity being known from tables. The resistance to any other spherical projectile with a different velocity can be determined thus:

If a round shot, 68 pr., meets a resistance of 1,000 lbs., with an initial velocity of 1,580 feet, required resistance to 100 pr. shot with a velocity of 1,650 pr.

$$1{,}000 : R :: 8^2 : 9^2$$

$$:: \overline{1{,}580}|^3 : \overline{1{,}650}|^3$$

$$R = \frac{1{,}000 \times 9^2 \times \overline{1{,}650}|^3}{8^2 \times \overline{1{,}580}|^3}$$

$$= 1{,}441 \text{ lbs}$$

The velocity a ball looses in consequence of this resistance or its retardation will be as

$$\frac{d^2 \; v^3}{d^3}$$

Or inversely as the weight.

With spherical projectiles the common shell has a higher initial velocity and, therefore, at short ranges less elevation is required than for solid shot; at long ranges the reverse is the case. The retardation of the denser solid shot being less than that of the shell.

Second cause: Eccentricity.--Eccentricity may also cause the projectile to acquire rotation, thus the force of the powder is equally distributed over the hind part of the projectile, and if the centre of gravity and centre of figure coincide exactly, there will be no rotation, but if the centre of gravity and the centre of figure do not coincide (are not in the same spot) as in Fig. 5 or 6 where the centre of gravity is not in the same spot as the centre of figure F, but to the left of it, the result will be, that, that part of the projectile on the right of F will be lighter than that part on the left of it, and would offer less inertia than the left part, it would therefore start the first, making the projectile whirl from right to left. The rotation would be from left to right if the centre of gravity G was on the right of centre of figure F, because the left side of the shot would then be the lightest and would start the first. Having explained how rotation is produced, let us now consider its effect.—Supposing the shot to rotate on its axis from right to left the result will be this; the side of the shot which rotates forward (the right side) meets with more resistance than the side which rotates backwards (the left side), for not only does the air oppose the onward motion of the projectile on the right side, but it also opposes its rotation, whilst on the left side it resists the onward motion of the shot and helps the rotary motion. The consequence of this is that the shot deviates to the side where it meets least resistance, that is to the left in this instance. One case would occur, when eccentricity would not help to produce rotation, it is when the centre of gravity is in the same straight line as the propelling force, either in front or in rear of the centre of figure F. Fig. 7. The effect of the eccentricity of the projectile would we must remark also tend to limit or extend the flight through the air, according as the rotary motion given to the projectile tended to make it deviate upward or downwards, that was the principle worked upon, by the utilizers of eccentric projectiles for obtaining long ranges.

Effect of the Resistance of the Air on Elongated Projectiles.—It having been discovered that the resistance of the air to spherical shot was proportional to their diameter and inversely as their weight. Endeavours were made to find a form of projectile which offering the least surface directly to the opposing force of the resistance of the air, would, at the same time, have the greatest mass to overcome the resistance, and the result was the adoption of the elongated projectile.

But as the elongated projectile naturally tends to rotate on the short axis passing through its centre of gravity, it was found necessary to give the projectile, by mechanical means, a rotation which would bring and keep the head of it towards the front, and thus present its smaller diameter to bear against the air, and expose to its resistance the least surface possible, whilst the mass of its elongated form gave the projectile greater power to overcome the resistance.

As a consequence, by using elongated projectiles the resistance of the air being much reduced, the motion of the projectile is more prolonged and greater distances are passed through in given times

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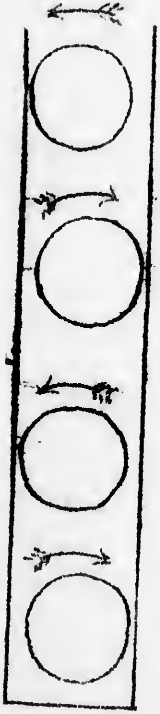

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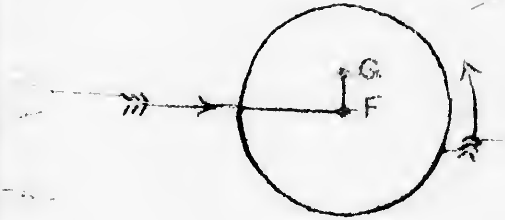

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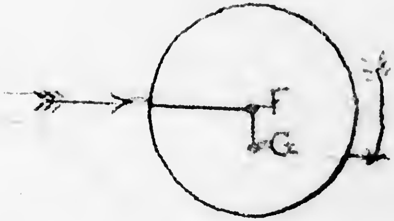

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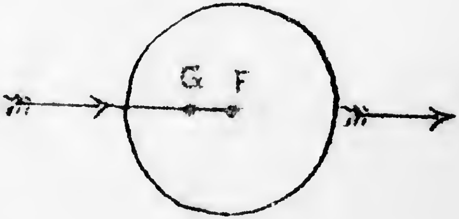

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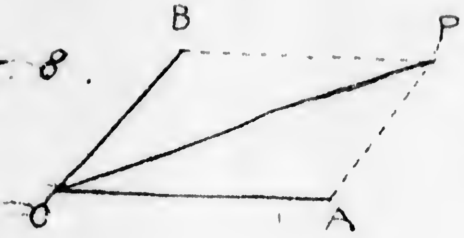

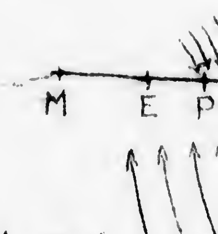

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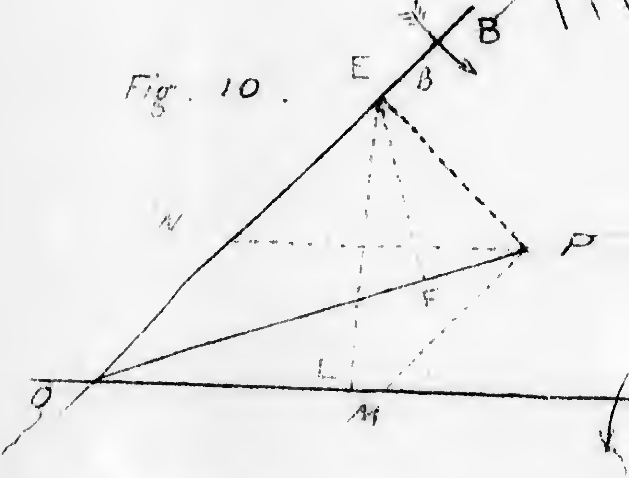

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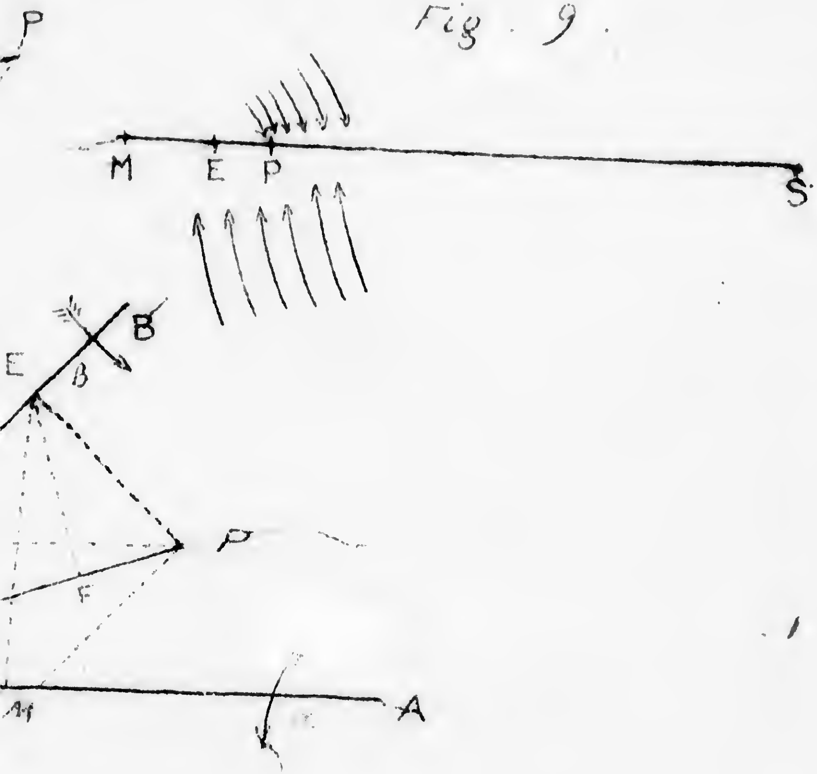

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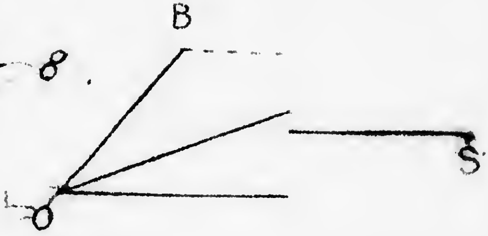

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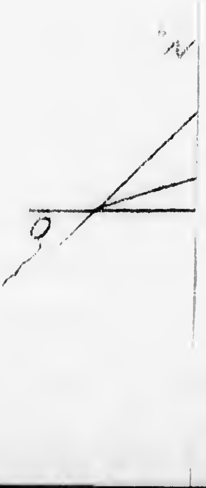

before the force of gravity has exerted its complete effect, viz., bringing the projectile to the ground.

As to the difference of resistance the air offers to an elongated projectile the following will afford a proof;—If one considers that for a 12 por. shot, elongated, and a 12 por. shot, spherical, moving at the same rate, the resistance of the air varies as the squares of their respective diameters, viz., 3" and 4".5, then the resistance would be as 9 is to 20.25, or as one is to 2.25, that is to say nearly half less for the elongated than for the spherical shot.

It remains to be ascertained whether the resistance of the air will, as in the case of the spherical projectile, send the elongated one to the right or left of its course.

V.

Deviation of Rifled Projectiles.—It will be necessary to make some further explanatory remarks and to consider a few preliminary cases of simple combinations of rotations in order to make the mathematical theory intelligible. *

Every force exerts its full effect, even though the effect may not be visible in the form of motion.

Thus, even the wind blowing against a wall has its force expended in compressing the particles of stone and in straining the mortar, some particles of which are compressed, while others are stretched.

So, also, the resistance of the air to a moving projectile is expended partly in retarding its velocity, partly in tending to turn it over, and partly in compression and in evolution of heat, which are practically of no consequence.

We have to consider the tendency to turn the projectile over, that is, to make it rotate about its shorter axis, remembering that though this rotation may not be perceptible at first sight, yet its full effect must be exerted in some manner.

If a billiard ball, at rest and free to move, be struck by two forces acting in different directions, it will take an intermediate direction; the exact magnitude and direction of its motion or velocity will be represented by the diagonal of a parallelogram, whose sides represent the velocities due to the two forces.

Ex. If O A and O B represent the separate velocities, Fig. 8, the ball will reach P in the same time that it would have reached A or B if struck by one force only.

This is the principle of the parallelogram of velocities, by means of which the resultant velocity of a body may be readily ascertained if two or more independent velocities are impressed upon it.

It will be shewn that the same principle can be extended so as to apply to rotations; so that, if a body be given independent rotations about different axes, a resultant axis can be found about which the body really rotates with a resultant velocity.

---

* Chapter V has kindly been supplied by Major Kensington, R. A., Professor Military College, Kingston.

An angle is most conveniently measured by the ratio of the arc subtending it to the radius of the arc, thus:

$$\text{Angle} = \frac{\text{arc}}{\text{radius.}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The unit of this system of measurement (called circular measure) is the angle subtended by an arc equal to its radius, and it contains

$$\frac{180^\circ}{3{\cdot}1416} = 57^\circ\ 18' \text{ nearly} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\text{Velocity} = \frac{\text{space}}{\text{time.}} = \text{space described in one second, if a second}$$

be the unit of time.. (3)

Linear velocity may be either in a straight or in a curved line.

A particle rotating round a fixed centre is said to move with "angular velocity," about that centre. Its "linear velocity," is measured along the circumference of the circle it describes

Since angle $= \dfrac{\text{arc}}{\text{radius}}$, it is evident that angular velocity =

$$\frac{\text{linear velocity}}{\text{radius}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Hence it is clear that different points of a rotating body move with different linear velocities according to their distance from the fixed centre or axis, but that the angular velocity of every point is the same. Also, if the radius of any point is known, and also its linear velocity, then the angular velocity of the whole body can be at once determined.

If the linear velocity of a point is nothing, then that point is in the axis of rotation.

If two such points can be found, then the straight line joining them is the axis of rotation.

As in equation (3) for linear velocity, so we have—angular velocity $= \dfrac{\text{angle described}}{\text{time of describing it}} =$ angle described in one second. (5)

So the velocity of the minute hand of a watch is $\dfrac{4 \text{ right angles}}{\text{one hour}} =$

$$\frac{2 \times 3{\cdot}1416}{60 \times 60} = \frac{{\cdot}010472}{6} = {\cdot}001745.$$

It must be remembered that this is the decimal of the unit angle of circular measure; see equation (2), so that it means that the hand describes ·001745 of 57° 18′ per second.

If the minute hand of a clock be one foot long, its point will move with a linear velocity of ·001745 feet per second, because arc = angle × radius; see eq. (1.)

If a watch be itself turned round in the same direction as the minute hand and with the same velocity, the hand will have a rotation compounded of the two rotations that is to say, ·0017 5 + ·001745 = ·00349 but if the watch be turned in the reverse direction its velocity is said to be negative; the hand will in this case always point in the same direction because it has no angular velocity for ·001745 — ·001745 = 0.

If the velocity of the watch in the reverse direction be greater than that of the hand, the true velocity of the hand will be negative, that is in the reverse direction.

Problem 1st.—Fig. 9.—If a body M revolves about a point E with an angular velocity "α" and if E and M together revolve also about S with an angular velocity $\frac{\text{“}\alpha\text{”}}{12}$, both velocities being of the same sign, that is, in the same direction; find the true axis and velocity of rotation of M, for any given position of the bodies.

The directions of the motions of different particles, due to the rotations about E and S respectively, are shewn in the figure; it is then evident that at some point P between E and S the linear velocities will be equal and opposite; that is the point P is at rest, and is consequently the axis of rotation.

These linear velocities are respectively $EP \times \alpha$ and $SP \times \frac{\alpha}{12}$

$$\therefore\ EP = \frac{SP}{12} = \frac{ES}{13}$$

To find the angular velocity, divide the linear velocity of a convenient point, "E" by its distance from P, for the angular velocity of any one point is the same as that of the whole body, as previously shown.

$$\therefore \text{ Angular velocity} = \frac{ES \times \frac{\alpha}{12}}{EP} = 13 \times \frac{}{12}\text{; for } \frac{ES}{EP} = 13$$

$$= \alpha + \frac{\alpha}{12}$$

= sum of the component angular velocities.

It is necessary to understand the last Problem thoroughly in order to work out the following one which is identically the same as the problem combining the rotations of a projectile.

In the last problem the axes of rotation were supposed parallel, being perpendicular to the plane of the paper.

Problem 2nd.—Let a body have two independent but simultaneous rotations about the axes O A, O B; Fig. 10.

Let the angular velocities be α and β respectively, both of the same nature, that is, revolving in the same direction, as seen from O.

The arrows shew the direction——left going over to the right——as in the case of a rifled projectile with right handed twist, seen from the muzzle.

Find the true axis and velocity of the resultant rotation.

Take O M : O N : : $\alpha : \beta$ that is proportional to the angular velocities, complete the parallelogram O M P N; O P shall be the required axis.

For at the point P the velocity downwards due to the rotation about O B is P E $\times \beta$.

And at the same point the velocity upwards due to the rotation about O A is P D $\times \alpha$, if P D and P E be drawn perpendicular to O A, O B respectively.

$$\text{But } \frac{PD}{PE} = \frac{OP \sin POM}{OP \sin POE} = \frac{\sin POM}{\sin OPM} = \frac{MP}{OM} = \frac{\beta}{\alpha}$$

$$\therefore \; PD \times \alpha = PE \times \beta.$$

Therefore the linear velocities at P are equal in magnitude, but opposite in direction; therefore the point P is at rest. Similarly any other point in O P is at rest. Therefore, O P is the axis of resultant rotation. Next, consider the motion of the point "E" to obtain the angular velocity, as in the preceding Problem.

Draw E L, E F perpendicular to O A, O P, respectively.

$$\text{Angular velocity of } \mathbf{E} = \frac{\text{linear velocity of E}}{EF} = \frac{EL \times \alpha}{EF}$$

For its linear velocity is only E L $\times \alpha$ since, being in O B, it has no velocity due to the rotation about O B.

$$\therefore \text{ Angular vel. of } E = \alpha . \frac{OE \sin AOB}{OE \sin BOP} = \alpha \frac{\sin OMP}{\sin OPM} = \alpha \frac{OP}{OM}$$

$$\therefore \text{ Angular velocity of } E : \alpha : : OP : OM$$

But O M was taken proportional to α. Therefore O P is proportional to the resultant angular velocity of E, that is of the whole body.

Thus, it appears that the principle of the parallelogram of velocities holds also for angular velocities or rotations.

That is:—*If straight lines be drawn representing the axes of rotation in direction, and the velocities of rotation, in magnitude; and if the parallelogram be completed; the diagonal will represent the direction of the axis and magnitude of velocity of the resultant rotation.*

The problem of the projectile may now be entered upon.

On leaving the gun, the axis of the projectile is, or should be, coincident with the line of flight; and by the law of inertia this axis will always remain parallel to itself unless some other rotation should be communicated to the projectile, which, compounded with the former rotation, would result in a rotation about some different axis.

The line of flight is a curve; therefore the axis of the projectile soon becomes inclined to the direction of the resistance of the air, which acts parallel to the line of flight, as shown by the arrows. Fig. 11.

In the case of the service projectiles of all modern rifled guns the resultant effect of this resistance passes above the centre of gravity of the projectile, and tends to give it a rotation about the shorter axis; or in plain language the resistance acts chiefly under the point and tends to lift it. If the given rotation were not sufficient, this tendency would turn the projectile over.

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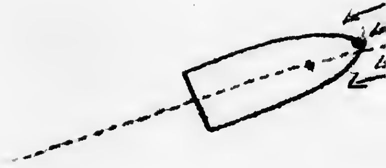

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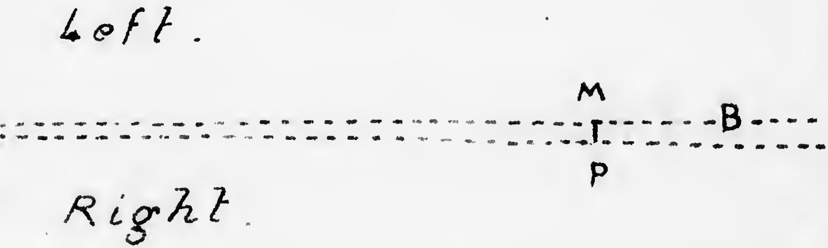

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In any case however, this pressure must produce a certain amount of rotation about the shorter axis. This rotation being compounded with the given rotation produces a resultant rotation about a new axis.

Let G M be proportional to the given angular velocity, Fig. 12, and G N or M P to that produced by the resistance of the air.

The diagonal G P is the new axis of rotation. It will be but very slightly inclined to G B, but sufficiently so to affect the flight of the projectile as follows.

As the projectile rotates about G P the point will roll over to the right.

The point is at all times the direction of least resistance, therefore the projectile follows its point and its path becomes slightly inclined to the right.

The resistance of the air, acting on the left of the point, now produces another slight rotation, which, being compounded with the existing rotation as before, causes the point to drop.

If now the point drops below the line of flight it will rotate over to the left, and then again upwards.

This is the explanation of the theory propounded by Professor Magnus, confirmed by Professor Bashforth and accepted by Colonel Owen in his Modern Artillery.

The theory is that the axis of the projectile does not remain parallel to its first direction throughout its entire flight, as was at first supposed, but that it has a conical motion about the line of flight, very nearly coinciding with it but always tending more to the right [in the case of a right-handed twist] in consequence of the increasing curvature downwards of the line of flight.

In the existing treatises on Artillery, this theory is supported by actual observation of projectiles fired with low initial velocities and therefore visible ; and by experiments with the gyroscope. Various reasons have been given, generally however based more upon supposition than upon exact calculations. The above mathematical investigation is thoroughly exact if only it is conceded that the tendency of the resistance of the air is to lift the point of the projectile. The method adopted for calculating the effect of combined rotations has been taken from the unpublished course of lectures given to the cadets of the Royal Military Academy, Woolwich, by Professor Crofton, F. R. S., under whom the writer had the advantage of serving.

One of the theories given for the derivation of rifled projectiles is that the air under the projectile is compressed by its weight so as to be denser than the air above ; and that the projectile rolls over upon the denser medium, to the right. This theory may, however, be said to be disproved by the experiments with flat-headed projectiles, recorded in Owen's Modern Artillery, page 257 (ed. 1873,) by which it is shewn that they deviate to the left instead of to the right.

The accepted theory accounting for this is that the tendency of the resistance of the air is not to lift the head of the projectile, but to lower it, so as to bring the axis more nearly into coincidence with the line of flight.

Thus, the primary effect must be to make the flat-headed projectile tend to the left for the same mathematical reasons as before.

To sum up the case of the service projectiles it must be repeated that the effect of the combined rotations is to cause the point to rotate over to the right and that the projectile follows its point, that is to say, the resistance of the air coming on the left, the projectile drifts to the right; and the more the point tends to the right the more the projectile drifts.

It is this drift that is called "*derivation*."

VI.

PENETRATION OF PROJECTILES.

The projectile, after having received a greater or less impulse from the powder in the bore of the gun and overcome all the resistance which opposed its onward motion in the gun, leaves the bore with a certain swiftness of motion, which is called initial velocity and which will vary according to the force of the impulse it has received from the explosion of the charge and also the amount of resistance it has met with in the bore. From this it appears that with two guns a smooth bore and a rifled gun, the propelling effect of the charge and the weight of the projectile being equal, the initial velocity of the smooth bore projectile will be superior to that of the rifled gun, because the resistance offered by the rifled bore to the passage of the projectile through it is greater than that offered by the smooth-bore to its own projectile. But as already explained in consequence of their form the resistance of the air is greater, to the motion of a projectile from a smooth-bore gun than to that of a rifled gun. The S. B. projectiles lose, therefore, more rapidly their power of motion than the projectiles of rifled guns.

Now let us consider how that same propelling power which causes projectiles to overcome, in a more or less degree, the effect of the forces of gravity and resistance of the air, is also implicated in their penetration.

In the first place penetration is the passing of an object completely or partially through another. A projectile moving through the air with a certain swiftness meets an obstacle, such as as a wall, it will penetrate through the material, of which the wall is constructed, till the force of motion it possessed is expended or the wall penetrated.

This force or power, we will bear in mind, might not only be expended in penetrating the obstacle, but also in breaking up or altering the form of the projectile, then the stronger the projectile is, by the quality and disposition of its material, the more of its power will be expended in destroying the obstacle, because less of that power would then be expended in altering the form of the projectile.

In considering the causes which make the penetration of projectiles vary, we will speak of spherical projectiles first, and afterwards of elongated projectiles.

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Experience proves that by doubling the velocity with which a cannon ball moves you nearly quadruple the penetrating effect of it. Thus an increase of velocity increases penetration. Of two 24 por. shot striking the same object, one moving at the rate of 1,200 feet per second, the other at the rate of 1,300 feet, the second projectile will penetrate the object a greater depth than the first.

The diameter and weight of the projectiles affecting, as we have already mentioned, their velocity, thereby also affecting their penetration. A 68 por. and a 32 por. shot leave their respective guns with a velocity of 1,200 feet per second, they meet, as previously explained, with a resistance from the air which varies as the square of their diameters, and is greater in the case of the 68 por., than in that of the 32 por. shot, but the power to overcome resistance of air is greater in the heavier shot, being as d^3, consequently if the 68 pr. shot struck the same object as the 32 por., it having at ordinary range a greater final velocity would * also have a greater penetration. So that it would appear that the larger the diameter of the projectile and the greater its density or weight the deeper will be its penetration, especially as the final velocity, that is to say, the rapidity it moves with when striking will be higher for the same initial velocity.

Considering the penetration of elongated projectiles, we find that it is greater than that of spherical ones of equal weight when both have the same initial velocity,—for the following reasons,—first, because the former present a less area to the resistance of the air and of the object, secondly it can have a pointed head, and thirdly it will have a greater final velocity, being less retarded during flight. In general, however, the elongated projectile of a rifled gun is fired with a lower initial velocity than the ball of an equal weight from a S. B. gun, and therefore at a short distance the latter might have a greater penetration than the elongated shot,—but as the range increases so will the penetrating power of the elongated projectile, for it will maintain its velocity much longer than the spherical.

12 por.'Armstrong shot elongated were fired with a charge of $\frac{1}{8}$ from a rifled gun and penetrated into solid oak, 40 inches at 400 yds. range and 35 inches at 1200 yards, 12 por. balls fired with a charge of $\frac{1}{3}$ from a S. B. gun penetrated into oak 43 inches at 109 yards range, 32 inches at 438 yards range $14\frac{1}{2}$ at 1094 yards.

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* This greater penetration is not only due to the greater velocity for if both had the same final velocity the 68 por. would penetrate further for the resistance varies as d^2 while the moving force varies as d^3. See page 8 on resistance of the air. The 68 por. should penetrate nearly twice as far as a 9 por. if velocities were equal.

VII.

CALCULATION OF FINAL VELOCITY.

The initial velocities of service guns are given in tables derived from the chronograph.

Col. Owen, R. A., gives the following simple formula derived from the cubic law of resistance, which gives the relation between the initial and final velocities, V and v, at any range or part of trajectory x.

$$v = \frac{V}{1 + c\ V\ x}$$

When V = initial velocity.

v = final velocity.

c = a co-efficient depending on the weight, form and diameter of the projectile.

The values of the co-efficient have been determined experimentally for service ogival headed shot for velocities between 900 and 1,700 feet, and for spherical between 850 and 2,150 feet. The co-efficient c varies as above stated, but for similar forms it will be as $\frac{R^2}{W}$ and $c = b\frac{R^2}{W}$, b, being a constant determined by experiment.

For elongated projectiles with velocities from 1,500 to 1,000 feet, per sec. Mr. Bashforth, finding the co-efficient varied but little, gives:—

$$b = \left\{ \begin{array}{c} \cdot000063 \\ \text{to} \\ \cdot000060. \end{array} \right.$$

Capt. W. H. Noble, R. A., gives about the same, and for spherical projectiles b = ·000081.

The following example will shew the practical use of the foregoing formula:—

Supposing a 12 lbs, projectile was substituted for that of 9 lbs. with the 8 cwt. M. L. R. field guns in Canada, the charge of powder remaining the same, the initial velocity of the 9 pdr. being taken at 1,400 feet per second, and that of the 12 pdr., 1,300 feet; find the remaining velocity of both projectiles at 2,000 yards, and ascertain which would be the most powerful projectile at the average artillery range of 2.000 yards?

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For 9 por. projectile, 3″ calibre :—

Where V = initial velocity = 1,400 feet per second.

v = remaining velocity to be ascertained.

c = co-efficient for weight, form and diameter of projectile = ·000062 $\frac{R^2}{W}$

x = distance travelled = 2,000 yards = 6,000 feet.

R = 1·5 = ·125 feet.

W = 9 lbs.

Then $v = \frac{V}{1 + c V x}$. Substituting above values.

$$v = \frac{1,400}{1 + \cdot 000062 \frac{\overline{\cdot 125}|^2}{9} \times 1,400 \times 6,000}$$

Using logrithims :—

$$\text{Log. V} = 1400 = 3\cdot 1461280. \quad \left.\begin{array}{r} \text{Log. } \cdot 000062 = \bar{5}\cdot 7923917 \\ \text{Log. R}^2 = \overline{\cdot 125}|^2 = \bar{2}\cdot 1938200 \end{array}\right\} \text{add.}$$

$$\left.\begin{array}{r} \bar{7}\cdot 9862117 \\ W = 9 = 0\cdot 9542425 \end{array}\right\} \text{sub.}$$

$$\therefore \text{Log. c} = \bar{7}\cdot 0319692$$

$$\left.\begin{array}{r} \text{Log. c} = \bar{7}\cdot 0319692 \\ \text{Log. 1400 feet} = V = 3\cdot 1461280 \\ \text{Log. 6000 feet} = x = 3\cdot 7781513 \end{array}\right\} \text{adding.}$$

$$\bar{1}\cdot 9562485 = \cdot 904167, \text{ nat. number} + 1.$$
$$= 1\cdot 904167 = \text{log. } 0\ 2797051.$$

$$\left.\begin{array}{rl} v = \dfrac{V}{1 + c V x} & \begin{array}{l} = \text{log. } 3\cdot 1461280 \\ = \text{"} \quad 0\ 2797051 \end{array} \end{array}\right\} \text{subtracting.}$$

$$\therefore v = \text{"} \quad 2\cdot 8664229 = 735\cdot 23 \text{ feet.}$$

Remaining velocity of 9 lbs. shot at 2000 yards = 735 feet per sec.

For 12 por. projectile same calibre 3″

V = initial velocity, 1300 feet.

v = remaining "

c = ·000062 = $\frac{R^2}{W}$

x = 2000 yards = 6000 feet.

R = 1·5″ = ·125 feet.

W = 12 lbs.

Then using same formula $v = \frac{V}{1 + c\,V\,x}$ substituting as before

$$v = \frac{1300}{1 + \cdot000062\ \overline{\frac{\cdot125}{12}}\Big|^2 \times 1300 \times 6000}$$

$$
\begin{array}{lrl}
V = 1300 = \text{Log } 3\cdot1139131 \ \text{Log.} & \cdot000062 = & \bar{5}\cdot7923917 \\
\text{“} \quad R^2 = \cdot125\,\big|^2 & & \bar{2}\cdot1938200 \\
\hline
 & & \bar{7}\cdot9862117 \\
\text{“} \quad W = 12 & = & 1\cdot0791812 \\
\hline
\text{“} & c = & 8\cdot9070305 \\
\text{“} & V = & 3\cdot1139131 \\
\text{“} & x = & 3\cdot7781513 \\
\hline
\text{Log } \cdot6 \quad 2969 & = & \bar{1}\cdot7991252 \\
\text{Log } \cdot62969 + 1 & = & 0\cdot2111049
\end{array}
\begin{array}{l}
\left.\right\} \text{Add.} \\
\\
\left.\right\} \text{Subtract.} \\
\\
\left.\right\} \text{Add.}
\end{array}
$$

$$\text{Log } v = \frac{V}{1 + c\,V\,x} \begin{array}{l} = 3\cdot1139131 \\ = 0\cdot2111049 \end{array} \Big\}\ \text{Subtracting.}$$

$$\text{Log } v = 2\cdot9028385 = 799 \text{ feet.}$$

i. e. the 12 por with the lowest initial velocity has the highest remaining velocity at 2000 yards range, the reason being that the 12 por. has greater weight to overcome resistance of air and presents only same area of resistance. It is in every sense the most powerful projectile containing also more space for bullets if a shrapnel and a larger bursting charge if common shell.

VIII.

ARMOUR PLATE PENETRATION.

There were two methods of attempting the destruction of iron-clad vessels when first introduced, termed respectively *racking* and *punching*, the former American, the latter the British system.

For *racking*, heavy projectiles of large diameter are fired with low velocities, to destroy and shake off the armour by repeated shocks without penetration, and thus to expose the vessel to the effects of ordinary projectiles.

For *punching*, elongated projectiles of moderate weight are fired with high velocities so as to perforate the armour, if near the water-line to sink the vessel, or at any other part to injure men or machinery, or explode the magazine within the vessel.

Racking was used chiefly by the Federals in the late American war, being especially adapted to their larger S. B. cast guns, with low charges and heavy spherical shot, which lose their velocity rapidly. Some experiments were made in England with heavy elongated projectiles and low charges, but the *racking* method was soon abandoned for *punching*, which causes more destruction, ensures greater accuracy of fire, and consequently requires a shorter time to effect the desired purpose.

DEFINITIONS.

The vis viva of a body in motion is the whole mechanical effect which it will produce in being brought to a state of rest without regard to the time occupied, and varies as the weight of the body multiplied by the square of its velocity.

When a projectile strikes an object it will penetrate until its accumulated or stored up work is spent, this work will be expended in penetrating, fracturing, or producing vibration in the object, and when the latter offers great resistance in breaking up or changing the form of the shot. The heat produced is said to be a measure of work done. When a shot has penetrated an iron plate without losing form the edges of the hole will be hot to the touch—the projectile comparatively cool, showing the work has been done on the plate not on the shot. It is *vice versa* when the shot is bulged or broken without penetrating.

Professor Tyndall considers heat a mode of motion. When motion is arrested an equivalent of heat is produced.

The mechanical effect or "work" accumulated in a moving body is represented by the weight which it is capable of raising one foot high, and is equal to the weight of the moving body multiplied by the square of its velocity and divided by twice the force of gravity, or $\frac{Wv^2}{2g}$

Energy, or Work Stored-up.—The unit of measurement is foot lbs. or foot tons, *i. e.*, the force that will raise 1 lb. or 1 ton through a space of 1 foot.

In order to estimate the probable effect of a projectile upon an object, it is necessary to calculate the *stored-up work, vis viva* or *energy*, as it has been variously termed, in the shot at the moment of impact.

This may be done by the *Rule of Work*:—

$$\text{Work or P. s.} = \frac{Wv^2}{2g},$$

Where W = weight of projectile.
v = final velocity.
g = accelerating force of gravity, (32·2 f. s.)

The punching effects of projectiles fired at an iron target are usually compared, by calculating what is termed the *energy per inch of* circumference in *foot tons*, which is found by dividing the *total* work or energy by the number of inches in the circumference of the shot, and by 2,240 (the number of lbs. in a ton).

$$\text{Energy per inch of circumference} = \frac{W\ v^2}{2g \times 2\pi R \times 2240}$$

$\pi = 3·1416$—where R = radius of shot.

Example:—If a 9 inch Palliser shell fired with a battering charge at a vessel 200 yards distant, have a final velocity of 1,304 feet, what is the total *energy* or *work* on impact in foot tons, and the *energy* per inch of circumference?

Here, $W = 250$ lbs., weight of projectile

$$R = \frac{8·92}{2} = 4·46 \text{ inches, radius of projectile.}$$

$$g = 32·2 \text{ f. s.}$$

$$\therefore \text{Total energy} = \frac{250 \times \overline{1304}|^2}{64·4 \times 2240}$$

$$= 2946·9 \text{ foot tons.}$$

And energy per inch of circumference

$$= \frac{2946·9}{2 \times 3·1416 \times 4·46}$$

$$= 105·16 \text{ foot tons.}$$

From experiments carried out by the Royal Artillery Ordnance Select Committee the following *practical* conclusions were drawn by Major W. H. Noble, R. A. The projectiles are in the first instance considered as fired *direct* at armour plates.

1st. An unbacked wrought-iron plate will be perforated with equal facility by solid steel shot, of similar form of head, and having the same diameter, provided they have the same *vis viva* on impact; and it is immaterial whether this *vis viva* be the result of a heavy shot and low velocity, or a light shot and a high velocity, within the usual limits of length, etc., which occur in practice.

2nd. An unbacked iron plate will be penetrated by solid steel shot, of the same form of head but different diameters, provided their striking *vis viva* varies as the diameter, nearly, that is, as the circumference of the shot

3rd. That the resistance of unbacked wrought-iron plates to absolute penetration by solid steel shot, of similar form, and equal diameter, varies as the square of their thickness nearly.

4th. These experiments have proved that, although in the case of cast-iron a light projectile moving with a high velocity will indent iron plates to a greater depth than a heavier projectile with a low velocity, but equal "work," it is not as necessary that there should be a high velocity when the projectiles are of a hard material, such as *steel* and *chilled iron*, and this result will be much in favour of rifled guns, by enabling them to prove effective with comparatively moderate charges.

To put these results in an Algebraic form we shall have, taking the units as the pound and foot:—

$$\frac{W \; v^2}{2 \, g} = 2 \, \pi \, R \, k \, b^2 \ldots\ldots\ldots\ldots\ldots\ldots \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where W = weight of shot in lbs.
v = velocity on impact in feet.
g = the force of gravity = 32·2.
$2R$ = diameter of shot in feet.
b = thickness of unbacked plate in feet.
k = a co-efficient depending on the nature of the wrought-iron in the plate, and the nature and form of head of the shot.

The shot is supposed to be of the best quality of steel, and the plate of the best quality of wrought-iron.*

Solving equation (1) for b we have :—

$$b = v \sqrt{\frac{W}{4 \pi R g k}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

and for k,

$$k = \frac{W v^2}{4 \pi R g b^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

In order to determine k, we can form a series of equations of the following conditions :—

$$\begin{aligned} 4 \pi R\ g b^2 k - W_1 v_1^2 &= O \\ 4 \pi R_2 g b^2 k - W_2 v_2^2 &= O \\ 4 \pi R_3 g b^2 k - W_3 v_3^2 &= O \\ \&c., \quad \&c., \quad &\&c. \end{aligned}$$

Substituting the experimental values of the different quantities and obtaining k, we find that for hemispherical headed shot :—

$$k = 5357200.$$

For ogival, ·9 of 5,357,200, or cut off cypher and multiply by 9, = 4821480.

Having thus determined the value of k, we can calculate the "work" necessary to penetrate any unbacked plate of given thickness.

Thus let us determine the "work" required to *just* penetrate a 5·5 inch plate with a hemispherical headed steel shot of 6·22 inches diameter.

Here we have,

$$\begin{aligned} R &= 3{\cdot}11 \text{ inches} = 0{\cdot}25917 \text{ feet.} \\ b &= 5{\cdot}5 \quad \text{"} \quad = 0{\cdot}45833 \quad \text{"} \\ k &= 5{,}357{,}200. \end{aligned}$$

And substituting these values in equation (1) we find that :—

$$\frac{W v^2}{2 g} = 1{,}832{,}522 \text{ lbs.}$$

$$= 818 \text{ foot tons.}$$

Practical experiments have proved the foregoing to be correct.

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* The quality of plate may be assumed to be a constant and the steel and chilled shot practically equal, the form of head of service projectiles does not vary, being hemispherical for S. B., ogival for rifled.

Therefore by means of the foregoing equations we can determine most of the effects against unbacked plates, and the following examples are given in proof:—

EXAMPLE I.

What thickness of unbacked wrought-iron plate will withstand the impact of a solid hemispherical headed steel shot of 115 lbs. weight and 6·92 inches diameter, fired with a charge of 22 lbs, from the 7 inch muzzle loading rifled Woolwich gun at 1,000 yards, the remaining velocity at that distance being 1,260 feet?

Here we have from equation (2),

$$b = v \sqrt{\frac{W}{4 \pi R g k}}$$

And substituting the values above, we find:—

$$b = 6·486 \text{ inches.}$$

The thickness of plate to resist this shot ought therefore to be more than 6·5 inches.

EXAMPLE II.

The 68 pr. smooth-bore gun is fired with a spherical steel shot of 72·0 lbs. weight and 7·91 inches diameter, the striking velocity at 200 yards being 1,365 feet.

What thickness of unbacked plate will it penetrate?

Here we have as before:—

$$b = v \sqrt{\frac{W}{4 \pi R g k}}$$

And substituting the above values:—

$b = 5·2$ inches; also proved by experiment.

EXAMPLE III.

The 13·3 inch gun of 22 tons was fired at an 11 inch plate with a spherical steel shot of 344·4 lbs. weight and 13·24 inches diameter; charge 90 lbs.; the striking velocity being 1,574 feet at 200 yards; ought it to have penetrated the plate?

Now the thickness of unbacked plate which this shot will penetrate can be found from equation (2).

$$b = v \sqrt{\frac{W}{4 \pi R g k}}$$

And substituting the above values we find.

$$b = 10·14 \text{ inches.}$$

A shot of the above nature indented an 11 inch unbacked plate to a depth of 4·9 inches, and broke the plate in two.

EXAMPLE IV.

The embrasures of a fort are protected with unbacked wrought-iron plates of 8 inches thickness, with what velocity should a 250 lbs. hemispherical-headed rifle shot of 8·92 inches diameter strike so as to ensure penetration?

Here we have from equation (1)

$$v = b\sqrt{\frac{4\pi R g k}{W}}$$

And substituting the above values we find.

$$v = 1197 \text{ feet.}$$

From this it follows that if the 9 inch rifled Woolwich gun was fired with its service charge of 43 lbs. and a 250 lbs. steel shot, it would penetrate an unbacked 8 inch plate at about 1,200 yards.

ON OBLIQUE FIRE.

We have hitherto considered the fire as being direct, that is to say, the plate has been supposed to have been placed perpendicular to the ground, and the gun to have been so directed that the plane in which the shot moved was perpendicular to the face of the plate, or nearly so. Let us suppose, however, that the plate has been set at an angle, or that the gun fires obliquely at an upright plate. The shot has then a tendency to glance off, and continue its motion in a new direction, and we shall have the following well known proportion, viz:

The force with which the shot, acting obliquely, will strike, is to that with which it would strike if acting directly, as the sine of the angle of incidence is to unity.

Equation (1) will therefore become.

$$\frac{W v^2}{2g} = \frac{2\pi R k b^2}{\text{Sin}^2\ \theta}$$

And (2)

$$b = v\ \text{Sin}\ \theta\sqrt{\frac{W}{4\pi R g k}}$$

It appears from this that the resistance of the plate increases as the value of θ diminishes.

We have already shown that a 4·5 inch unbacked plate, when fired at direct, requires a force represented by 28 foot tons per inch of shot's circumference to ensure penetration.

Let us suppose, however, that we place the plate in such a position that it makes an angle of 38° with the ground. From equation (4) we find that the force required to penetrate it in this position amounts to 1,445 foot tons for a shot of 6·22 inches diameter, or 73·9 foot tons per inch of shots circumference. We may, expect, therefore, that a less force will not penetrate a 4·5 inch unbacked plate placed at an angle of 38°.

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SECTION II.

CONSTRUCTION OF ORDNANCE.

CONSTRUCTION OF S. B. CAST ORDNANCE.

General Form, and why.—The general form of S. B. cast guns is conical.* The strain from the discharge decreases from the breech to the muzzle, and the thickness of metal being proportionately reduced, the advantage is thus gained of lessening the weight of the gun without impairing its efficiency.

Division of Parts.—A S. B. cast gun is divided into five parts, cascable, first reinforce, second reinforce, chase and muzzle.

Swell of Muzzle.—The increased thickness of metal at the muzzle is termed the "swell."

It strengthens a part liable to be impaired by an enemy's fire and affords also a good position for a notch or sight.

Trunnions.—The "trunnions" are cylindrical pieces of metal by which the gun is supported on its carriage. They are usually of the same diameter and length as the diameter of the bore.

Their position on a gun or howitzer is a little in front of the centre of gravity of the piece; this allows the breech to preponderate, and thereby rest steadily on its carriage.

They are placed also a little below the axis of the piece to enable the quarter-sights to be made use of, but it increases recoil by the effect on the carriage.

In all new guns the axis of the trunnions passes through the axis of the gun, thereby lessening the destructive effects on the carriage, caused by the tendency to rotate round the axis of the trunnions when it is not in the same plane as that of the gun.

Preponderance.—This excess of weight in rear of the trunnions is termed the preponderance, which is reduced to a minimum to allow the breech to be easily elevated or depressed.

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* This form is not altered by the Palliser process of conversion.

Definition of Calibre.—The diameter of the bore is termed the calibre of the gun.

Definition of Windage.—Windage is the difference between the diameter of the bore and of the projectile.

Necessity of Windage.—Windage is a necessity in S. B. guns:—

1. From the impossibility of casting shot perfectly spherical or of uniform diameter.
2. To allow of increase of diameter from rust or expansion when heated.
3. To permit loading with greater facility when the bore becomes foul from continued firing.

These conditions fulfilled, windage must be as small as possible.

Advantages of Windage.—1. It admits the passage of the flame round the projectile on the discharge of the gun which ignites the "time fuze."

2. Diminishes the strain on the gun when firing.

Disadvantages of Windage.—1. Loss of a portion of the force of the charge from the escape of the elastic fluid round the shot, resulting in a reduced initial velocity.

2. Irregularity in the flight of the projectile from its centre of gravity lying below the axis of the gun, thus permitting the gas to escape over the top of the projectile, and cause it by a succession of rebounds in the bore, to leave the muzzle in an accidental direction.

3. Injury to the bore of the gun from the rebounds of the shot in its exit.

Vent.—The vent of a gun is the channel passing through the metal from the exterior of the breech into the bore, by means of which it is fired.

Bouched with Copper.[*] —In service ordnance vents are constructed two-ninths of an inch in diameter, and they are bouched with copper, from the fact that this metal withstands the chemical action of gunpowder better than any other.

Chambers.—The chamber of a gun is the cell or cavity at the bottom of the bore to receive the charge of powder.

Forms of Chamber.—There are two forms of chamber adopted in the service.

1. The cylindrical.
2. The conical or gomer.

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[*] In shell guns the vent is in the base ring. In shot guns it is in front of the base ring, in what is termed the vent-patch. This is one means of distinguishing a shot gun from a shell gun.

They may also be distinguished by the shell guns having only two muzzle mouldings, whilst shot guns have three. The third moulding on shot guns, however, has sometimes been turned down, leaving the gun with only two mouldings. This was done to enable them being run out of the port-holes of wooden ships. There are some shot guns at Digby, N. S., which have the third moulding turned off.

The first is nearly obsolete and adapted only to small charges.

The second has the advantage that when the shot is home, until it commences to move, all windage is destroyed, and the axis of the shot is in a line with the axis of the bore, except when the bore of the gun is horizontal or nearly so, when the shot naturally rests on the bottom of the bore.

In using reduced charges this form has the disadvantage of allowing a space to exist between the charge and projectile.*

Measurement of S. B. Cast Guns.—A S. B. cast gun is measured from behind the base ring along the axis to the face of the muzzle.

Length of Bore.—1. The length of bore is mainly regulated to allow of the complete combustion of the charge, so that none may remain unexpended or be wasted.

Diameter of Bore.—1. The diameter of the bore depends upon the form and nature of projectile employed.

2. It must be suited also to the size of the charge, for as the diameter decreases the cartridges will be lengthened, and the conversion of the powder into gas becomes slower in its action.

Amount of Metal in a Gun, vide "Owen's Modern Artillery," page 19.—The amount of metal in a gun must depend upon the charge, the weight and form of projectile, the material used, and the method of construction.

SMOOTH-BORED ORDNANCE.

Definition of Ordnance.—The term Ordnance includes artillery of all kinds, in its most comprehensive signification.

Classification of Ordnance.—Ordnance is divided into three classes, Guns, Mortars and Howitzers.

Purposes.—Guns are used for projecting shot and shell at low angles, and are fired with large charges, to obtain high initial velocity, and consequently a flat trajectory.

Smooth bore guns are of two kinds, solid shot, and shell guns.

Solid Shot Guns.—Solid shot guns are designated by the weight of the projectile used with them.

The different natures are 6, 9, 12, 18, 24, 32, 42, 56 and 68 pounders.

Shell Guns.—Shell guns are designated by diameter of the bore in inches.

They possess the advantage of being lighter pieces, and yet firing shells of as large diameter.

There are two sizes, 10 and 8 inch.

Bronze Guns.—Bronze guns were adopted for field purposes on account of the comparative lightness of this metal, and from their being less liable to burst than iron guns of the same calibre. Bronze guns are now only used by Austria which has a special method of manufacture.

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* It is being questioned whether this space is a disadvantage provided the gun be strong enough; powder chambers larger than the diameter of the bore, have been experimentally introduced for rifled guns.

Howitzers.—Howitzers are a description of shell-gun, with a dispart patch; shorter, but with a bore of larger diameter than a gun of proportionate weight; and intended to fire shells at low angles and reduced velocity.

Mortars.—Mortars are the shortest piece of ordnance in the Service; the trunnions are placed in rear of the vent at the breech; the bore is very large compared to the length of the piece, and is provided with a gomer chamber.

Use.—They are used at high angles, generally at 45 degrees, for reaching objects by their vertical fire, when injury cannot be effected by direct fire.

Construction.—They are constructed stronger than guns, on account of the high elevation at which they are fired, and shorter, because the difficulty of loading them would be increased by their length.

Fired from Beds.—Mortars are fired from beds instead of carriages, on account of their high elevation, the recoil forcing the piece downwards, as well as backwards; imparting a strain that no wheel carriages could long sustain.

There are 5 sizes of mortars for land service, viz.: the 13", 10" and 8" of iron weighing 36 cwt., 18 cwt. and 9 cwt. respectively, and the 5½" Royal and 4 2-5" Coehorn, made of bronze, the two latter are of the same calibre as the 24 and 12 por. guns.

There are no special projectiles made for them, the 24 por. and 12 por. common shells being suitable, 4 men can carry one of these pieces a moderate distance when it is found necessary to change their position.

Rendering Ordnance useless.—Smooth-bore ordnance can be disabled by knocking a trunnion off, or they can be made useless for the time being by spiking the vent with a nail or properly formed spike made for the purpose.

SIGHTS FOR S. B. ORDNANCE.

Sights.—The following are the sights used with S. B. Ordnance.

Millar's Sights.—Tangent scale or hindsight at the breech and dispart, or foresight, in front of 2nd reinforce.

The dispart or foresight is necessary in order to gain a line parallel to the axis of the gun, in consequence of the gradual decrease of metal from breech to muzzle.

Above the clearance angle of the gun, a No. 1 wooden tangent scale is used and graduated up to 3 degrees:—a No. 2 wooden tangent scale is used for those guns not fitted with Miller's sights, but can be of service only above the line of metal elevation.

Short Radius.—The brass tangent scale may be said to be a tangent to an arc, the radius of which is the distance from the highest point of the foresight to the back of the hind sight and the divisions is calculated accordingly; this distance is called the *short radius.*

Long Radius.—The wooden tangent scale may be said to be a tangent to an arc of which the radius is the distance from the notch on the swell of the muzzle to the back of the hind sight; this distance is called the *long radius.*

RULE FOR LENGTH OF DEGREE ON TANGENT SCALE

A practical rule for finding the length of a division or degree on the tangent scale, is to divide the length in inches between the two sights by 57.

The brass tangent scale is set an angle of 76°, so that it may slide up and down without touching the breech of the piece.

Adjustment of Fore and Hind Sights.—To adjust the fore and hind sights, the gun is levelled across both trunnions, and in the bore. These sights must then be adjusted to fulfil the following conditions:—

1st. They must be placed at the proper radial distance apart.

2nd. When the scale is without elevation the top of the notch and the top of the foresight should be parallel to the axis of the gun.

3rd. When the scale is elevated to the clearance angle, its notch and the apex of the foresight and the notch on the muzzle, must be in a straight line.

4th. The line of sight and line of metal must coincide, *i. e.*, be in the same vertical plane.

FOR SIGHTING S. B. ORDNANCE.

Visual Lines.—Prior to the sights being adjusted the following visual lines are carefully traced.

Line of Metal.—The line of metal is an imaginary line joining the highest point on the base ring and the swell of the muzzle.

Quarter-sight Line.—The quarter-sight line is not the true quarter-sight, but is raised above the trunnions to clear the cap-squares, so as to permit the divisions of the quarter-sight scale to be made use of.

This line is marked by a notch on both sides of the gun, at the base ring and muzzle.

Line of Horizontal Axis.—The line of horizontal axis is the true quarter-sight line, and marked only on the right side of the gun, at the base ring, trunnion and muzzle.

Vertical Line of Axis of Trunnion.—The vertical line of axis of trunnion is also only marked on the right side of the gun. It is simply a perpendicular to the line of horizontal axis.

Quarter-sight Scale.—The 32 por. gun and iron guns downwards have a quarter-sight scale up to 3° on both sides of the gun.

The divisions of this scale are cut on the sides of the base ring beginning with a notch which, with another cut in the sides of the swell of the muzzle, gives a line of sight parallel to the axis, and corresponds with the quarter-sight line previously explained.

This scale gives an elevation of 3°.

In the event of the other sights being out of order, or destroyed, the quarter-sight scale can be made available.

This scale is used to lay also at a less elevation than the line of metal.

Testing Sights.—A rough method of testing the correctness of the sights on a smooth-bore gun is to raise the tangent scale to the angle of clearance, and pass a silk thread from the top of the tangent scale over the dispart sight to the muzzle notch; the dispart sight should be exactly touching and directly under this thread if the sighting is true.

Quadrants.—Angles of elevation or depression may be given to ordnance without using the sights by means of either the spirit level quadrant, or the gunners quadrant. They only, however, give the elevation above the horizon, but by laying the gun point blank at the object, and determining its elevation above or depressed below the horizon, the required elevation may afterwards be given.*

COPPER VENTING.

All cast-iron and brass ordnance are vented before issue with bouches of pure copper, mortars only if it is required.

Natures of Vent.—They are invariably of the same diameter, but vary in length according to the thickness of metal.

There are two natures of vent.

The cone vent and through-vent.

The cone vent is a cylinder, terminating in a frustrum of a cone, which is screwed into the piece, the thread not being carried beyond the cylindrical portion.

The cone vent is used for all new guns, and for reventing guns, if they will admit of it.

The through-vent is cylindrical throughout its whole length, the thread is carried to the bottom.

If an impression of the bottom of the vent shows fissures which would not be removed by the insertion of a cone vent, a through-vent is used.

Necessity of Reventing.—A gun must be revented if the vent admits of a guage, ·25 inch passing down it. If the fissures at the bottom of the vent do not radiate from its centre more than ·35 inch a cone vent may be used for reventing. If more than ·35, and not more than ·45, a through-vent must be used.

Beyond these limits the gun must be condemned. New vents are constructed with 7 threads to an inch.

CONSTRUCTION OF RIFLED ORDNANCE.

Two Classes.—The rifled ordnance in the Canadian service are breech and muzzle-loaders.

B. L. Guns.—The B. L. rifled guns are divided into two classes.

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* The sights for the rifled guns now in possession of the Canadian Militia Artillery have been described specially for those guns under their respective headings.

Screw B. L. rifled gun and wedge B. L. rifled gun.*

Screw.—The screw B. L. is locked after loading by a breech screw, securing a vent-piece firmly against the rear of the chamber of the bore; the vent-piece being dropped into position through a slot in the top of the breech.

The B. L. guns are all rifled on the same system, the "Armstrong," named after the inventor.

Armstrong System.—The general principles of construction of this system consist in having steel or wrought-iron shrunk on to the tube so as to give the necessary additional strength and security. The barrel is rifled with a series of narrow grooves separated by lands of rather less width, and the twist given to the rifling is rapid and uniform.

Description of Projectile.—The projectile used with these guns is coated with lead, and made somewhat larger than the bore of the gun.

Action.—On the discharge this projectile is forced through the barrel, and the lands cut into and grip its soft coat or covering, a rotatory motion proportionate to the twist of the rifling being thus imparted to it.

Windage.—Windage is thus entirely done away with, and the axis of the projectile is made coincident with that of the bore, hence the accuracy of fire is very great. The whole force of the powder is fully developed on the projectile, thus permitting a reduction in the charge, which is moreover necessary to lessen the strain on the gun.

Disadvantages in Heavier Natures.—The Armstrong screw "B. L." system is not adapted to the heavier nature of guns from the great difficulty of effectually closing the breech.

Disadvantage of Want of Windage.—1. The absence of windage necessitates the use of a percussion arrangement to ignite the fuze, entailing increased complication and expense in manufacture.

2. Detonating compositions must be used in this class of percussion action, thereby engendering increased liability to accident and to deterioration in store and during transit.

Natures of Screw B. L.—The screw B. L. guns in the Canadian service are, 6 por. and 7 inch guns.

Muzzle-Loaders.—There are three classes of rifled muzzle-loaders in the Canadian service, viz:—

1. 7 por. M. L. R. bronze mountain guns.
2. 9 por. M. L. R. wrought-iron field guns.
3. Palliser converted M. L. rifled 64-32 por. 7" and 8".

The Woolwich guns are rifled on what is known as the Woolwich system, which is nearly indentical with the French system, the gun is rifled with three or more single grooves, and the projectile has two studs to each groove.

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*There are no wedge B. L. R. guns in Canada.

Grooves.—The grooves cut in the bore of a rifled gun, are simply a portion of the thread of a female screw having a long pitch.

Lands.—The lands are the spaces between the grooves.

Loading and Driving Edge.—The 9 por. M. L. R. gun has a loading and a driving edge, the loading edge is more perpendicular to the surface of the lands than the driving edge which is sloped off so that the stud in coming out must get a bearing somewhere on its surface so as to centre the projectile in the bore, *i. e.*, make its axis coincident or nearly so with that of the gun.

Two Classes of Twist.—Two classes of twist are adopted, known as the uniform and increasing twist

In the first case the spiral commences at the moment the projectile moves, and is constant throughout the length of bore.

Increasing Twist.—In the second the projectile is allowed to move directly forward for a short distance (*i. e.*, without rotatory motion,) the spiral then commences, slight at first, but increasing towards the muzzle.

Advantages of Increasing Twist, Vide "Majendie," p. 5-6.—The increasing twist is preferred, as the strain on the gun and consequent wear is reduced, while it possesses a slight advantage in accuracy of fire.

The muzzle-loading rifled guns adopted into the British service at present, are:—

The converted 32 pr., and 8″ S. B.—64 pr......	Uniform Twist.
" " 68 pr., and 8″ S. B.—80 pr......	
7-inch—115 pr.	Uniform Twist.
8-inch—180 pr.	Increasing Twist.
9-inch—250 pr.	
10-inch—400 pr.	
12-inch—600 pr.	
* 35 ton gun—700 pr.	

Palliser System.—In the Palliser converted system the 32 pr., 8″, and 68 pr., S. B., are bored out, and a wrought-iron tube inserted rifled with three grooves.

Building Up of Guns.—The original building-up principle was introduced by Sir William Armstrong.

There are three methods in use for the construction of M. L. rifled guns, viz: the Armstrong Fraser and Palliser methods.

Armstrong Method.—In the Armstrong method, the breech-piece is forged solid, a number of small coils are then shrunk on it and hooked together to prevent longitudinal separation.

Fraser Method.—In the Fraser method, instead of a solid breech-piece being forged, a breech coil composed of treble and double coils is welded to the trunnions to form one mass, and the whole is shrunk on in one operation, and the muzzle strengthened by a tube of two coils united.

Advantages.—A cheaper iron is used with the Fraser construction with as good results, while the shrinking on is performed in one operation.

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* The stud system is apparently being gradually superseded by the polygroove with a gas check which imparts rotation.

Palliser Method of Conversion or Construction.—A smooth-bore cast-iron gun is bored out to a depth of about two inches and a wrought-iron coiled barrel inserted. In the United States, cast-iron jackets have been cast specially to fit over the coiled barrels. Advantages, cheapness and extreme durability. There being, it is believed, no instance on record of a real Palliser converted gun having burst.

Advantage of Rifled Ordnance.—1. Accuracy, because the projectile being made to rotate on a fixed axis equalises the effects of irregularity of the mass, and prevents accidental revolution.

2. Simpler action of percussion fuze, the head being kept steadily to the front.

3. The projectile used can be elongated and greater range and penetration thereby obtained, also greater capacity for the bursting charge of shell, and space for bullets in Shrapnel.—*See "Majendie," p.* 9.

4. Less powder is necessary in proportion to the weight of the projectile.

5. There is a flatter trajectory.

6. All projectiles can be brought up to the same weight.

7. The head of the projectile used can be of any desired form.

8. A lighter gun can be used and heavier projectile fired therefrom.

Disadvantage.—Bad ricochet, increased complication, and extra expense of manufacture, increased strain on gun, the necessity of using soft coated or studded projectiles which are easily injured, and their liability to jam in the bore.

Advantages of B. L. Guns.—In B. L. guns unconsumed portions of the cartridge can be seen and removed before loading, and there is no danger of the shot not being home.

The detachment also is more under cover.

Disadvantages of B. L. Guns.—In B. L. guns a percussion arrangement with detonating composition is necessary to ignite the fuze, and the extreme cold of the climate of Canada makes them difficult to manipulate in winter.

Advantages of Muzzle-Loading Guns.—A muzzle-loading rifled gun is simpler in construction, less liable to get out of order, requires less attention, and permits the fuze to be ignited by the flash of the discharge.

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PRACTICE OF GUNNERY.

SECTION I.

DEFINITIONS.

A. *Axis of the Piece.*—Is an imaginary line passing down the centre of the bore.

B. *Axis of the Trunnions.*—Is an imaginary line passing through the centre of the trunnions at right angles to the axis of the piece.

C. *Line of Fire.*—Is the prolongation of the axis of the piece.

D. *Line of Sight.*—Is the line passing through the notch of the tangent scale and tip of the foresight, to the object.

E. *Trajectory.*—Is the curved line described by the centre of gravity of a projectile, in passing from the gun to the object.

F. *Plane of Fire.*—Is the vertical plane passing through the axis of the gun.

G. *Angle of Elevation.*—Is the angle which the line of fire makes with the line of sight.

H. *Angle of Clearance.*—The angle of elevation obtained when the tops of the tangent scale and dispart sight, and the notch on the muzzle are in line.

I. *Angle of Departure.*—Is the angle a tangent to the trajectory, makes with the line of sight on the shot leaving the muzzle.

J. *Jump.*—Is the difference between the angle of departure and the angle of elevation, it is scarcely a subject for practical consideration.

L. *Parallelogram of Error* is the probable rectangle or, strictly speaking, ellipse due to the inevitable inaccuracy of the gun, the shorter axis is the error right or left; the longer axis is due to variation of range.

K. *Angle of Descent.*—Is the angle made by a tangent to the trajectory with a horizontal plane, at the first graze, or at the point of impact on the object.

M. *Range.*—Is the distance from the muzzle of the gun to the second intersection of the trajectory with the line of sight.

N. *Dispart.*—Is half the difference between the diameters of those parts of the gun, upon which the sights are placed.

O. *Point Blank.*—A gun is laid point blank, when the production of its axis will pass through the object aimed at.

P. *Point Blank Range.*—Is the range obtained at the first graze of the shot, when the piece placed on its carriage is fired with the service charge, on a horizotal plane with no elevation; that is to say, when the axis of the piece is parallel to the plane.

Q. *Line of Metal.*—Is a visual line joining the notches cut on the highest points of the base ring and swell of the muzzle, when the trunnions are perfectly horizontal.

R *Line of Metal Elevation.*—Is the elevation obtained when the gun is laid upon an object by means of the line of metal (there being no dispart patch).

S. *Quarter Sight Line.*—Is a line joining a notch on the base ring and a notch on the muzzle made on both sides of the gun, it is parallel to the axis but a little above it so as to clear the cap squares of the trunnions.

T. *Line of Horizontal Axis.*—The line of horizontal axis is the true quarter sight line, and marked only on the right side of the gun, at the base ring, trunnion and muzzle.

U. *Vertical Line of Axis of Trunnion.*—Is only marked on the right side of the gun. It is simply a perpendicular to the line of horizontal axis.

V. *Deflection.*—Is the horizontal distance of the trajectory to the right or left of the line of fire.

W. *Derivation.*—Is the constant bearing away to the right or left, in its flight, of an elongated projectile, caused by the rotatory motion imparted to it on its longer axis.

II.

The former division of the Practice of Gunnery into "horizontal fire" and "vertical fire" has been lately changed on the recommendation of a committee of Royal Artillery officers, assembled for the purpose of considering what terms were to be used in distinguishing the various natures of artillery fire, having reference to the angle of elevation, and it was determined that they should be classed under three terms, viz:

1ST "DIRECT FIRE."

From guns with service charges at all angles of elevation not exceeding 15°.

2ND "CURVED FIRE."

From guns with reduced charges and from howitzers and mortars at all angles of elevation not exceeding 15°.

3RD "HIGH ANGLE FIRE."

From guns, howitzers and mortars at all angles of elevation exceeding 15°.

The above terms to have reference to the condition within the vertical plane.

The term "direct" being already used as above in reference to the vertical plane, "front" or "frontal," is therefore to be used instead of "direct," in reference to the horizontal plane, and the old term "vertical," is to be included in that of "high angle fire."

Oblique, *cross*, *reverse* and *enfilade* fire then become varieties of either "direct or curved" fires, or of both according to the position of the guns relatively to the object, just in the same manner as "front," or "frontal," may be "curved" or "direct." Ricochet fire becomes a variety of "curved fire" with S. B. guns, which are placed in the prolongation, or nearly so, of a line of troops or works, the charge being reduced and the elevation not exceeding 15°. It is used to dismount guns covered by parapets and traverses, &c., or against troops similarly protected, the projectile just clearing a parapet, for instance, and rebounding along the adjacent face of the work.

"Ricochet" is not suitable to rifled guns, the bounds or ricochets of their projectiles being too irregular to be reliable. It has been superseded by curved fire with percussion fuze, the projectile just clearing the parapet or traverses, and exploding on impact behind them. Curved fire may be "front" or "frontal," as has been already mentioned. It is so when the guns from which it is obtained are placed perpendicularly to a line of troops, face of works, or other object, and the projectile fired so that it will just clear an intervening parapet or other covering mass and strike the object—breaching fortresses is performed in this manner, of which more hereafter.

"Curved" or "direct" fire, with rifled guns, may be used for enfilading, its application depends upon the nature of the object and its position relative to the firing batteries.

Enfilade curved fire will be used if the guns are intended to dismount ordnance along a face of works protected by traverses, or create casualties among defenders. The siege of Duppel is a good illustration of the effectiveness of this mode of using curved fire. The Prussians enfiladed the faces of the works, dismounting ordnance and creating casualties, silencing the batteries, and in a comparatively short time rendering their capture easy.

Enfilade direct fire will be used if it is intended to enfilade a line of troops * in the open, or any object not screened by an intervening

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* At Duppel the left of the Danish entrenched position rested on an arm of the sea, the south shore of which was high and steep, on this the Prussians erected an enfilade battery of 4 or 6 rifled guns corresponding to our 40 por., into this arm a Danish iron clad the Rolfe Krake penetrated, but was unable to elevate sufficiently to disturb the comparatively feeble Prussian battery, which opened fire first on the extreme right or most distant part of the Danish works, silencing the guns there with common shells and percussion fuzes, gradually reducing the range as the Danish guns were silenced in succession. This was contrary to the easier practice of firing short at the nearest part of the line of works to be enfiladed,

cover. The parallelogram of error in "curved" or "direct" *enfilade* fire is always more advantageous than in "curved" or "direct" *front* or *frontal* fire, unless the object in the latter case has great depth.

III.

LAYING GUNS AND HOWITZERS.

In order that a projectile fired from a gun or howitzer may strike the required object it is necessary to lay the gun, that is to say:

1. Bring the axis of the piece in a vertical plane with the object.*
2. Give the axis of the piece a certain elevation above the object (unless firing with a S. B. gun at a distance within point blank range.)

But as the axis of the piece is not visible it is necessary to make use of notches or sights outside the piece on its exterior surface, to determine practically the position of the axis. In S. B. guns two notches are cut on the highest points on the base ring and the swell of the muzzle, and the visual line joining them is called, as already mentioned in definitions, the *line of metal*, and it is by sights placed on the line of metal and in the same vertical plane as the axis of the piece that their axis may be brought in line with the object.

It is necessary in order to counteract the effect of gravity on the projectile, as already mentioned in the principles of gunnery, to give the axis of the gun a certain elevation; this is done by

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and increasing the range according to the visible effect produced. It was necessary to silence the works on the Danish right first, for strategic reasons, the attack by Prussian infantry was ordered on that flank to cut the Danes from their line of operation and retreat, and to hem them into the angle formed by the arm of the sea before mentioned, the Prussian fire was so accurate as to render the attack by the infantry comparatively easy. The officer commanding the Danish artillery was tried by court-martial for loosing so few gunners in the defence, but acquitted on the ground, that he proved that the Prussian fire was so accurate it passed harmlessly over the nearer works, dismounting the guns and putting gun detachments *hors de combat* in succession from the right; and after a short time, to save unnecessary loss of life, he found it advisable to withdraw the detachments from the guns in succession as soon as the unerring fire reached them. Possibly a very active commandant with highly trained gunners, spare carriages and material at hand, might have remounted the guns and recommenced the defence.

* Capt. G. T. French, R. A., C. M. G., late Lt.-Col. Inspector of Artillery in Canada, has invented a system of laying guns and mortars behind parapets which intercept the sight of the object, it has been approved by the War Office.

means of sights, and in both S. B. and rifled guns the tangent scales of their respective sights are divided so that the divisions correspond with the various ranges required. In heavy rifled guns the sights are not placed always along a line on the top of the piece, but sometimes in a line parallel to the axis of the piece, right and left of it.

SIGHTS OF S. B. GUNS.

S. B. guns are laid by means of a fore or dispart sight and a hind sight. The length of the dispart or fore sight is according to the dispart of the gun at that part of it, on which those sights are placed.

The tangent scales of the hind sights are: one of brass and the other of wood for heavy S. B. guns, the brass tangent is graduated to the *short radius*, that is to say, the distance which separates the hind from the dispart sight, and the wooden tangent scale is graduated to the *long radius*, that is to say, the distance which divides the hind sight from the notch on the muzzle. Elevation up to 3° can also be given by means of the quarter sight to the lower nature of S. B. ordnance from the 32 por. downwards.

Quarter sights consist of notches cut, one on the side of the base ring and the other on the side of the muzzle, giving a line of sight parallel to the axis of the piece, but a little above it so as to clear the capsquare of the trunnion, and from the notch on the base ring going upwards degrees and minutes are cut in the metal of the gun, up to 3°.

SIGHTS OF RIFLED GUNS.

A. Breech-loading Armstrong guns are laid by means of a tangent sight and a trunnion sight on each side of the gun, placed on lines parallel to the axis of the piece.

The tangent sights are inclined towards the left at an angle, 2° 16" in breech-loading guns, to counteract the derivation of the projectiles caused by the rifling, because when laying the gun this inclination of the tangent scale causes the axis of the piece to point to the left of the object sufficiently to compensate the drifting of the projectile to the right during its flight.

This tangent scale or bar is provided with a sliding leaf, which is graduated to give ½° deflection right or left, so that an exact allowance may be given in laying the gun for wind or other disturbing influence on the course of the projectile, also when aiming at a moving object, for the motion of that object towards one side or the other of the range, and finally in cases when the carriage is not level.

B. Muzzle-loading rifled guns are laid, some by means of a breech tangent scale and a trunnion or fore sight on each side of the gun, others, as the 64-32 por., by a hind sight with tangent bar and a fore sight placed on the highest surface of the gun, the trunnions being perfectly horizontal.

The 9 por. M. L. R. has the fore sight on a dispart patch at the muzzle. In all cases the tangent bars are inclined at angles to the left varying for different guns to counteract derivation, these bars are also provided with sliding leaves to give deflection. Apart from wind as a disturbing agent there is also the inclination of the piece when its trunnions are not perfectly horizontal; this imperfect levelling of the trunnions would have no effect if firing with no elevation, but if firing with elevation it would tend, by inclining the axis of the piece towards the side which is lowest, to throw the projectile low and to the right or left of the object aimed at, and the greater the elevation the more considerable will be the error. (Fig. .) The line of sight making an angle with the line of fire.

Angles of elevation or depression are also given by means of the spirit level quadrant, and also by the gunner's quadrant. These instruments only give the elevation above the horizon, but if you first lay the gun point blank on the object and ascertain the degree of elevation the quadrant marks when the long arm is properly placed in the bore of the gun, the required elevation may afterwards be given.

Angles of depression are taken by placing the quadrant against the face of the piece of M. L. R. guns or in the powder chamber of B. L. R. guns.

At gun practice it is unadvisable to alter the elevation after each round unless the error is considerable, short or over, but the result of several rounds should govern these alterations, as there is a certain parallelogram of error due to each gun.

The ranges corresponding to the angles and minutes of the tangent scales are determined by experiment, a range curve being constructed representing the mean range of a gun fired with its service charge at certain elevations. It is with the aid of this range curve that range tables are made.

To make use of range tables when at practice the distance of the object aimed at must be known, as it is according to its greater or less distance that elevation is given when firing.

RANGE FINDING.

The distance of an object may be ascertained by judging, which is very uncertain for the long ranges of artillery, and also by means of instruments, practice will enable you to estimate distances pretty accurately up to 600 or 700 yards, but when firing at objects over that range instruments should be used. A pocket sextant is the most portable and useful instrument for that purpose, and the ranges are found with it by means of tables, either of natural tangents with right angled triangles or in oblique angled triangles, the principle of which is, by the proportion as one side is to the sine of its opposite angle, so is any other side to the sine of its opposite angle.

The following tables of natural tangents is given as an example of the application of the above principle to right angled triangles. The known side, as a base, being 100 yards in length, or when long ranges are required, 200 yards, the result being of course doubled:—

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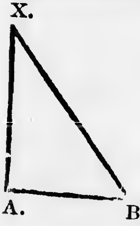
se doubled:—

NATURAL TANGENTS TO A BASE OF 100.

D'g.m	R'ge.	D'g.m	R'ge.	D'g.m	R'ge.	D'g.m	R'ge.	D'g.m	R'ge.
				83.48	920	85.33	1285		
		81.0	630	52	30	36	99		
		6	38	56	40	39	1314		
		12	46	84.0	51	42	30		
		18	53	3	59	45	45		
		24	61	6	67	48	61		
		30	69	9	76	51	77	86.50	1807
		36	77	12	84	54	95	52	26
77.30	451	42	85	15	93	57	1412	54	46
45	60	48	94	18	1001	86.0	30	56	66
78.0	70	54	702	21	10	2	42	58	87
15	80	82.0	11	24	20	4	54	87.0	1908
30	91	6	20	27	29	6	66	2	29
45	502	12	30	30	38	8	79	4	51
79.0	14	18	39	33	48	10	92	6	74
10	22	24	49	36	58	12	1505	8	97
20	31	30	59	39	68	14	19	10	2020
30	39	36	70	42	78	16	32	12	44
40	48	42	80	45	88	18	46	14	69
50	57	48	91	48	98	20	60	16	94
80.0	67	54	802	51	1109	22	74	18	2120
10	77	83.0	14	54	20	24	89	20	47
20	87	4	22	57	31	26	1604	22	74
30	97	8	30	85.0	43	28	19	24	2202
40	608	12	38	3	54	30	35	26	31
50	19	16	47	6	66	32	50	28	60
		20	55	9	78	34	66	30	91
		24	64	12	90	36	83		
		28	73	15	1203	38	99		
		32	82	18	16	40	1717		
		36	91	21	29	42	31		
		40	901	24	43	44	52		
		44	10	27	56	46	70		
				30	70	48	88		

TO MEASURE DISTANCES USING TABLES.



If two Sextants are used it will facilitate the operation. Suppose A. X. to be the distance required, and A. B. the base, which must be carefully measured. Two men place themselves one at each end of base, the man at A. having set the index of his sextant at 90° moves himself back or forward (a pace or so only is generally required) or the man at B. is made to move until he is reflected immediately above the object X., the line A. B. will then be at right angles to A. X. The man at B. having set the index of his sextant at zero, looks at A. through the clear glass, and moves the index screw until the object A. is reflected immediately above the man at A., the index arm will then indicate the number of degrees and minutes in the angle A. B. X. On reference to the tables opposite the angle thus obtained, will be found the distance A. X.

Example.—Suppose the base used to have been 100 yards, and the angle A. B. X. to have been 84 deg. 17 min., the distance A. X. would be 1000 yds.

ONE SEXTANT WITHOUT TABLES.

If one Sertant only is used, it is set at 90° at A. A fishing reel measured in yards is stuck in the ground at A. by a spike screwed into the butt of a fishing rod or other pole to which the reel is fastened, the pole serving to mark the end of the base. The line is run 100 yds. or any convenient length by an assistant at right angles to A. X. The man at A. with Sextant corrects the man at B. getting him reflected over X. Sticks his sword or a lance in the ground at A. if no staff has been provided for the fishing reel, walks to B. and takes the angle when X. is reflected over B. Then without tables, distance A. B. *in feet* × 1150 divided by angle at X. in minutes = *range in yds.*

N. B.—Angle X = 90 − angle B.

ROUGH RULE FOR SAFE RANGES.

Projectiles from rifled and S. B. guns with full service charge, as a general rule, pass over the undermentioned distances, on the sands at Shoeburyness, before coming to rest.

	1°.	5°.	10°.
Rifled Guns:			
M. L. 7 inch	5,000 to 6,000 with battering charges.	6,000	5,500
M. L. 8 inch			
M. L. 9 inch			
M. L. 13 inch			
B. L. 12 por	3,500	4,000	4,500
B. L. 40 por	4,000	4,500	5,000
B. L. 7 inch			
B. L. 64 por			
Smooth-Bore:			
18 por	3,000	4,000	3,500
24 por			
32 por			
8 inch			
68 por	3,000	3,300	4,000
10 inch	3,000	3,500	3,500

Elongated projectiles fired from rifled guns with a right handed twist ricochet to the right, the final graze being often from 400 to 500 yards to the right of the line of fire.

IV.

SHELL FIRING.

In shell firing, as the fuzes burn a certain length in a certain time, and as the shells to which the fuzes are adapted move a certain distance during a certain time, the *time of flight* must be known in order that the fuzes be prepared so as to explode the shells at the required distance.

A ready rule to determine the length of fuze for shell of S. B. and rifled guns respectively will be given hereafter.

The fuze when used to explode common shell fired amongst troops in masses, should be bored so that the shell will explode a few feet before reaching the ground. If fired against houses or earthworks the shell should be made to explode after having lodged in the object, and the fuze should be bored long.

When firing shrapnel shell, the fuze should be so prepared, that it would cause the shell to burst 20 to 80 yards short of the object, if a column, a greater distance if in line or extended order, for if the shell burst too soon (the fuze being short) the whole or the greater part at least, of the bullets contained in the shell will strike the ground before reaching the object, losing thus accuracy and power of penetration, and if the shell passes the object without exploding its effect as shrapnel will be lost. Common shell with percussion fuze makes effective practice, the fuze acting on graze does not require any adjustment.

But with shrapnel and percussion fuze the practice is generally inferior to that made with shrapnel and time fuze.

Wood time fuzes are apt to burn more slowly than is intended particularly if kept long in store. After firing one or two rounds the length of fuze should be corrected from observation.

It is generally possible from the position of the gun to estimate the line and often the height of the burst of the shell, but not the distance at which it occurs. When firing shrapnel, bad practice commonly arises from a too sanguine estimate of effects, judging from the appearance of the burst alone, particular attention should therefore be paid to any visible marks of the bullets grazing. On water, splashes will be seen; on ground, puffs of dust; on ice very distinctly scored marks and a sort of a haze produced by minutes particles of ice flying up; on wet or boggy ground nothing is commonly visible.

Shrapnel should be burst closer to compact masses of troops than to more open formation. There are then three points of observation for judging the effect of shrapnel, the point of rupture, the line of foam or puffs of dust, and the object.

If firing with percussion fuze, the shell must be made to burst on impact quite near and in front of the object, the effect of the bursting can readily be judged in this case by the smoke earth, stones, &c., knocked up by the splinters. In firing at an object, on a rocky site, the shells will be canted up or off, and the results on the object very uncertain, sometimes very destructive, at others just the reverse.—If the object is on the side of a hill, the shell will probably penetrate, should the ground be soft, or be deflected should it be rough or stony. In any broken ground whatever or uncleared land, attempts to produce good effects by bursting shells on impact will probably end in disappointment.

* The main purpose of shrapnel must be steadily kept in view—viz., with a shell of a certain weight to cover any given area with as powerful and effective a bullet fire as possible, and thus to disable a large number of the enemy. To take an extreme case, for instance, we might suppose a battery, supplied with a solid shot of the same weight as its shrapnel, firing at a single rank. Each projectile could disable one man only; whereas it will be seen further on that a shrapnel, effectively burst with a time fuze, would account for from 19 to 23. It is to this crucial test of numbers disabled that all practice should be referred.

If the shrapnel shell of a field gun is burst lying at rest upon fairly level ground, the head and bullets will be found from 35 to 40 yds. to the front; the splinters, some to the right, some to the left front, nearly as far forward; and the base blown 50 or 60 yds. to the rear. If the 16-pr. M. L. shrapnel is burst enclosed between four 9-ft. × 9-ft. targets, the whole of the bullets and splinters will be found inside, and only two or three small dents will be visible on the targets. The same will be the case with the 9-pr. M. L., except that the dents will be hardly perceptible.

Any effect produced by the shell is therefore evidently not due to the bursting charge, which may be said to have practically no accelerating and but very little disturbing tendency.

The destructive effect of the splinters and bullets—that of the latter being by far the most important of the two—is simply due to the velocity which the shell may have at the time it bursts, and which they, as component parts of it, retain. When the shell opens, they continue to travel forward with this velocity, and would move in lines *parallel* to what would have been the trajectory of the shell if it had not burst, were it not for three causes:—

1. The disturbing effect of the bursting charge.
2. The centrifugal force imparted by the rotation of the shell.
3. A loss of velocity, greater than that which the shell in its original condition would have experienced, due to the difference of their form and weight.

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* The following remarks are from the R. A. I. proceedings, by Major S. J. Nicholson, R. H. A.

These causes produce a cone of dispersion.

Cones of Dispersion.

It is evident that since the velocity of rotation remains very much the same, whereas the velocity of translation suffers considerable diminution as the range increases, the cone of dispersion will gradually increase with the range.

The following may be suggested as the probable angles of cones of dispersion at ranges up to 3000 yds. :—

Under 500 yards........	7°	2000 to 2500 yards.....	10°
500 to 1300 "	8°	2500 to 2800 "	11°
1300 to 2000 "	9°	2800 to 3000 "	12°

1. The diameters of the cone of dispersion for different angles will be, speaking roughly, as follows :—

For 8°......................	·14 of the length.
9°......................	·15 "
10°......................	·17 "

The following table may be of use; it represents the fronts covered laterally by various cones at various lengths from the point of burst :—

TABLE A.

Length from Burst in Yards.

	20 YDS.	40 YDS.	60 YDS.	80 YDS.	100 YDS.	120 YDS.	140 YDS.	160 YDS.	180 YDS.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
8°	8·4	16·8	25·2	33·6	42·0	50·4	58·8	67·2	75·6
9°	9·3	18·6	27·9	37·2	46·5	55·8	65·1	74·4	83·7
10°	10·5	21·0	31·5	42·0	52·5	63·0	73·5	84·0	94·5

As a general rule, it would be quite near enough to say that for ordinary ranges the cone of dispersion is from 8° to 9° and the diameter from ·14 to ·15 the length from burst of shell.

Taking one of the angles just mentioned as those due to ordinary ranges—viz., 8°—the following will be the square yards of area in the cone at different lengths of burst:—

TABLE B.

Length of Burst in Yards.

	20 YDS.	40 YDS.	60 YDS.	80 YDS.	100 YDS.	120 YDS.	140 YDS.	160 YDS.	180 YDS.	200 YDS.
	sq. y'rds	sq. y'rds	sq. y'rds	sq. y'rds	sq. y'rds	sq. y'rds	sq. y'rds	sq. y'rds	sq. y'rds	sq. y'rds
8°......	6	24	55	98	154	222	302	394	498	615

When a 9 por. M. L. shrapnel shell is burst at rest, the following is the average result:—

Splinters, effective..........................	22
" non-effective....................	6
Bullets....................................	63
Effective total.................	85

The following will therefore be the number per square foot at the different areas, as above stated:—

TABLE C.

Length of Burst in Yards.

GUNS.	20 YDS.	40 YDS.	60 YDS.	80 YDS.	100 YDS.	120 YDS.	140 YDS.	160 YDS.	180 YDS.	200 YDS.
	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.	per sq. ft.
9 por..	1·6	·4	·17	·1	·06	·043	·03	·024	·02	·015
16 por..	2·5	·62	·26	·15	·1	·07	·05	·04	·03	·024

My manuscript notes, papers, as well as books of reference on this subject having been destroyed by fire, the completion of this subject must be postponed for a second edition.

T. BLAND STRANGE, Lt.-Col., R. A.
I. of A., Canada.

V.

CURVED FIRE.

Although what has already been mentioned, is applicable in a great measure to curved as well as to direct fire, and curved fire has to a certain extent been described and its advantages pointed out, still it may be useful to allude to it specially, and at the same time, to ricochet fire as a variety of curved fire with shot from S. B. guns.

In ricochet fire the gun is laid at the crest of the epaulment of a work with an angle of elevation varying from 5° to 10°, and fired with a reduced charge, in order that the projectile may just clear the parapet and rebound on the other side of it. No more elevation than necessary should be given to the gun, otherwise the projectile would rebound too high or penetrate into the ground, being in both cases more or less ineffective.

A good plan when the exact range is unknown is to commence firing short of the parapet, and increase the elevation till the shot strikes a point as near the crest of the parapet as possible; the least increase of elevation will then attain the object.

This ricochet fire carried on with round shot, has been replaced by what is properly called curved fire with rifled guns.

By curved fire large shells with percussion fuzes may be thrown into works, exploding on graze and causing more damage than the ricochet.

Curved fire has been long ago employed to dislodge troops behind cover by means of common shell from S. B. guns and howitzers, and also in some cases to breach masonry. (*Jones, Sieges of the Peninsula.*)

Experiments carried on in November 1861 in Plumstead marshes by the late Ordnance Select Committee proved conclusively that Armstrong rifled guns could, though fired with greatly reduced charges, so as to have a high angle of descent; still retain a precision of direction and uniformity of range which adapted them, in a greater degree than S. B. guns, for silencing guns covered by parapets or earthworks, and breeching sunken defences and masonry.

Previous experiments carried on at Eastbourne, in August, 1860, with one rifled 80 por., one 7 inch and one 40 por. Armstrong breechloader, against a Martello tower, and a subsequent experiment carried on at Bexhill, in November of the same year, with two 68 pors. and two 32 pors. S. B. guns, also against a Martello tower, had established the fact that the rifled guns had performed half as much work again as the S. B. guns with a greatly diminished expenditure of powder and iron. The results stood as follows:—

	Iron.	Powder.
For rifled guns.....	2,953 lbs.	511 lbs.
For S. B. guns...................	9,684 "	3,729 "

The same practice of breaching revetments, &c., has been carried on since with muzzle-loading rifled guns, with very satisfactory results *

In these days of long range, small arm breach loaders, breaching batteries, have to be opened at considerable distances, and often in such positions that they may be built and armed without observation: the gunners, therefore, labor under the disadvantage of not being able to see the object of fire. The masonry of a fortress being covered by the glacis the shell must be made to lob over the crest of the glacis or protecting counter-guard, and strike the escarp wall sufficiently low for the debris to form a practicable breach, Figs. 6 and 8. This means a curved trajectory, or a considerable angle of descent, necessitating high elevation and low final velocity, combined of necessity, with diminished penetration and accuracy, demanding considerably more skill from the gunners than the old method of direct fire at short range.

For curved fire, the distance of the batteries from the work being known from the map or calculated by range finder, the required angle of descent must be ascertained by construction from the profiles of the fortress, and the amount of the charge that will give such angle found from practice tables or calculated. Some visible part of the work directly above or near the spot of the required breach is selected, and fired at with a given number of rounds, to find the point of mean impact, which is then transferred to the spot intended to breach, calculating the decrease of elevation and the amount of deflection to the right or left. A horizontal cut is first made in the masonry, about one third the height of the wall from the bottom, Figs. 6 and 7.

When this cut is supposed to be effected by a series of shots, vertical cuts upwards are then made from the extremities of the horizontal one, and intermediate cuts made until the wall comes down, (Fig. 8),.but this extreme theoretical accuracy is not obtained in practice, especially when the completion of the first horizontal cut can only be conjectured from certain phenomena, viz.:

1st. The concussion and explosion of a shell has a hard, sharp sound, if it hits solid masonry; on the other hand, it has a hollow and faint sound if it hits masonry either wholly or part broken through; in this latter case the shell exploding in the earth behind the wall.

2nd. Fragments of stone are hurled into the air as long as the masonry resists.

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* The late interesting experiments at Eastbourne with curved fire from rifled guns and howitzers have not yet been published officially.

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Pl. 3

FIG. 7

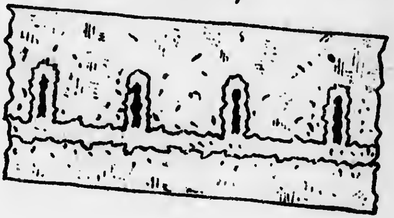
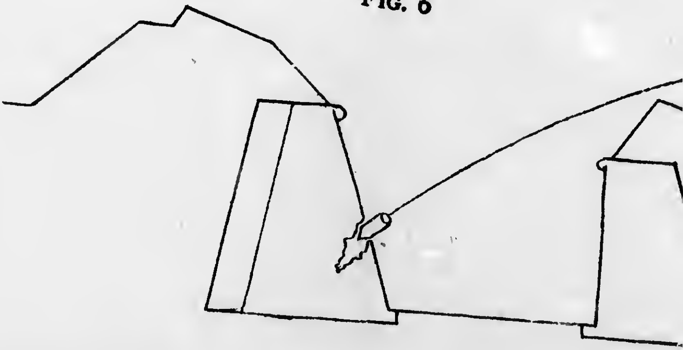
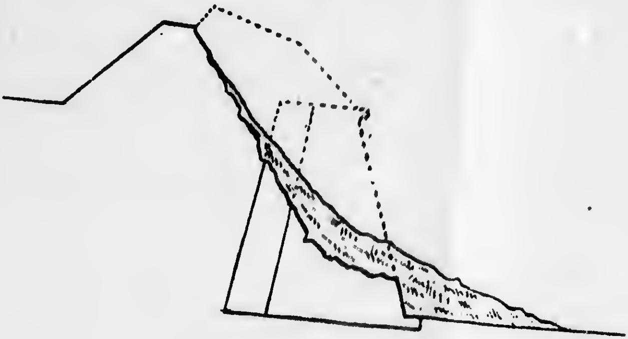


FIG. 6

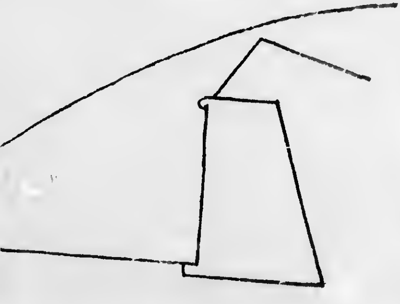


BREACHING BY CURVED FIR

FIG. 8



6



NG BY CURVED FIRE

Pl. 3

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3rd. The smoke from the explosion of the projectile soon rises above the wall, is of a bluish tinge, and forms a "ball" if the masonry remains intact. If the masonry has been broken through the smoke appears after some delay, is of a darkish grey color and rises slowly, as if coming from a chimney pot.

RANGES OF 7" B. L. GUN WITH 90 LBS. SHELL AND REDUCED CHARGES.

DEGREES.	YARDS.	CHARGE.	TIME OF FLIGHT.
10	690	2 lbs. 4 ozs., 1-40th of 90 lbs.	5.2
12	850	" " "	6.3
15	980	" " "	7.4
10	806	2 lbs. 9 ozs, 2 drs., or 1-35th.	5.5
12	915	" " "	6.4
15	1094	" " "	7.8
10	916	3 lbs., or 1-30th of 90 lbs.	5.8
12	1045	" " "	6.9
15	1244	" " "	8.4
10	1070	3 lbs. 9 ozs., 9 drs. or 1-25th.	6.3
12	1270	" " "	7.6
15	1500	" " "	9.2

The charges were made up to the length of powder chamber with cork discs, and had lubricators; these latter were of little use, for though they broke up, the grease was blown out of the gun without lubricating the bore, which got very foul. Wet sponges should be used. Sawdust or wood shavings will answer when cork cannot be got, in this case the gun must be cleaned with a wet sponge or the grooves will clog and ignited sawdust may remain.

VI.

HIGH ANGLE FIRE.

Under this new term as before stated, is comprised fire obtained from guns, mortars and howitzers, at all angles of elevation exceeding 15°, and the old term vertical fire is done away with.

Projectiles are generally fired from mortars elevated at an angle of 45°, though in some instances they have been fired from mortars at a smaller angle as will be seen by range tables given hereafter, at close ranges where penetration is desired, they are fired at higher angles than 45°.

The laying of a mortar so as to ensure a correct direction to the projectile fired from it, is accomplished by means of a plummet which is held in the hand, immediately behind the mortar, and the string of which plummet is made to coincide with two pointing rods placed upon the parapet, and directed upon the object.

The mortar is then traversed till the centre line drawn with chalk on its highest surface coincides with the plummet string.

Sometimes when there is no parapet between the mortar and the object, or the object can be seen above the parapet, the mortar is laid on the object itself, by bringing the object, the line on the mortar and the string of the plummet in the same vertical plane.

Should the bed on which the mortar rests, be level, this line drawn on the surface of the mortar, will be in the same vertical plane as the axis of the mortar, but if the bed inclines to the right or left, this line will no more coincide with the axis. To remedy this another chalk line must be drawn on the highest surface of the mortar, readily found by means of a small level issued for the purpose.

If the platform is in good order and level the mortar may be laid by means of a line chalked on the platform, on each side of the bed, or by a batten of wood nailed to the platform and touching one side of the bed, when the mortar is accurately laid—a very useful expedient in night firing.

The elevation of the mortar being fixed, or generally so, no means are thus afforded of limiting or extending the range, except by reducing or increasing the charge of powder used. A ready rule will hereafter be given to find the quantity of powder necessary for given ranges.

The large mortars, viz., the 13, 10 and 8 inch, are generally used to bombard towns, works, magazines, &c., for this purpose the fuzes of their shell should be bored long, so that they may cause the shells to burst after having penetrated the object to be destroyed, the shells act in those cases as mines at long ranges, mortar shells fall with the velocity due to their own weight, and practically the higher they fall from the more power of penetration they have.

The small natures of mortars, viz: the 5½ inch and 4 2-5 inch are used to fire shell against troops behind cover, the shells should therefore explode the instant they reach the ground, or a little before, for if they burst after having penetrated the ground, their splinters will fly upwards instead of spreading low and on every side; the destructive effect will, therefore, be greatly decreased.

The following is a table of ranges obtained from the small mortars, viz: 5½ and 4 2-5 inch at 15° elevation, it is given as it is not usually found in treatise, &c.

5½ INCH.			4 2-5 INCH.					
AT 15°.			AT 15°.			AT 25°.		
ozs.	drs.		ozs.	drs.		ozs.	drs.	
6	0	350 yards.	4	8	450 yards.	4	0	510 yards.
7	0	400 "	4	12	500 "			
7	8	450 "						
8	0	500 "						

Small coehorn and royal mortars, viz., 5½ and 4 2-5 inch mortars were often attached to field batteries in India, carried four in a cart. They are very useful for attacking fortified villages surrounded with a belt of jungle wood impenetrable to direct or even curved fire. The 7 por. M. L. R. mountain gun, used in Abyssinia, of which there is a battery in Canada, can be used as mortars by taking off the wheels and reversing the gun on its carriage. They fire a double shell with bursting charge equal to that of a 24 por. S. B. common shell.

There are also 8, 10 and 13 inch mortars on travelling beds that have been used in China for field service, but there are none in Canada, and they will probably be superseded by rifled mortars and howitzers.

Rifled mortars (28 inch rifled mortars,) were used by the Germans with effect at the siege of Strasburg in 1870.

M. L. rifled 8" howitzers are now in the service, they give very good results.

S. B. guns have also been employed for high angle firing. At the siege of Gibraltar one 18 por. and five 32 pors. were sunk and secured with timber at an elevation of 42°, in order to fire shells into the Spanish camp and Artillery park.

The following tables shew the results of practice carried with different kinds of ordnance both at curved and high angle fire:—

RANGES OBTAINED FROM RIFLED ORDNANCE WITH REDUCED CHARGES.

NATURE.	CHARGE.	ELEVATION.	RANGE.	NATURE.	CHARGE.	ELEVATION.	RANGE.
7" B. L.	lbs.	° ′	yards.	7" B. L.	lbs.	° ′	yards.
Howtz. (A)	2.00	10 0	370	Howtz. (A)	4.00	10 0	960
"	"	15 0	520	"	"	15 0	1340
"	"	20 0	640	"	"	20 0	1680
"	"	25 0	770	"	"	25 0	1040
"	"	30 0	820	"	"	30 0	2190
"	"	35 0	850	"	"	35 0	2400
"	3.00	10 0	610	"	5·00	10 0	1230
"	"	15 0	930	"	"	15 0	1880
"	"	20 0	1130	"	"	20 0	2320
"	"	25 0	1330	"	"	25 0	2600
"	"	30 0	1540	"	"	30 0	2850
"	"	35 0	1650	"	"	35 0	3160
	ozs.				ozs.		
7" gun.....	10	3.24	1060	7" gun	6	5.55	1060
"	9	3.32	1060	"	2.88	15.15	1060

…ded with
… fire:—

…E WITH

RANGE.
yards.
960
1340
1680
1040
2190
2400
1240
1880
2320
2600
2850
3160
1060
1060

RANGES OBTAINED FROM SMOOTH-BORED GUNS WITH REDUCED CHARGES.

GUN.	WEIGHT	ELEVATION.	RANGES.				
	cwt.		400 yards.	500 yards.	600 yards.	700 yards.	800 yards.
10"	86	15°	15 ozs.	19 ozs.	22 ozs.	25 ozs.	28 ozs.
		Time....	4¾"	5¼"		6¼"	6¾"
"		10°	20 ozs.	24 ozs.	28 ozs.	32 ozs.	36 ozs.
		Time....	4"	4½"	[illegible]	5¼"	6"
8"	65	10°	14 ozs.	18 ozs.	22 ozs.	25 ozs.	28 ozs.
		Time....	4"	4½"	5"	5½"	6"
32 por...	58	10°	7 ozs.	8½ ozs.	10 ozs.	12 ozs.	14 ozs.
		Time....	4"	4½"	5"	5½"	6"

THE FOLLOWING TABLE OF RICOCHET PRACTICE, SHEWS
FECT, AT DIFFERENT RANGES, WITH GUNS AND
PRACTICE CARRIED ON AT WOOLWICH BETWEEN THE

NATURE.	RANGE.	CHARGE.		PROPORTION THE CHARGE BORE TO THE SHOT.	ELEVATION BY QUADRANT DEGREES	NUMBER OF ROUNDS FIRED.	NUMBER OF SHOTS THAT TOOK EFFECT.	GRAZES MADE ALONG THE FACE OF THE WORK.	OF ROUNDS FIRED PROPORTION THAT TOOK EFFECT.	NUMBER OF TIMES TRAVERSES WERE STRUCK.	REMARKS.
	yds	lbs	oz								
24 Por. Iron 9 ft.	400	0	8	48	11	15	10	13	⅔	....	Work without traverses.
		0	10	38½	7¾	15	9	10	⅔ nearly	....	
		0	12	32	6¼	30	18	26	⅔	....	
	600	0	12	32	9½	30	15	19	½	....	
		1	0	24	6½	30	17	19	½ nearly	....	
		1	4	19	4¾	10	6	7	½	....	
	800	1	0	24	8½	30	10	11	⅓	....	
		1	4	19	6½	30	10	10	⅓	....	
		1	8	16	5½	15	9	11	⅔ nearly	....	
		2	0	12	3¾	15	6	8	2-5	....	
	600	0	12	32	9½	20	7	5	....	3	Work trave'ed.
		1	0	24	6½	30	11	7	....	6	
18 Por. Iron 8 ft	400	0	9	32	6½	30	23	27	⅔ nearly	....	Work without traverses.
	600	0	12	24	7¼	30	8	11	¼	....	
		1	0	18	5	30	10	13	½	....	
	800	1	0	18	7	30	10	10	⅓	....	
		1	8	12	4¼	30	12	13	⅓ nearly	....	
	600	0	12	24	7¼	30	9	8	....	5	Work trave'ed.
		1	0	18	5	30	13	9	....	9	
12 Por. Iron 8⅛ ft	400	0	6	32	6½	30	16	19	½ nearly	....	Work without traverses.
		0	8	21	4½	30	20	21	⅔	....	
	600	0	8	21	7¾	30	11	12	½ nearly	....	
		0	10	19	6	30	12	15	⅓	....	
		0	12	16	4¾	5	2	2	2-5	....	
	800	0	12	16	6½	30	7	10	¼ nearly	....	
		1	0	12	4½	30	15	16	½	....	
	600		8	24	7¾	15	7	3	....	6	Work trave'ed.
			10	19	6	15	6	2	....	5	

THE CHARGE, ELEVATION, TIME OF FLIGHT, AND EFFECT OF HOWITZERS, COLLECTED FROM A SERIES OF RICOCHET 14TH JUNE AND THE 2ND OCT. 1821, WITH ROUND SHOT.

Nature.	Range.	Charge.		Proportion the charge bore to the shot.	Elevation by quadrant degrees.	Number of rounds fired.	Number of shots that took effect.	Grazes made along the face of the work.	Of rounds fired, proportion that took effect.	Number of times traverses were struck.	Remarks.
	yds	lbs	oz								
9 Por. Field Service Bronze.	600	0	5	28	9½	10		2	....	....	Work without traverses.
	....	0	6	24	7½	10	1	1	....	....	
	....	0	7	20	6½	10	3	3	....	....	
68 Por. Car'nade	600	2	0	34	6¼	10	4	5	....	...	
24 Por. Howtz'r	600		12	32	6½	25	15	16	....	....	Work without traverses.
	....	1	0	24	4¾	10	2	2	....	....	
12 Por. do.	600		10	19	5¾	10	3	3	....	....	

Recent experiments shew that the above table is sufficiently accurate for all practical purposes.

ROUGH RULES FOR GUNNERS.

Ordinary S. B. Guns.

Charge.—Up to 42 pr. ⅓ weight of shot.
56 and 68 por. ¼ " "

Range.—P. B. { field guns, 300 yards.
garrison guns, 400 yards.
Every ¼° up to 1° gives 100 yards range.
Beyond 1° " 2° " 90 "
" 2° " 3° " 80 "
" 3° " 5° " 75 " nearly.

Fuze.—Substract 5 from range in hundreds for common shell, and 6 for shrapnel shell.

Bursting Charge for Shrapnel Shell.—Multiply highest calibre (8") by 10 for charge in drs. Reduce by 10 for each calibre. 68 por. or 8" = 80 drs. 56 por. = 70. 42 por. = 60. 32 por. = 50. 24 por. = 40. 18 por. = 30.

Iron Mortars

Charge.—4½ times the hundreds of yards in range plus 10 = charge in ounces for the 13 inch.
For 10" ½ the above.
" 8" ⅓ "

Fuze.—Add 17 to the number of hundreds of yards in range for tenths of fuze.

Tackles.

Power.—The number of returns from the movable block gives the power gained.

Combinations.—When one tackle is put on to the running end of another, multiply the powers together for the result; but friction very much diminishes the gain.

Rope for Blocks.—Length of block, divided by 3, gives size of rope to fit.

Rifled Guns.

B. L.—Charge, ⅛ weight of projectile.

Range 7-inch.—500 yards = 58'
From 500 to 1000 yards 15' for every 100 yards
" 1000 to 1500 " 17' " "
" 1500 upwards, 20' " "

Range by Depression.—For high coast batteries. Height of battery in feet, multiplied by 1150, divided by angle of depression in minutes, gives range in yards.

Deflexion.—Error in inches, divided by hundreds of yards in range, gives deflexion in minutes.

One Wheel High—Shot tends towards lowest wheel. Difference of level in inches, multiplied by degrees of elevation, gives required deflexion towards highest wheel, in minutes.

Garrison B. L. & M. L. Fuze, (*9 and 20 Sec.*)—⅔ range in hundreds gives length of fuze in tenths for common shell; or every 150 yards, require 1-10 fuze. For shrapnel, ½ range in hundreds.

Length of 1°.—To make a tangent scale for any gun, length between sights in inches, divided by 57 (year of Indian Mutiny), gives length of one degree in inches.

Rope Strength.—Square of circumference in inches, divided by 6, gives breaking strain in tons (nearly).

Weight.—Square of circumference, divided by 4, gives weight in lbs. per fathom.

Displacement.—One gallon of water weighs 10 lbs.

RANGE TABLES FOR ORDNANCE IN CHARGE OF CANADIAN MILITIA.

9 Por. M. L. R. Rifled Field Guns.--Charge 1 lb. 12 oz.

RANGE.	ELEVATION		TENTHS OF FUZE.	RANGE.	ELEVATION		TENTHS OF FUZE.
yards.	deg.	min.		yards.	deg.	min.	
100	0	0	0	1900	4	18	11·5
200	0	6	1	2000	4	40	12
300	0	14	1·5	2100	5	2	13
400	0	26	2	2200	5	24	14
500	0	39	2·5	2300	5	47	15
600	0	52	3	2400	6	10	16
700	1	5	3·5	2500	6	34	16·5
800	1	18	4	2600	6	59	17
900	1	31	4·5	2700	7	25	18
1000	1	44	5	2800	7	52	19
1100	1	57	6	2900	8	20	20
1200	2	12	6·5	3000	8	48	
1300	2	28	7	3100	9	18	
1400	2	45	8	3200	9	49	
1500	3	2	8·5	3300	10	21	
1600	3	20	9·5	3400	10	53	
1700	3	38	10	3500	11	27	
1800	3	58	11				

RANGE TABLES.—(*Continued.*)

7 Por. M. L. R. Field and Mountain Guns, (Bronze.)

Charge, 10 oz. Weight 224 lbs.

RANGE.	ELEVATION.		TIME.
yards.	deg.	min.	seconds.
200	0	55	1·1
300	1	24	1·6
400	1	55	2·1
500	2	27	2·6
600	3	1	3·2
700	3	36	3·7
800	4	13	4·2
900	4	51	4·7
1000	5	32	5·3
1100	6	14	5·8
1200	6	58	6·3
1300	7	46	6·8
1400	8	32	7·4
1500	9	22	7·9
1600	10	11	8·4
1700	11	8	9·0
1800	12	5	9·7
1900	13	4	10·3
2000	14	5	11·0
2200	16	15	12·3
2400	18	35	13·6
2600	21	6	14·8

RANGE TABLE FOR RIFLED FIELD GUNS.

6 por. Armstrong, B. L. R.

DISTANCE OF OBJECT.	ELEVATION.		TIME OF FLIGHT.	LENGTH OF FUZE. E time
Yds.	deg.	m.	sec.	inches.
200		9	·58	·27
300		20	·86	·40
400		34	1·22	·56
500		55	1·56	·76
600	1	15	1·92	·92
700	1	35	2·30	1·06
800	1	55	2·65	1·21
900	2	16	3·00	1·38
1000	2	37	3·36	1·54
1100	3		3·73	1·71
1200	3	22	4·10	1·90
1300	3	44	4·47	2·05
1400	4	6	4·83	2·21
1500	4	29	5·20	2·39
1600	4	53	5·60	2·57
1700	5	19	6·00	2·75
1800	5	45	6·40	2·91
1900	6	10	6·78	3·11
2000	6	35	7·20	3·30
2100	7		7·60	3·49
2200	7	26	8·02	3·67
2300	7	52	8·46	3·84
2400	8	16	8·90	4·08
2500	8	41	9·32	
2600	9	6	9·80	
2700	9	33	10·30	
2800	9	59	10·78	
2900	10	26	11·28	
3000	10	53	11·80	

Length of bore, 4' 5".
Total length, 5' 0·1".
Calibre, 2·5".
Weight, 3 cwt.
Charge, 12 ozs.
No. of grooves, 32.
Twist of rifling, 1 turn in 30 calibres.

E time fuze (only issued for sea service,) burns at the rate of 1" in 2 18 seconds.

The time of flight can be obtained approximately by dividing the number of hundreds of yards range by 3; and the length of fuze (E time) by dividing the number of hundreds of yards range by 6.

Rough Rule for Elevation.

500 yards, 55'.

500 to 1000 yards add 20' for each hundred yards.
1000 to 1500 yds., add 22' for each 100 yds.
1500 to 2000 " " 25' " "

Example by above rule :—
500 yards, 55'.
1000 yards, 55' + 100' = 2° 35'.
1500 yards, 2° 35' + 1° 50' = 4° 25'.
2000 yards, 4° 25' + 2° 5' = 6° 30".

RANGE TABLES.—(*Continued.*)

6 Por. S. B. Bronze Field Gun.—Charge, 1 lb. 8 ozs.—Weight, 6 cwt.

SOLID SHOT.		SPHERICAL CASE.				COM. CASE.	
ELEVATION.	RANGE.	LETTER ON FUZE AND LENGTH.	ELEVATION.	RANGE.		ELEVATION.	RANGE.
				FROM	TO		
deg.	yards.	In Tenths.	deg.	yards.	yards.	deg.	yards.
P. B.	250		1	380	640	P. B.	100
1/4	300	B 2	1 1/4	570	800	1/4	125
1/2	400	C 3	1 5/8	720	930	1/2	150
3/4	500	D 4	2 1/4	845	1045	3/4	175
1	600	E 5	2 7/8	955	1145	1	200
1 1/4	650	·6	3 3/8	1060	1210	1 1/4	225
1 1/2	700	·7	4	1160	1330	1 1/2	250
1 3/4	750	·8	4 5/8	1255	1415	1 3/4	275
2	800	·9	5 1/4	1345	1500	2	300
2 1/4	850	1·0	5 7/8	1430	1580		
2 1/2	900	1·1	6 3/8	1510	1655		
2 3/4	950	1·2	7 1/4	1585	1725		
3	1000	1·3	7 5/8	1655	1785		
3 1/4	1050	1·4	8 1/4	1720	1840		
3 1/2	1100	1·5	8 7/8	1780	1890		
3 3/4	1150	1·6	9 3/8	1835	1940		
4	1200	1·7	10 1/4	1885	1980		
4 1/4	1250	1·8	11	1953	2020		
4 1/2	1300	1·9	11 5/8	1980	2055		
4 3/4	1350	2·0	12 3/8	2025	2090		
5	1400						

RANGE TABLES.—(*Continued.*)

9 Por. S. B. Field Guns (Bronze.)—Charge 3 lbs.—Weight, 13½ cwt.

SOLID SHOT.		SPHERICAL CASE.				COM. CASE.		RICOCHET.		
ELEVATION.	RANGE.	LETTER ON FUZE AND LENGTH.	ELEVATION.	RANGE.		ELEVATION.	RANGE.	CHARGE.	ELEVATION.	RANGE.
				FROM	TO					
Deg.	yds.	In 10ths.	deg.	yds.	yds.	deg	yds.	ozs	deg	yds.
P. B.	300	B 2	1¾	640	920	P. B.	150	7	5	500
¼	400	C 3	1⅞	800	1060	¼	175	6	6¾	500
½	500	D 4	2¼	930	1180	½	200	5	6¾	500
¾	600	E 5	2¾	1050	1290	¾	225	7	6½	600
1	700	·6	3¼	1160	1390	1	250	6	7½	600
1¼	775	·7	3¾	1260	1480	1¼	275	5	9½	600
1½	850	·8	4⅜	1360	1570	1½	300			
1¾	925	·9	5⅛	1455	1655					
2	1000	1·0	5¾	1550	1740					
2¼	1050	1·1	6⅜	1640	1820					
2½	1100	1·2	7	1725	1895					
2¾	1150	1·3	7⅝	1805	1965					
3	1200	1·4	8¼	1885	2035					
		1·5	8⅜	1960	2100					
		1·6	9⅜	2030	2160					
		1·7	10	2095	2215					
		1·8	10¾	2165	2275					

RANGE TABLES.—(*Continued.*)

12 Por. S. B. Field Guns (Bronze.)—Charge, 4 lbs.—Weight, 18 cwt.

SOLID SHOT.		SHRAPNEL SHELL.				COM. CASE.		RICOCHET.		
				RANGE.						
ELEVATION.	RANGE.	LENGTH OF FUZE.	ELEVATION.	FROM	TO	ELEVATION.	RANGE.	CHARGE.	ELEVATION.	RANGE.
Deg.	yds.	In 10ths.	deg.	yds.	yds.	deg.	yds.	ozs	deg	yds.
P. B.	300	·2	1⅜	660	960	P. B.	150			400
¼	400	·3	1⅞	820	1110	¼	175			400
½	500	·4	2¼	960	1230	½	200	6	6½	500
¾	600	·5	2¾	1080	1340	¾	220	5	7	500
1	700	·6	3¼	1195	1445	1	250			600
1¼	775	·7	3¾	1305	1545	1¼	275			600
1½	850	·8	4⅜	1415	1645	1½	300			
1¾	925	·9	5⅛	1520	1740					
2	1000	1·0	5¾	1620	1830					
2¼	1050	1·1	6⅛	1720	1920					
2½	1100	1·2	7	1815	2005					
2¾	1150	1·3	7⅝	1905	2085					
3	1200	1·4	8¼	1990	2160					
		1·5	8⅞	2070	2230					
		1·6	9⅜	2140	2290					
		1·7		2200	2340					

RANGE TABLES.—(*Continued.*)

24 Por. S. B. Bronze Howitzer.—Charge, 2½ lbs.—Weight, 12½ cwt.

Common Shell.			Shrapn'l Shell			Com. Case.		Ricochet.		
Fuze.	Elevation.	Range.	Fuze.	Elevation.	Range.	Elevatio	Range.	Charge.	Elevation.	Range.
in.	deg.	yds.	in.	deg.	yds.	deg.	yds.	ozs.	deg.	yds.
	P. B.	250	1	1	450	B.	150	6	7½	400
	¼	300	1½	1¼	500	¼	175	9	4¾	"
	½	350	2	1½	550	½	200	8	9	500
	¾	400	2½	1¾	600	¾	225	10	7½	"
1	1	450	3	2	650	1	250	11	6	"
1½	1¼	500	3½	2¼	700	1¼	275	11½	5½	"
2	1½	550	4	2½	750	1½	300	12	5¼	"
2½	1¾	600	4½	2¾	800	1¾	325	14	5	"
3	2	650	5	3	850	2	350	9	7¾	600
3½	2¼	700	5½	3¼	900	2¼	375	12	6½	"
4	2½	750	6	3½	950	2½	400	1 lb	4¾	"
4½	2¾	800	6½	3¾	1000					
5	3	850	7	4	1050					
5½	3¼	900	7½	4¼	1100					
6	3½	950	8	4½	1125					
6½	3¾	1000	8½	4¾	1150					
7	4	1025	9	5	1175					
			9½	5¼	1200					

10 Inch Howitzer.

Weight	Charge	Elevations.									
		P. B.	1	2	3°	4°	5°	6°	7°	8°	9°
42	7	300 ·2	500 ·3	700 ·5	900 ·7	1100 ·8	1300 ·9	1400 1·	1600 1·3	1800 1·6	

8 Inch Howitzer.

Weight	Charge	P. B.	1	2	3°	4°	5°	6°	7°	8°	9°
22	4		300 ·2	600 ·5	700 ·6	900 ·8	1100 1·	1300 1·3	1500 1·7		

RANGE TABLES.—(*Continued.*)

18 Por. Garrison S. B. Gun.—38 or 42 Cwts.

Charge, 6 lbs.

RANGE.	SHOT AND SHRAPNEL SHELL.		COMMON SHELL.	
	ELEVATION.	FUZE.	ELEVATION.	FUZE.
Yards.	Deg.	Inches.	Deg.	Inches.
300				
400	P. B.		P. B.	
500	¼		¼	·2
600	½		½	·2
700	¾		¾	·3
800	1	.2	1	·3
900	1¼	.3	1¼	·4
1000	1½	.4	1½	·5
1100	1¾	.5	1¾	·6
1200	2	.6	2	·7
1300	2⅜	.7	2⅜	·7
1400	2¾	.8	2¾	·8
1500	3	.9	3	·9
1600	3½	1.0	3½	1·0
1700	4	1.1	4	1·1
1800	4½	1.2	4½	1·2
1900	5	1.3	5	1·3
2000	5½	1.4	6	1·5
2100	6	1.5	7	1·7
2200	6½	1.6		1·9
2300	7	1.7		2·0
2400	8	1.8		
2500	9	1.9		
2600	10	2.0		

RANGE TABLES.—(*Continued.*)

24 Por. Garrison S. B. Gun.—50 and 48 Cwt.

Charge, 8 lbs.

RANGE.	SHOT AND SHRAPNEL SHELL.		COMMON SHELL.	
	ELEVATION.	FUZE.	ELEVATION.	FUZE.
yards.	Deg.	Inches.	Deg.	Inches.
300				
400	P. B.		P. B.	
500	¼		⅛	
600	½		¼	
700	¾		½	
800	1	·2	¾	
900	1¼	·3	1	·2
1000	1¾	·4	1½	·3
1100	2	·5	2	·4
1200	2¼	·6	2½	·5
1300	2½	·7	2¾	·6
1400	2¾	·8	3	·8
1500	8	·9	3½	·9
1600	3½	1·0	4	1·0
1700	4		4½	1.1
1800	4½		5	1·2
1900	5		6	1·3
2000	6		7	1·4
2100	7		8	1·6
2200	8		9	1·8
2300	9		10	2·0
2400	10			

RANGE TABLES.—(*Continued.*)

32 Por. Garrison S. B. Gun.—56 Cwt.

Charge. 10 lbs.

RANGE.	SHOT AND SHRAPNEL SHELL.		COMMON SHELL.	
	ELEVATION.	FUZE.	ELEVATION.	FUZE.
Yards.	Deg.	Inches.	Deg.	Inches.
300				
400	P. B.		P. B.	·2
500	3/8	·2	1/4	·2
600	3/4	·2	1/2	·3
700	1	·3	3/4	·3
800	1 1/4	·3	1	·4
900	1 1/2	·4	1 1/4	·4
1000	1 3/4	·4	1 1/2	·5
1100	2	·5	1 3/4	·6
1200	2 3/8	·6	2	·7
1300	2 3/4	·7	2 3/8	·8
1400	3	·8	2 3/4	·9
1500	3 3/8	·9	3	1·0
1600	3 3/4	1·0	3 1/2	1·1
1700	4		4	1·2
1800	4 3/8		4 1/2	1·3
1900	4 3/4		5	1·4
2000	5		5 1/2	1·5
2100	5 3/8		6	1·5
2200	5 3/4		6 1/2	1·6
2300	6		7	1·7
2400	6 1/2		7 1/2	1·8
2500	7		8	1·8
2600	7 1/2		8 1/2	1·9
2700	8		9	1·9
2800	8 1/2		10	2·0
2900	9			
3000	10			

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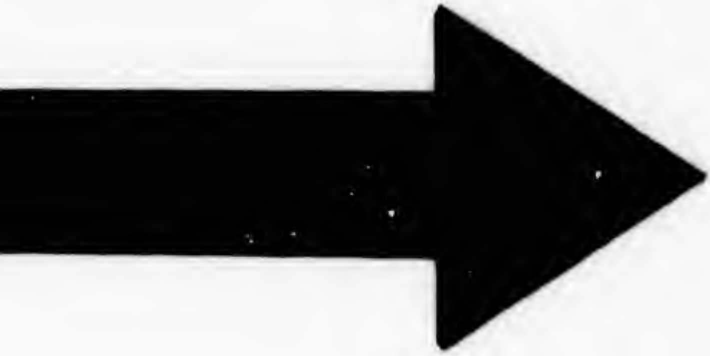

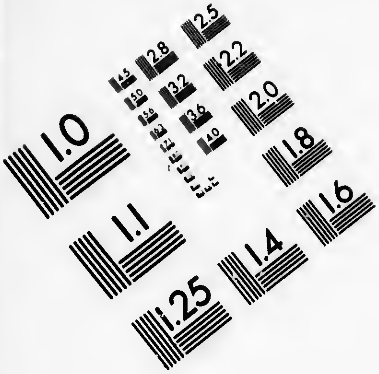

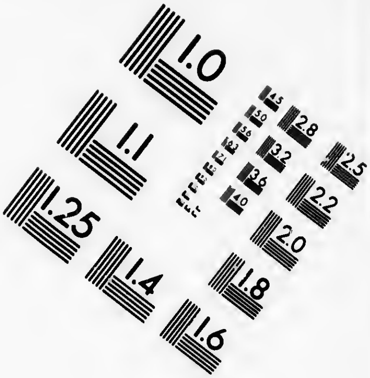

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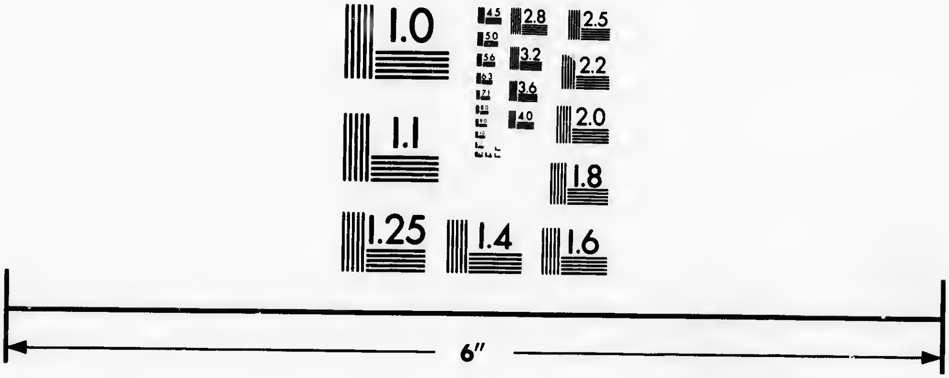

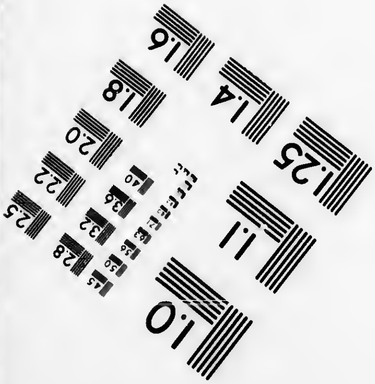

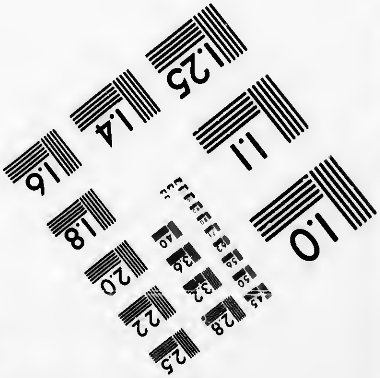

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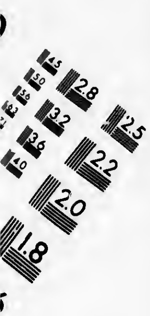
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3.6
4.0
2.2
2.0
1.8


1.1
1.0

RANGE TABLES.—(*Continued.*)

42 Por. Garrison S. B. Gun.—67 Cwt.

Charge, 10½ lbs.

RANGE.	SHOT AND SHRAPNEL SHELL.		COMMON SHELL.	
	ELEVATION.	FUZE.	ELEVATION.	FUZE.
Yards.	Deg.	Inches.	Deg.	Inches.
300				
400	P. B.			
500	⅛			
600	¼	·2	¼	·2
700	½	·2	¼	·3
800	¾	·3	½	·3
900	1	·3	¾	·4
1000	1⅜	·4	1	·4
1100	1¾	·4	1⅜	·5
1200	2	·5	1¾	·6
1300	2⅜	·6	2	·6
1400	2¾	·7	2½	·7
1500	3	·8	3	·8
1600	3⅜	·9	3½	·9
1700	3¾	1·0	4	1·0
1800	4		4½	1·1
1900	4½		5	1·2
2000	5		5½	1·3
2100	5½		6	1·4
2200	6		6½	1·5
2300	6½		7	1·6
2400	7		7½	1·7
2500	7½		8	1·8
2600	8		9	1·9
2700	9		10	2·0

IELL.
FUZE.
Inches.
·2
·3
·3
·4
·4
·5
·6
·6
·7
·8
·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6
1·7
1·8
1·9
2·0

RANGE TABLES.—(*Continued.*)

56 Por. Garrison S. B. Gun.--98 and 87 cwt.

RANGE.	SHOT AND SHRAPNEL SHELL, 14 LBS.		COMMON SHELB. 10 LBS.	
	ELEVATION.	FUZE.	ELEVATION.	FUZE.
Yards.	Deg.	Inches.	Deg.	Inches.
300			P. B.	·2
400	P. B.		1/4	·3
500	1/4		1/2	·4
600	1/2	·2	3/4	·4
700	3/4	·2	1	·5
800	1	·3	1 1/4	·5
900	1 1/4	·3	1 1/2	·6
1000	1 1/2	·4	1 3/4	·6
1100	1 3/4	·5	2	·7
1200	2	·6	2 3/8	·7
1300	2 1/4	·6	2 3/4	·8
1400	2 1/2	·7	3	·8
1500	2 3/4	·8	3 3/8	·9
1600	3	·9	3 3/4	1·0
1700	3 3/8	·9	4	1·1
1800	3 3/4	1·0	4 3/8	1·2
1900	4		4 3/4	1·3
2000	4 1/2		5	1 4
2100	5		6	1·5
2200	5 1/2		6 3/8	1·6
2300	6		6 3/4	1·7
2400			7 1/4	1·8
2500	6 1/2		8 1/4	1·9
2600	7		8 3/4	2.0
2700	8		9 3/8	
2800	9		10	

RANGE TABLES.—(*Continued.*)

8 Inch Garrison S. B. Gun.—65 Cwt.

Charge, 10 lbs.

RANGE.	HOLLOW SHOT AND SHRAPNEL SHELL		COMMON SHELL.	
	ELEVATION.	FUZE.	ELEVATION.	FUZE.
Yards.	Deg.	Inches.	Deg.	Inches.
300	½		¼	
400	¾		½	·2
500	1	·2	¾	·2
600	1¼	·3	1	·3
700	1½	·3	1¼	·3
800	1¾	·4	1½	·4
900	2	·5	1¾	·5
1000	2¼	·6	2	·6
11	2½	·7	2⅜	·7
120	2¾	·7	2¾	·8
1300	3	·8	3	·9
1400	3⅜	·8	3½	1·0
1500	3¾	·6	4	1·1
1600	4	1·0	4½	1·2
1700	4⅜	1·0	5	1·3
1800	4¾		5½	1·4
1900	5		6	1·5
2000	5½		6½	1·6
2100	5		7	1·7
2200	6½		8	1·8
2300	7		9	1·9
2400	8		10	2·0
2500	9			
2600	10			

RANGE TABLES.—(*Continued.*)

68 Por. Garrison S. B. Guns.—95 Cwt.

Charge, 16 lbs.

RANGE.	SHOT AND SHRAPNEL SHELL.		COMMON SHELL.	
	ELEVATION.	FUZE.	ELEVATION.	FUZE.
Yards.	Deg.	Inches.	Deg.	Inches.
300				
400				
500	P. B.		P. B.	
600	¼		⅛	
700	½		⅜	
800	¾		¾	
900	1	·2	⅞	
1000	1¼	·3	1	·2
1100	1½	·4	1¼	·3
1200	1¾	·5	1½	·4
1300	2	·6	1¾	·5
1400	2¼	·7	2	·6
1500	2¾	·8	2¼	·7
1600	3	·9	2¾	·8
1700	3¼	1·0	3	1·0
1800	3¾		3¼	1·0
1900	4		3½	1·1
2000	4¼		4	1·2
2100	4¾		4½	1·3
2200	5		5	1·4
2300	5½		5½	1·5
2400	6		6	1·6
2500	6½		6½	1·7
2600	7		7	1·8
2700	7½		7½	1·9
2800	8		8	2·0
2900	8½		8½	
3000	9		9	

RANGE TABLES.—(*Continued.*)

64 Por. Garrison R. M. L. Converted Guns of 58 Cwt.—Charge, 8 Lbs., R. L. G. Powder.—Projectile, Common Shell.

Mean Elevation due to each 100 yards of Range by Interpolation.

DISTANCE OF OBJECT.	ELEVATION.		TIME OF FLIGHT.	LENGTH OF FUZE.	DISTANCE OF OBJECT.	ELEVATION.		TIME OF FLIGHT.	LENGTHS OF FUZE.
Yds.	deg.	m.	sec.	inches.	Yds.	deg.	m.	sec.	inches.
100		10	·25	·05	2100	4	48	6·16	1·40
200		21	·50	·10	2200	5	6	6·51	1·50
300		32	·75	·15	2300	5	25	6·87	1·60
400		43	1·02	.25	2400	5	44	7·23	1·65
500		55	1·29	·30	2500	6	4	7·59	1·75
600	1	7	1·57	·35	2600	6	24	7·96	1·[illegible]
700	1	19	1·86	·45	2700	6	45	8·32	1·90
800	1	32	2·15	·50	2800	7	6	8·70	2·00
900	1	45	2·42	·55	2900	7	28	9·09	
1000	1	58	2·72	·60	3000	7	50	9·47	
1100	2	12	2·99	·70	3100	8	13	9·87	
1200	2	26	3·29	·75	3200	8	36	10·27	
1300	2	40	3·58	·80	3300	9		10·68	
1400	2	55	3·89	·90	3400	9	24	11·09	
1500	3	10	4·20	·95	3500	9	49	11·51	
1600	3	25	4·51	1·05	3600	10	14	11·93	
1700	3	41	4·81	1·10	3700				
1800	3	57	5·15	1·20	3800				
1900	4	14	5·48	1·25	3900				
2000	4	31	5·82	1·35	4000				

-Charge, 8
ell.

rpolation.

LENGTHS OF FUZE.
inches.
1·40
1·50
1·60
1·65
1·75
1·
1·50
2·00

RANGE TABLES.—(*Continued.*)

7 Inch Wrought-iron Garrison Rifled B. L. Guns of 82 Cwt.—Charge, 11 Lbs.—Common Shell, 90 Lbs.

Mean Elevation due to each 100 yards of Range by Interpolation.

DISTANCE OF OBJECT.	ELEVATION.	TIME OF FLIGHT.	LENGTHS OF FUZE.	DISTANCE OF OBJECT.	ELEVATION.	TIME OF FLIGHT.	LENGTHS OF FUZE.
Yds.	deg. m.	sec.	inches.	Yds.	deg. m.	sec.	inches.
100	9	·26	·05	2100	5 27	6·62	1·35
200	21	·56	·10	2200	5 47	6·97	1·40
300	33	·86	·15	2300	6 7	7·30	1·50
400	45	1·16	·20	2400	6 27	7·65	1·55
500	58	1·46	·30	2500	6 47	7·97	1·65
600	1 11	1·77	·35	2600	7 7	8·31	1·70
700	1 25	2.08	·45	2700	7 27	8·65	1·75
800	1 40	2·39	·50	2800	7 47	9·00	1·85
900	1 55	2·71	·55	2900	8 7	9·36	1·90
1000	2 10	3·03	·60	3000	8 27	9·71	2·00
1100	2 26	3·34	·70	3100	8 47	10·06	
1200	2 43	3·66	·75	3200	9 7	10·42	
1300	3	4·00	·80	3300	9 27	10·80	
1400	3 17	4·30	·90	3400	9 47	11·17	
1500	3 34	4·61	·95	3500	10 7	11·63	
1600	3 52	4·95	1·00	3600	10 27	12·00	
1700	4 11	5·29	1·10	3700			
1800	4 30	5·61	1·15	3800			
1900	4 49	5·95	1·20	3900			
2000	5 8	6·29	1 30	4000			

RANGE TABLES.—(*Continued.*)

40 Por. B. L. Gun.—Charge, 5 Lbs.—Projectile, Common Shell.

Mean Elevation due to each 100 yards of Range.

DISTANCE OF OBJECT.	ELFVATION.	TIME OF FLIGHT.	LENGTHS OF FUZE.	DISTANCE OF OBJECT.	ELEVATION.	TIME OF FLIGHT.	LENGTHS OF FUZE.
Yds.	deg. m.	sec.	inches.	Yds.	deg. m.	sec.	inches.
100	10	·35	·05	2100	5 27	6·60	1·35
200	21	·65	·10	2200	5 45	7·00	1·40
300	33	·95	·15	2300	6 4	7·35	1·45
400	45	1·25	·20	2400	6 24	7·70	1·55
500	58	1·55	·25	2500	6 44	8·05	1·60
600	1 12	1·85	·35	2600	7 5	8·45	1·70
700	1 27	2·15	·40	2700	7 27	8·80	1·75
800	1 42	2·45	·50	2800	7 49	9·20	1·85
900	1 57	2·75	·55	2900	8 12	9·60	1·90
1000	2 13	3·05	·60	3000	8 35	10·00	2·00
1100	2 29	3·35	·65	3100	8 58	10·40	2·10
1200	2 46	3·70	·75	3200	9 22	10·80	2·20
1300	3 8	4·00	·80	3300	9 46	11·25	2·25
1400	3 21	4·30	·85	3400	10 10	11·65	2·30
1500	3 39	4·65	·95	3500	10 35	12·05	2·40
1600	3 57	4·95	1·00	3600	11	12·45	2·50
1700	4 15	5·30	1·05	3700	11 25	12·90	2·60
1800	4 33	5·60	1·10	3800	11 50	13·35	2·70
1900	4 51	5·95	1·20	3900	12 16	13·80	2·75
2000	5 9	6·30	1·25	4000	12 42	14·25	2·85

n Shell.

LENGTHS OF FUZE.
Inches.
1·35
1·40
1·45
1·55
1·60
1·70
1·75
1·85
1·90
2·00
2·10
2·20
2·25
2·30
2·40
2·50
2·60
2·70
2·75
2·85

RANGE TABLES.—(*Continued.*)

Mortars, 45 Degrees.

RANGE.	13 INCH.			10 INCH.			8 INCH.			
	CHARGE.		FUZE.	CHARGE.		FUZE.	CHARGE.			FUZE.
Yards.	Lbs.	ozs.	Inch.	Lbs.	ozs.	Inch.	Lbs.	oz.	dr.	Inch.
200										
250										
300										
350										
400	1	12	1·8	0	15	1·8	0	9	8	1·8
450	1	15	1·9	1	0	1·9	0	9	12	1·9
500	2	1	2·0	1	2	2·0	0	10	12	2·0
550	2	3	2·1	1	3	2·1	0	12	8	2·1
600	2	5	2·2	1	4½	2·2	0	13	12	2·1
650	2	7	2·3	1	6	2·3	0	14	10	2·3
700	2	9	2·4	1	7½	2·4	0	15	4	2·4
750	2	11½	2·45	1	8½	2·45	0	15	4	2·45
800	2	13½	2·5	1	10	2·5	1	0	10	2·5
850	3	0	2·55	1	11	2·55	1	1	4	2·55
900	3	2	2·6	1	12	2·6	1	2	0	2·6
950	3	4	2·65	1	13	2·65	1	2	12	2·65
1000	3	7	2·7	1	14	2·7	1	3	8	2·7
1050	3	9	2·75	2	0	2·75	1	4	0	2·75
1100	3	11	2·8	2	1½	2·8	1	4	12	2·8
1150	3	14	2·85	2	2½	2·85	1	5	4	2·85
1200	4	0	2·9	2	4½	2·9	1	6	0	2·9
1300	4	5	3·0	2	6½	3·0				
1500	4	11	3·2	3	0	3·2				
1700	5	10	3·4	3	4	3·4				
2000							2	0	0	
2400				4	0					
2900	9	0								

RANGE TABLES.—(*Continued.*)

Mortars at 45 degrees.

RANGE.	5½ INCH BRASS.			4 2-5 INCH BRASS.		
	CHARGE,		FUZE.	CHARGE.		FUZE.
Yards.	Ozs.	drs.	Inch.	Ozs.	drs.	Inch.
200				2	0	1·5
250				2	3	1·65
300	4	8	1·65	2	6	1·65
350	4	12	1·7	2	9	1·7
400	5	0	1.75	2	12	1·75
450	5	4	1·8	3	0	1·8
500	5	8	1·85	3	4	1·85
550	5	12	1·9	3	8	1·9
600	6	0	1·95	3	12	1·95
650	6	4	2·0	4	0	2·0
700	6	8	2·1	4	5	2·1
750	6	12	2·2	4	10	2·2
800	7	1	2·3	4	15	2·3
850	7	6	2·4			
900	7	11	2·45			
950	8	0	2·5			
1000	8	6	2·55			

RANGES FOR CARRONADES.

NATURE.	WEIGHT.	CHARGE.	ELEVATION.					
	Cwt.	Lbs.	½°	1°	2°	3°	4°	5°
68 por.	36	5	270	500	730	940	1100	1260
		5½		650	890	1000	1100	1280
42 por.	22	3½	280	510	780	940	1040	1180
32 por.	17	2½	220	380	600	800	975	1170
		2⅔		560	830	900	970	1080
24 por.	13	2	200	430	680	820	930	1090
18 "	10	1½	180	400	640	770	900	1030
12 "	6	1	150	360	510	730	850	920

RASS.

FUZE.

Inch.
1·5
1·65
1·65
1·7
1·75
1·8
1·85
1·9
1·95
2·0
2·1
2·2
2·3

5°
1260
1280
1180
1170
1080
1090
1030
920

TECI

TACT

DISCI

SCIEI

GUN, (

AMMUN

Che

Sho

Car

Fuz

Tube

Prim

Portf

Matcl

Fuze-
Wad,
Gunp

CARRIAGI
Limbe
SLEIGI

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