THE BALLISTICS OF THE RIFLE

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The subject of this paper, "The Ballistics of the Rifle," is one having for its foundation three things, viz., the gun, the powder-charge, and the bullet. Of the first this paper will not treat; only reference to the action of the powder-charge will be made, and very little in a specific manner will be said about the bullet, for each would form the subject of a long and interesting paper. I only propose to treat on the actions produced by the gun, the powder-charge and the bullet in combination; and perhaps I may treat my subject in a superficial manner, but there are two reasons why that has to be done, (1) because it is necessary my paper should be as terse and brief as possible, and (2) because I am only a layman dabbling in the science of gunnery and obtaining knowledge by study alone, without the great advantages which practical experience confers; and I have to acknowlege that I have made a good use of the books I have consulted, and often used, without giving credit, the words of their several authors.

According to the scientific artillerists, and there are *three* distinct kinds of ballistics, viz., interior ballistics, exterior ballistics, and the ballistics of penetration. The first refers to the action of the powder charge after its ignition in the bore, its action on the projectile up to its emergence from the muzzle, and the action of the projectile during its passage through the bore. The second refers to the motion of the projectile to a point of impact, and the influences which retard it, or cause it to deviate from its path; and the third refers to the energy developed on the impact, and how the amount of such energy can be determined.

The foregoing is the natural sequence, because it begins with the cause and ends with the effect, but strange to say, the artillerist now-a-days begins with the effect, and works backward to discover or determine a cause which will produce the effect he desires. Thus, an armour plate of a certain thickness is to be perforated by a projectile. To effect perforation this projectile must be made of a certain shape, class of metal, weight and diameter, and its energy or perforating power must be fixed, and then the gun to be used must be selected, and the nature and weight of the powder-charge to give the required muzzle velocity must be determined, thus harking back from the effect to the cause.

In this paper the sequence mentioned has not been followed, as it was considered desirable not to do so, for we are to treat only of the rifle, and not of great guns and their immense charges of powder.

It is needless here to enter on the history of gunpowder, for that can be found in any encyclopædia, and all that is required for the purposes of this paper is to say that it is an explosive compound, by the ignition of which a force is created capable of propelling to distant or inaccessible points missiles in the shape of shot and shells and bullets, and imparting to them a deadly and destructive force or power; and also that it is not so much an explosive, as a substance mechanically compounded, which, on ignition, gives off gases with great rapidity. In this respect it differs from guncotton and compounds having nitroglycerine as their base, for whilst the explosion of those compounds is almost instantaneous, the ignition or burning of gunpowder is comparatively slow.

All projectiles on being discharged from a rifled gun possess, (1) a *velocity of translation* due to the propelling power of the powder-charge; (2) a *velocity of rotation* due to the spirality of the rifling and the velocity at the moment of leaving the muzzle of the gun; (3) an *energy* due to their weight and velocity during flight; and (4) a *penetrative* power due to the shape and materials of which they are composed and their velocity at the moment of impact; and these points have been taken for consideration.

The velocity of translation varies with the dimensions, shape and weight of the bullet, the amount and nature of the powder-charge, the amount of friction experienced in passing through the bore of the arm from which it is propelled, and the retarding influence of the atmosphere.

The path followed by a bullet in its translation from the gun to a point of impact is called its *trajectory*, and this path is further changed by the reason of the "drift" of the bullet, which is a movement to the right or left according to the direction of the rotation of the bullet.

There is not any such thing as "point-blank," "a term," as one writer says, "not yet expunged from popular speech," for as soon as a bullet leaves the muzzle of a gun the force of gravity begins to act, and between that force, the force of translation, and the retarding influence of the atmosphere, the path of a bullet in its flight is a curved line.

In early days when the science of gunnery was in its infancy, there were many theories as to the flight of projectiles, some believing that they were impelled in a straight line and then fell perpendicularly, and others that the first part of the course was straight, then curved, then directly to the earth. Another theory was that the path followed was a portion of a circle whose radius equalled that of the earth; and still another, that it was a parabolie curve affected by the resistance caused by the atmosphere.

As previously stated the trajectory of a bullet, and indeed of any projectile great or small, is a curve, not regular for any particular make of gun, but irregular, in that it varies at every point in its course, such variations being increased or decreased by the weight and density of the powder-charge; the weight, shape and dimensions of the projectile; the atmospheric conditions at the time when the gun was discharged; and the velocity of the projectile at different points in its path.

Every object or missile projected by any force whatever has its trajectory. A stone thrown at a dog, water issuing from a hose-pipe during a conflagration, or molten metal flowing from an aperture in the foundry-man's melting furnace, all have curved paths to their points of impact; and there is but one course where moving bodies have not any trajectory, and that is where they fall perpendicularly from a height, but though such course is a straight line, the mass or object is retarded in its descent by the resistance caused by the atmosphere, and this resistance is one of the most potent, if not *the most potent* of the influences which affect the flight of a bullet. Were it not for the retarding influence thus offered, a bullet would go on with undiminished speed regardless of distance, and the differences of size, shape or weight would not matter anything, for all projectiles starting with the same velocity would follow the same path and traverse the same distance, being brought to a state of rest by the force of gravity.

The resistance which hinders the onward progress of a bullet in its flight through a still atmosphere varies with its diameter, its sectional area, its velocity, its shape and steadiness during flight, and the density of the atmosphere.

As regards the sectional area it is found, other things remaining the same, that the greater the area exposed, the greater the resistance; thus the sectional area of elongated projectiles is circular, and the resistance they meet with varies as the squares of their respective diameters.

For many years the determination of the velocity, or velocities of a projectile at different points in its trajectory engaged the attention of eminent men of different nations, but their results were to a certain extent empirical, and it is only within the last thirty years, when electric recording instruments were employed for determining velocities that sufficient experimental data has been accumulated from which to deduce results useful for general application. Omitting reference to early observers it may be stated that Mons. Helie in France, and the Rev. F. Bashforth in England, arrived independently at results of great importance; Mr. Bashforth being at the time he made his experiments at Woolwich and Shoeburyness, Professor of Applied Mathematics to the advanced class of Royal Artillery Officers at Woolwich. Relative to these results mention will be made further on.

The shape of the head of a projectile has an influence on its forward motion, for if it be curved or pointed the air resistance is less than if flat. Mr. Bashforth found that at a certain velocity if the resistance to a projectile with a hemispherical head be represented by unity, the resistance to others of the same diameter, but with heads of different shapes, would be as follows:—

Hemispherical head	1·00
Hemispheroidal head	0·78
Ogival (1 diam.) head	0·83
do. (2 diam.) head	0·78
Flat head	1·53

It may thus be seen that the hemispheroidal, which is the shape of the Snider bullet, and the ogival, whose head is pointed and struck with a radius equal to two diameters, encounter equal resistance, whilst the flat head meets with *twice* the resistance that they meet with.

As previously stated, the elements affecting the flight of a projectile through the atmosphere vary as its weight, diameter, shape of head, velocity, and the retarding influence of the atmosphere; and Prof. Bashforth, from the results of his investigations, has prepared a set of tables, by the use of which, the weight, diameter and initial velocity being known, the remaining velocity of a projectile at any unit of distance over a given range can be determined; and from such velocities the times of flight can be calculated, and from them the trajectory, the drop of the bullet and its energy and penetrative power, as well as the angles of sight can be determined.

As muzzle, or initial velocity is a most important factor in these calculations, being the starting point for determining the remaining velocities and times of flight, it may be well to explain that it is obtained mechanically by means of an instrument called a chronograph, of which there are many kinds, notably those of Prof. Bashforth and Le Boulengé, the latter having the most extended use, and is the one used at the cartridge factory, Quebec.

This instrument consists of two electro magnets affixed to a vertical standard, which are each capable of sustaining a brass rod tipped with iron, the suspending power being so regulated that it is