Simple Methods of Determining Rifle Muzzle Velocities

By A. L. Hodges

THE experimental muzzle velocity of a rifle is really the velocity several feet away from the muzzle, while the real velocity, and the one that is used in formulae, is that taken at the muzzle. But so very close are the two that the resultant error is negligibly small.

There are two classic ways of getting the muzzle velocity of a rifle and also two other ways. The latter have never been tried before as far as the author's knowledge extends. The two classical ways are the ballistic pendulum method and the electric screen method. The two new ways are the gravity method and the mechanical equivalent of heat method.

It was the writer's intention to perform the ballistic pendulum experiment method and the gravity method so as to determine which was the better; and he did so, although a certain error of adjustment, unforeseen, vitiated the gravity method result. However, a description of the four methods will serve to show the possibilities of each.

If a bullet be shot into a mass suspended so as to swing without rotation, the momentum formula holds good; that is to say, between inelastic bodies the total momentum before impact is equal to the total momentum after impact. If we have one body stationary, it has no momentum before impact. If the other body be caught in it at impact, the velocity of each after impact is the same.

Accordingly, if a bullet be shot into a pendulum made of wood, and if m stands for the mass of the bullet, M the mass of the wood, v the velocity of the bullet before impact, and V the common velocity of the contained bullet and pendulum after impact, we have the following formula: $mv = (M + m)V$. Then, as we can measure beforehand every term in this formula but v , we can solve for v . The factor v is measured indirectly of course as will be explained later, and there are certain errors which prevent us from announcing the result beyond two significant figures. This accounts for the marking of the present army rifle bullet at 2,700 feet per second instead of 2,700 and odd feet. For this particular bullet there may be an error also in the weighing of the powder behind different ones in the third place.

The second method is to shoot a bullet through screens placed at certain distances apart, so that when the bullet hits a screen it makes an electrical contact which is registered on a chronometer—an accurate timepiece. If the screens are 100 feet apart, let us say, and the registering chronometer indicates that it took the bullet one twenty-seventh of a second to go that distance, we have the velocity of the bullet to equal 2,700 feet a second. But there are errors in a chronometer, especially to the fraction of a second; so that unless an enormous number of records have been taken for every part of the chronometer circuit and the average computed, this method allows of error. Further, the actual mark made on the rotating drum has dimensions which are comparable with the space between marks, thus another error is included.

The third method, that of gravity, depends upon the fact that a body shot horizontally will fall as fast as a body dropped straight—from a resting position—to the earth. Therefore, its vertical distance fallen would exactly equal that of a body dropping by gravity, which obeys the formula $s = gt^2$, in which s equals the vertical distance fallen, g the acceleration due to gravity and t the time taken. If we can get a gun exactly horizontal and shoot it through a target a certain distance away, all we have to do is to get the difference in level between the muzzle of the gun and the hole the bullet makes in the target. This, then, is s . Knowing g we may solve for t . This t is also, of course, the time taken for the bullet to traverse the horizontal distance between the muzzle of the gun and the target. Suppose t came out one twenty-seventh of a second and the horizontal distance gone in that time was 100 feet. We would get 2,700 feet as the velocity of the bullet. Let us see, though, if we could not get things to a greater degree of accuracy than two places. The horizontal distance can be measured very accurately with a steel tape, to within a tenth of a foot at least. This would put four significant figures with anything over a hundred feet. The surveyor's level can measure accurately to a thousandth of a foot. A fall of over a tenth of a foot would then have three significant figures,

Arrangement of the pendulum in the determination of rifle bullet velocities

Above: Principle involved in determining muzzle velocity by the gravity method. Below: Sectional view of the pot used in the mechanical equivalent of heat method

and a fall of over a foot would have four. The remaining thing to investigate is the degree of accuracy with which we may level a gun barrel. With care, it is obvious that this can be done as well as in the instance of the surveyor's level. So the result should appear with three significant figures and possibly four—something that has never been done yet, as far as the present writer's knowledge extends.

The fourth method is that of the mechanical equivalent of heat. If a moving body is absolutely stopped by a body at rest, and if both bodies remain at rest after impact, the entire energy of the moving body is converted into heat. As the mechanical equivalent of heat has been determined to four significant figures, and as the mass of a body can be determined to four places if it is of any mass at all of practical use, and as the temperature of a liquid may be determined to a hundredth of a degree fairly well, this method should be of value. Suppose we have a steel calorimeter with a very small radiation constant—a steel pot of a half inch thickness enclosed within an asbestos framework would serve. Line the pot inside with a 2-inch sheet of lead having pores through which water could circulate. Now fill the pot with water and measure the common temperature of the whole thing. Then take an army rifle and shoot rapidly a clip of cartridges into the lead mass. After stirring the water thoroughly, measure the temperature. As the specific heat of iron and of lead are known, as the

mass of the pot and of its lining and of the bullet are known, and since the temperature may be measured, we would have an equation which would finally lead us to the velocity with which the bullets were shot. It would be as follows: Letting M be the mass of the iron pot and its specific heat, m the mass of the total lead (including the weight of the bullets and the lead lining) and b the specific heat of lead, and n the mass of the coatings of the bullets, and c the specific heat of the same, and t the difference in temperature before and after firing, and O the mass of water, we would have for the total number of calories of heat generated, symbol $H = Ot + Mat + mbt + nct$. Now we know, naturally, that the total kinetic energy which was transformed into heat is equal to—in case the number of bullets shot was five— $5/2 mv^2$, if m = mass of one bullet and v its velocity. So then, the mechanical equivalent of heat being known, we have an equation all of whose terms have been measured but one, and that one being v . For $5/2 mv^2 = K(Ot + Mat + mbt + nct)$, K being the mechanical equivalent of heat.

In the actual experiment with the ballistic pendulum performed in the laboratory by the writer, the wires were 233 cm. long, and the pendulum was a cylindrical core obtained from a veneering works and weighing 47 pounds. The bullet, having to be shot into the block horizontally, presented some difficulties. A steel wire was stretched above the block but in the same vertical plane as its axis, to the opposite wall. Another steel wire was run under this from the center of the end of the block and made as near horizontal as possible. This latter wire was run through the barrel of the rifle held in a wooden vise. The resulting velocity of the pendulum and contained bullet was not measured directly, but simply the chord of the arc through which the pendulum was thrown, was measured. Two ways were provided to measure this chord.

A string which would pull out but would not go back was attached to the pendulum. Subsequently, an experimenter could pull the pendulum out to the end of the string and measure the arc chord at leisure. Also a camera was set to take a time exposure of the pendulum under a mercury arc lamp, the idea being that the blur made on the negative against a scale set up behind the pendulum would show accurately where it stopped, its stopping point to make the biggest effect on the negative on account of length of time in one place. However,

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What the French Helmet Will Stand

By Edward C. Crossman

IN the first year of the war, when the queer cap of the French poilu continued to grace his sunny brow instead of the present steel pot, a couple of quiet and business-like strangers appeared at the testing station of a huge American corporation making explosives, and asked if anyone there could test for them the bullet-resisting qualities of a steel helmet they had with them. The obliging assistant to the man in charge volunteered to do the testing. Trotting out a New Springfield, the American service rifle, and setting up the experimental helmet at a distance of 80 yards, he shot a neat round hole in the steel, through and through. The strangers smiled, thanked him, gathered up the perforated helmet and departed, first asking permission again to submit a helmet or so to his rifle. A few days later they returned with another helmet, and the assistant shot a hole in this one, likewise.

The strangers knew nothing about rifles or the effect thereof, they even expressed their surprise at the ability of the powder man to hit the helmet at such a distance.

But a third, and a fourth, and a fifth time they put in their appearance at the plant. By that time the powder man knew they were officials of a Philadelphia steel company of old and established reputation. Each time the brown service rifle obligingly shot a neat round deckle-edge hole in the helmet and each time the visitors gathered up the steel pot and went their way.

Finally there came a helmet that merely dented where the bullet struck it. Two shots had to land in the same spot to get through. It may be explained that the service rifle of our Government has a striking energy of 2430 foot-pounds, and a muzzle velocity of 2700 feet per second, with a bullet in sharp point form weighing 150 grains. The next helmet—still of the light-weight steel necessary to keep the affair from telescoping the poor soldier's neck—refused to let the service bullet through. The powder man, with a quiet

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Half-inch steel plate after penetration tests

Block of 3/4-inch steel and a .28 bullet like the one that hit it

The old type blunt nose bullet (A), giving more certain penetration on oblique surfaces than sharp point bullets like B and C. At the right, various types after impact

RECENTLY PATENTED INVENTIONS

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vides means for concealing from lateral points of view the illuminating elements in the lamp.

Household Utilities

WINDOW JACK—O. W. SANDHOLM, 43 North Chase Ave., Rockaway Beach, N. Y. In this case the invention refers to seats and particularly to a window sill seat or jack, and has for an object the provision of an improved arrangement whereby the same may be applied and removed quickly and when applied be held against accidental removal.

SIFTER—G. B. WHEELER, 2069 Third Ave., New York, N. Y. The invention relates particularly to sifters for sifting salt, soap, powder and the like where limited quantities are desired from time to time, and provides an arrangement whereby any desired quantity may be secured and when the device is not in operation the discharge openings will be closed.

HAM SHAPER—H. ADELMANN, 530 Westchester Ave., Bronx, N. Y. This invention relates to improvements in cooking meats, with particular reference to hams and corned beef and the like, in which the meats are preferably delivered in a compressed form, suitable for slicing, the bones and inedible parts being removed preliminary to the cooking.

BED SPRING—F. W. HILL, Lyndonville, N. Y. This invention provides a spring mattress frame having a joint so that one part may be positioned at an angle to another part and so supported in position as to provide a head rest in the case of a bed mattress or couch, or a back rest in the case of a chair or the like, but having facilities whereby the movable section may be restored to normal position in the same plane as the relatively fixed part, by simply pulling upon a cord or cords at one end of the structure.

WINDOW SCREEN—F. S. BANKS, R. F. D., No. 42, Norwalk, Conn. The invention has reference to improvements in window screens, and has for an object the provision of an improved structure in which the frame may be adjusted at each end so as to adopt the same to various widths of windows within certain limits.

Machines and Mechanical Devices

EMBOSSING MACHINE—O. E. STRAWN, 818 Idaho St., Boise, Idaho. The invention relates to embossing machines of the type suitable for use in connection with the Crump process for embossing in which a fusible powder is dusted onto a freshly printed surface, the ink of which, is not yet dry, so as to cause the powder to adhere to the ink, after which, heat is applied, thus affecting the molecular condition of the powder and causing the printed letters to apparently swell and at the same time harden.

AUTOMATIC LUBRICATOR—E. R. McKINZIE. Address, Jos. A. Fowler, 42 W. 2d St., Memphis, Tenn. The object here is to provide means for positively feeding the sticks forwardly in the guides during operation of the elevator or like construction, of such nature as to maintain

AUTOMATIC LUBRICATOR

a substantially uniform pressure at all times, provide adjustment for this purpose, and at the same time permit of the use of springs in connection with the lubricating sticks to yieldingly hold the same at the desired pressure against the elevator guide.

COLOR PHOTOGRAPHING APPARATUS—W. H. DOHERTY, 7 Woodward Park St., Dorchester, Mass. This camera is an improvement over that form in Mr. Doherty's application for Letters Patent, Serial No. 758,328, in that, while being an apparatus for color photography, the present form provides for either two plates in focal plane, or three plates, of different color screen results, and further, that in this present form he arranges the plates when two in number in one focal plane located in the conventional position or, when three in number, in another focal plane also located conventionally in the rear of the camera.

PAPER ENGAGING ELEMENT FOR PAPER FEEDING MACHINES—A. BROADMEYER, Address W. O. Hickok Mfg. Co., Harrisburg, Pa. This invention relates to improvements in paper engaging elements which, in connection with a vertically adjustable table, engages the paper stack upon such table, and controls vertical movement of the table as the paper is fed from the stack, the present improvement aiming to provide a readily adjustable paper engaging element.

PAPER STACK AGITATING MEANS FOR PAPER FEEDING MACHINES—A. BROADMEYER, Address W. O. Hickok Mfg. Co., Harrisburg, Pa. The improvements are directed to the

means for directing blasts of air against the forward portion of a paper stack near the edge of the sheets of the stack at a point where they are initially engaged to successively remove the same, the improvements aiming to provide blast directing means capable of ready and quick adjustment in connection with the paper stack, as well as a wide range of action, and adapted to promote wholly effective results in such action.

SPAR POLE FOR LOG-SKIDDING MACHINES—D. G. MANGES, Tellico Plains, Tenn. This invention provides a metallic construction including freely adjustable sheaves, certain of which receive the main or trolley cable and the others of which receive the operating cables, and all of which provide for the reception of sheave blocks in order to receive a guy wire threaded through the same and the sheave block of a single guy cable.

Musical Devices

ADJUSTABLE TONE ARM AND SOUND BOX COUPLING—L. MARKELS, care of Sykes, McCole & Potter, 170 Broadway, New York, N. Y. This improvement refers more particularly to an adjustable connection whereby the sound box can be set to operate on phonograph records having the up and down or lateral sound undulations. It provides a pair of stops on the tone arm arranged at 90 degrees apart so that the back of the sound box body can engage with either stop and thereby be set at the proper position for operating on either type of disk phonograph record.

AUTOMATIC WINDING DEVICE FOR PHONOGRAPHS—G. BEDFORD, 110 Malbone St., Brooklyn, N. Y. This improvement has particular reference to phonographs of the spring motor type. The primary object is to provide means whereby the spring will be automatically wound to its full capacity simultaneously with the lifting of the lid of the casing, requiring no attention whatever of the operator for this purpose.

Prime Movers and Their Accessories

MEANS FOR EQUALIZING PISTON DISPLACEMENT—J. C. MORISON, 616 E. Hurton St., Anne Arbor, Mich. In this case the invention has reference to means for equalizing the piston displacement during each half engine stroke, and the object thereof is to eliminate vibration in reciprocating engines due to the variation in the piston displacement, particularly in those of high speed.

Railways and Their Accessories

SCALE—G. H. KAISER, 41 E. 11th St., Portland, Ore. This invention provides a removable pivot, adjustable holder and removable holder for scales used on railroads, wherein the pivot and bearing is as arranged that it may be quickly removed for sharpening or repairs, and may be replaced by a new pivot and bearing to permit the scale to be used continuously.

Pertaining to Recreation

SPRING-GRIP DUMB-BELL—L. G. LEWIS, 42 Berners St., London, W., England. The uses of spring-grip dumb-bells has hitherto been liable, through inattention, to fail of obtaining the full benefit which should result from the exercise which such appliances are designed to afford. The present invention overcomes this difficulty by insuring that the user shall receive notification of the fact when his grip is closed to the fullest extent.

Pertaining to Vehicles

SIGNALING DEVICE—T. RICHARDSON, 2016 Perdido St., New Orleans, La. The improvement provides a device more especially designed for use on automobiles, auto-trucks and other similar vehicles, and arranged to enable the operator of the vehicle to display a signal to a following vehicle to prevent accidents when stopping or turning out.

AUTOMOBILE JACK—F. O. COOLEY and A. J. MILLIGAN, Care of Clyde Iron Works, Duluth, Minn. This invention has the following advantages: It is the only twin "auto jack" whose two sides are independent of each other, it being possible to raise, stop or lower either side at any time while operating the same; it has adjustable swivel seats to clear truss and steering rods; in raising or lowering the full

AUTOMOBILE JACK

force is obtained on the sides alternately, that is, one side raises on the up stroke as does also the opposite on the down stroke; it is impossible to tip or drop the load in the various operations; has ball bearings throughout; and may be used as jack, turntable or transport, and to test the emergency brake, and repair tires, springs or wheels.

Designs

DESIGN FOR A DRINKING VESSEL OR SIMILAR ARTICLE—W. J. GRAHAM, Bellaire, Ohio. This ornamental design for a drinking vessel shows an article somewhat elongated and tapering slightly from top to bottom. The form is simple but exceedingly attractive and the design is beautified by a running vine around the vessel.

NOTE.—Copies of any of these patents will be furnished by the SCIENTIFIC AMERICAN for ten cents each. Please state the name of the patentee, title of the invention, and date of this paper.

Machine Guns by the Thousands

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assembled therefrom. These guns invariably operate perfectly. This feature of interchangeability is essential, for it makes possible the utilization of the parts of two or more damaged guns in making one good gun, on the battlefield.

The guns are fitted to their individual tripods by the Russians, who number the tripod the same as the gun and stamp both with their metal stamp, which is a signal that the gun has passed all inspections and is officially accepted.

The tripod of the Colt gun, at the beginning of the present war, was three feet or more in height, and the gunner sat on a bicycle saddle placed on the rear leg. But the flat plains on which the Russian armies are waging their major campaigns make necessary the employment of extra low tripods. The present tripods are slightly over a foot in height, and are provided with an arm rest so that the gunner, laying flat on the ground, can place his arms on the rest so as to permit of steady aiming.

The packing of the guns for shipment is conducted with the greatest care under the supervision of a Russian inspector. In order to protect the metal parts against rust all the guns and extra parts are liberally coated both inside and outside with a heavy gun grease or rust preventive. The guns and barrels so coated are then inserted in their respective leather "boots" or casings, and placed into wooden cases which are sufficiently heavy to protect their contents throughout the journey almost half-way around the globe.

It seems hardly possible that an idea entertained by a group of men less than a year ago should have developed into what is probably the largest machine gun producing plant in the world, yet such is an accomplished fact. And it is certainly comforting in times like the present for Americans to know that we have such progressive plants as this one, ready for instant service in the hour of national need.

Simple Methods of Determining Rifle Muzzle Velocities

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the camera did not show up anything on account of the diaphragm stop having been set at 64.

The gravity method, although seemingly easy, frustrated two attempts at a determination. Obviously, the chief point in that method is to get the gun barrel horizontal. In the author's experiment a sight was taken from a surveyor's level to about three hundred yards distant and a target there set up with a line marked on it coinciding with the line determined by the horizontal wire in the instrument. No correction for curvature of the earth here has to be made for obvious reasons; the bullet falls out of a straight line only for the formula to hold. Next, a target was set up in the same line of sight at 100 yards distant and the same process gone through with. Following, an upright was set up about 6 feet from the instrument and made fast. It was intended that a sight should be taken on this and a point made in the line of sight at which a hole was to be bored to receive the end of the rifle. But the instrument happened to be a long focus one and the upright could not be seen; nevertheless, the hole was placed on estimate. Another upright was then erected within a few inches of the instrument and another hole bored. The rack holding the gun was run up and down through these uprights. The necessity for estimating the two holes, however, proved to be the undoing of the experiment for the values were not concordant nor true. Another attempt will probably be made at a later date with better apparatus.

In conclusion, if the determining of the muzzle velocity of a rifle is of great import to anyone—such as the government testing stations or arms manufacturers, a special set-up of such a device might prove of value. The gravity method assuredly would give better values than either the ballistic pendulum or the electric screen method.

What the French Helmet will Stand

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grin, trotted out a box of special match ammunition yept "Palma," after the celebrated long range match for which it was loaded. This uses a bullet of 180 grains instead of 150, with the same muzzle velocity. At the muzzle it strikes a blow of 2900 foot-pounds.

The big bullet merely shattered itself against the helmet, to the abject amazement of the powder man. This bullet, by the way, in the hands of the writer, has shot through half-inch plates of boiler-steel at the muzzle, and through quarter-inch plates at 500 yards. The helmet was merely rested against a head-sized rock to give natural conditions—not that the head of the poilu is akin to a rock, but this was the nearest approach possible with the limited equipment available. A second bullet, in practically the same place, still failed to get through. And at the range of 40 yards the experimenter smote the helmet again and again in nearly the same spot, until finally the eighth shot shattered the helmet into pieces at the point of the terrific pounding.

Each time of course the impact of the bullet drove helmet and rock through the air, and a solid support to the steel might have told a different story—but the helmet on the head of a man is not solidly supported. When the eighth Palma bullet finally shattered the helmet the pleased strangers carefully gathered up all the fragments and thanked the shooter and went away never to return.

Later, upon telling the officials of the Government Frankford Arsenal about the trial, the powder man met with laughter, jeers and contumely, the Government men refusing to listen to such a yarn. The peeved powder man wrote the company making the helmets—or the steel therefor—asking for one to demonstrate to the Government officials, but met with polite refusal, nor has he seen a helmet since.

The helmet tried out weighed as near as the experimenter could tell, about 6 pounds, shaped like the helmets shown on French soldiers in the photographs from the front, and supported on the head by a light framework akin to the sun helmets worn in the tropics. Evidently the material was some alloy like tungsten, heat-treated, and not only hard, but tough. The shattering under the final blow indicated a glass-like hardness that was still devoid of the brittleness of most very hard and thin steel plates.

The writer, probably like most persons not on the inside, took it for granted that the helmet of the French and British was merely a protection against shrapnel, which has no great punch, and little penetration, being merely half-inch lead balls, travelling with the remaining velocity of the shell at its bursting point, plus about 200 feet per second imparted by the bursting charge within. As the shell itself has but 1700 feet per second initial velocity, and probably not over 900 or 1000 at the bursting point, the best laid shrapnel merely means a shower of round leaden balls with velocity not exceeding 1200 feet per second, and probably nearer 800 as the average. With the scanty penetration of the round missile, this 170 grain leaden pill with its low velocity would be halted by almost any discouraging obstacle.

But a helmet that will resist the impact of a bullet of 180 grains, sharp pointed, 30 caliber, and travelling at 2700 feet per second, is a different thing, more especially since care was taken, according to my informant, to make the impact of the bullet at right angles to the steel. A helmet capable of such resistance, would nine times out of ten turn a bullet from the German rifle fired at a distance of 200 yards or more and do it without serious injury to the soldier because of the sloping form of of the helmet, and the difficulty of getting a right-angled hit against the steel. The spitzer form of bullet is easily deflected against a sloping surface, more easily than the older form of blunt nose, the long shoulders sliding neatly off inclined surfaces which the blunt nose bullet, with more "biting" area to its point, would penetrate.