just sufficient to hold the rods in suspension. These rods are of unequal length, the longer, which in time of use is covered with a removable tube of zinc or copper, is called the *chronometer*, and the shorter rod is known as the *registrar*.

In connection with this instrument, which is set up and observed in an office or special room, there is, at a distance outside, a firing shed, and at a stated distance therefrom a screen, usually a heavy plate of iron, free to swing on hinges affixed to its top edge. When a test is to be made a rifle is secured in a fixed rest in the firing shed, and across its muzzle a fine wire is placed, which is electrically in circuit with the chronometer, and the iron plate or screen is placed in circuit with the registrar, both circuits passing through a "disjunctor," the use of which is to regulate the proper falling of both rods, and thus eliminate error.

To use the instrument the rifle is loaded with one of a lot of cartridges to be tested, the chronometer and registrar are suspended by their respective magnets, and all communications and adjustments being in order, the rifle is fired. As the bullet emerges from the muzzle the wire is severed, the circuit to the chronograph is broken and the chronometer falls. The bullet passes over the intervening space and strikes the iron plate, which, swinging under the blow, breaks the circuit to the registrar, which falls on a trigger releasing a catch, and a knife actuated by a spring is forced forward and cuts or indents a mark on the tube carried by the chronometer. Both rods are caught in proper receptacles and the chronometer is taken out, and a measurement made with a graduated rod from zero to the indent on the tube gives the velocity in feet, or yards or metres. The velocity thus obtained is a mean between the actual velocity at the muzzle and that at the screen or iron plate.

Usually the velocities of ten cartridges are taken, the average of which is accepted as the velocity of the lot of which the cartridges were taken as a sample.

To enable a determination being made of the remaining velocities, *the co-efficient of retardation* must be determined, and it is a very simple calculation, for we have only to divide the square of the diameter of the bullet in inches, by its weight in pounds, or expressed algebraically—

$$\frac{d^2}{w}$$

where d represents the diameter in inches and w the weight in pounds.

The diameter of a M. H. bullet is 0·45 inch, and its weight 480 grains, thus—

$$\frac{d^2}{w} = \frac{0.45^2 \times 7000}{480} = 2\ 953$$

which is a factor representing the amount of retardation experiened in passing through the atmosphere a distance of *one foot*.

We are now in a position, using Bashforth's tables, to determine the remaining velocities at any point in the trajectory of a M. H. bullet, and for that purpose will assume that its muzzle, or initial velocity is 1300 feet per second, and that velocities, time, etc., are to be determined at points 50 yards apart, over a range of 500 yards.

As the factor 2,953 represents the retardation in *one foot*, then 2,953 multiplied by 150, or the number of feet in 50 yards, will amount to 442·95. In the *space* table we find opposite 1300 the

Number....................	42,178·80
From which deduct	442·95
Leaving	41,735·85

and by an inverse process we find that numoer in the table represents 1223, which is the velocity at 50 yards. Again subtracting 442·95 we obtain 41,292·90, which is the tubular number for 1155, the velocity at 100 yards, and in this manner the remaining velocities can be determined.

Having found the velocities we are able, with the assistance of the table for *time*, to calculate the "time of flight" of the bullet over the units of distance selected. In this table for 1300, the muzzle velocity, we find the number 231 6071, and opposite 1223, the velocity at 50 yards, 231·2549, deducting which we have ·3522, and dividing that number (0·3522) by 2·953 (the factor of retardation), we obtain 0·1186 second as the period taken by the bullet to pass from the muzzle, a distance of fifty yards. As the velocity at 100 yards is 1155 f.s., we have only to deduct the tabular number for that amount, or 230·8847 from 231·6071 (which is a constant amount), and the difference, 0·7224 divided by 2·953 gives 0·2446 seconds, the time occupied by the bullet in passing over 100 yards, and in this manner the remaining velocities can be calculated.

The times of flight over a 500 yard range having been determined, the heights from the place, or line of aim, to the trajectory at each unit of distance, 50 yards, may be calculated ; but here the force of gravity has to be taken into account. This force is universal, and is the tendency of everything to fall in a direct line to the earth. If a bullet be dropped from a height it starts from a state of rest, and at the end of *one* second of time will have fallen 16·1 feet, and have attained a velocity of 32·2 feet, and this amount, 32·2, is termed *the accelerating force of gravity*, and has for its symbol the letter g. The distance through which a body falls in a given time is determined by the equation $D = (\frac{1}{2}\ g)\ t^2$, where D is the distance to be obtained, g the accelerating force of gravity, or 32·2, and t the time, or duration of the fall.

The heights at the different points on the trajectory for 500 yards can be calculated by the formula

$$H = (\tfrac{1}{2}\ g)\ t\ (T - t),$$

where H is the height to be obtained, T the whole time of flight, and t the time over a given distance. This will more plainly appear when put into figures. Thus, the whole time of flight over 500 yards is 1·4747 seconds, and the time over 50 yards 0 1186 second, then we have

$$\frac{32{\cdot}2}{2} \times 0{\cdot}1186 \times (1{\cdot}4747 - 0{\cdot}1186 = 1{\cdot}3561) = 2{\cdot}589 \text{ feet ;}$$

at 100 yards the figures will be :

$$\frac{32{\cdot}2}{2} \times 0\ 2446 \times (1{\cdot}4747 - 0{\cdot}2446 = 1{\cdot}2301) =$$

4 844 feet, and in this manner the remaining heights can be calculated.

The following statement gives the results from the foregoing calculations :

Distance.	Velocities.	Time.	Trajectory.	Drop.
Yards.	f. s.	Secs.	Feet.	Feet.
0	1300	0	0	0
50	1223	0·11859	2·780	0·1085
100	1155	0·24463	4·844	0·9632
150	1094	0·37880	6·083	2·310
200	1015	0·51908	7·992	4·354
250	1009	0·66640	8·572	7·149
300	975	0·81996	8·615	10·80
350	946	0·97263	7·867	15·21
400	917	1·13137	6·213	20·71
450	890	1·30000	3·666	27·21
500	864	1·47471	0	35·00

The "drop" of the bullet is the distance through which it falls under the influence of gravity at any point in its flight, and is determined by the formula $\frac{1}{2}\ g\ t^2$:—using the results previously obtained, the amounts in the fifth column of the foregoing table have been determined.

The angle of elevation is found by dividing the "drop" at 500 yards by 1500, the number of feet in 500 yards, the result being the natural tangent of the angle required, which in this case is 0 02333, and from a take of natural tangents we find that this represents an angle of 1° 20′ 12″.

A difference of *one grain* of powder in a cartridge will make a difference of ten feet in the muzzle velocity. According to the standard fixed by the British Government for the M-H cartridge the charge is 85 ± 2 grains, or—one cartridge may contain 87 grains and another 83 grains and both pass inspection, and yet the M-V of the first may be 1340 f. s., and of the latter 1300 f. s.

Let us see what effect this would have on a rifleman's score at 500 yards, if he had to fire consecutively two cartridges filled as above.

For the 87-grain cartridge we have a M-V of 1340 f. s.; then the remaining velocity at 500 yards will be 876 f. s., the "time" over the range 1·4335 seconds, and the "drop" of the bullet will amount to 33·0855 feet.

For the 83-grain cartridge we have a M-V of 1300 f. s.; then the remaining velocity at 500 yards will be 864 f. s., the "time" will be 1·4747 seconds, and the "drop" will amount to 35·0084 feet ; then 35·0084 − 33·0855 = 1·9229 feet, or 23 inches, which will be the difference in position of the two shots on the target, always assuming that both were fired under the same conditions of holding, aim, etc.

From this illustration *three* things may be gathered : (1) a reason for unaccountable "drop" shots, (2) that to ensure uniformity in shooting—other things being equal—all cartridges must contain exactly the stipulated weight of powder, no more, no less, and (3) that the longer the range the greater will be the difference between the points of impact on the target.

Retardation is increased or diminished by changes in barometric pressure, and variations in the height of the thermometer ; and it is further affected by the amount of moisture in the atmosphere. Prof. Bashforth's tables were calculated on the assumption that a cubic foot of dry air at a temperature of 62° Fahr., and a barometric pressure of 30 inches of mercury, weighs 534·22 grains.

When the barometer rises above or falls below 30 inches, the weight of a cubic foot of air is diminished or increased, and a further change takes place as the thermometer varies from 62°. The change due to moisture contained in the air so far as it affects so small an object as a rifle bullet, may be disregarded.

As the co-efficient

$$\frac{d^2}{w}$$

was determined under the conditions assumed by Prof. Bashforth, it will be necessary when extreme accuracy is required to modify it to suit changed conditions of atmospheric pressure and temperature, but as such calculations require the weight of a cubic foot of the air existing at the time of the trial, and recourse be had to meteorological tables for corrections for temperature and moisture, calculations which are beyond the scope of this paper, reference is only made thereto ; but it must be borne in mind that a change in

$$\frac{d^2}{w}$$