APPARATUS FOR MEASURING THE SPEED OF PROJECTILES.*

This new instrument for the reliable measurement of very minute intervals of time was developed in some preliminary experiments at the United States Artillery School, Fortress Monroe, Va., in measuring the velocity of projectiles from the new 3·2 inch B. L. field rifle adopted by the army.

In the course of these experiments, which were necessarily limited to two weeks' time, observations were taken at intervals as small as 5 feet, and as many as ten consecutive observations at 5 foot intervals, beginning at the muzzle of the gun and extending to 45 feet distance, were easily obtained from a single shot. This instrument being admirably adapted for recording the passage of the projectile at a number of points of its trajectory, it was made an object to study the law of variation of the velocity of a projectile near the muzzle of a gun. From measurements on the negatives it is clearly evident from each that the velocity actually increases after leaving the gun, a fact which has long been suspected, but which, so far as we know, has not previously been demonstrated experimentally.

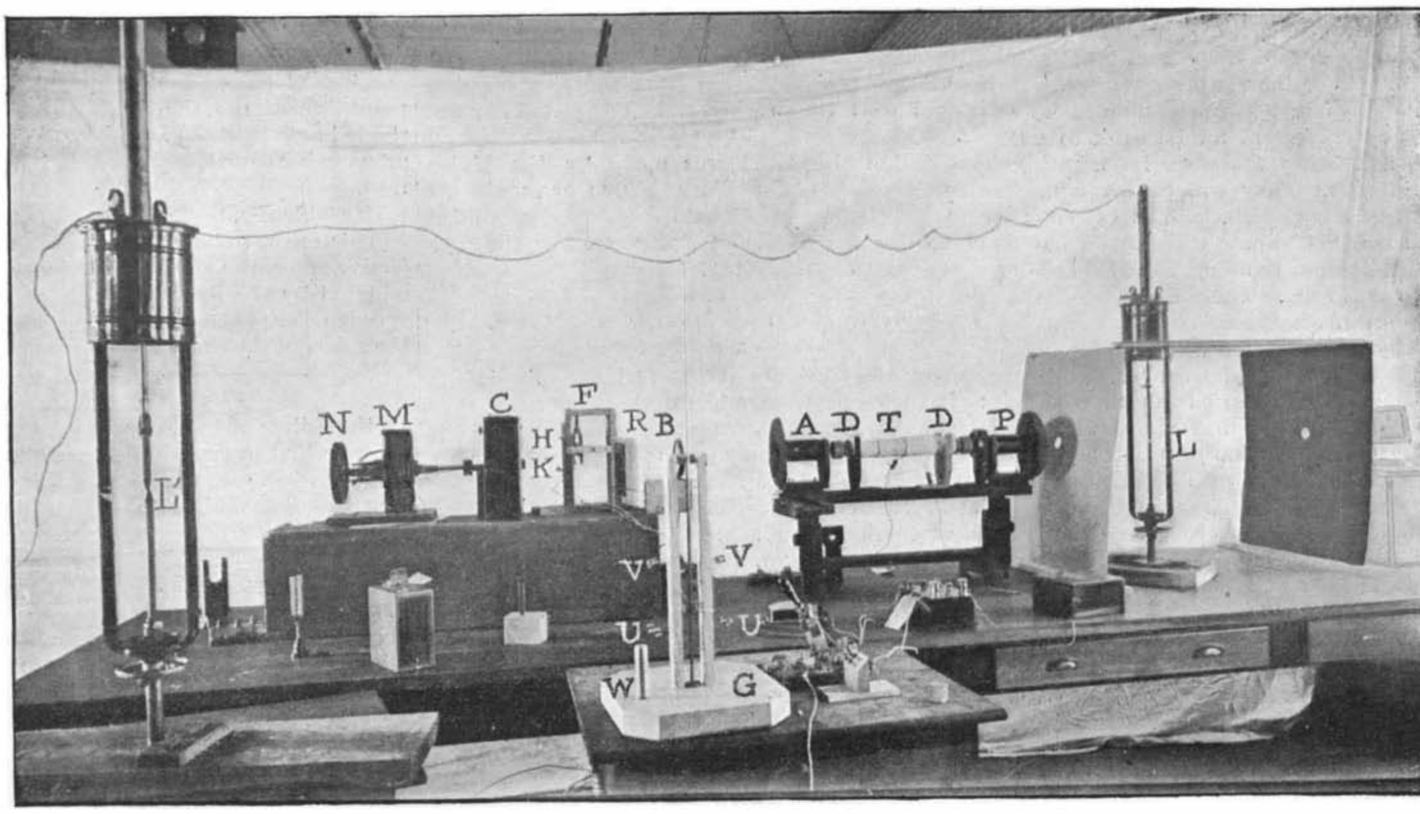


Fig. 1.—ARRANGEMENT OF LABORATORY APPARATUS.

The particular form of transmitter used in these experiments depends for its action upon the use of polarized light. A sensitive photographic plate is made to rotate at a known speed in a light-tight box, and light is admitted to the plate through a narrow slit by means of a "massless" shutter, as the inventor terms it. Any material shutter would possess a certain amount of inertia, and would not admit of a practical result. By the use of a polarizer the light is admitted or shut off without the movement of any material thing.

As is well known, the most efficient polariscope consists of a pair of Nicol prisms. When the prisms are "crossed," the light is totally extinguished, as though the beam had been interrupted by an opaque body. By turning the analyzer ever so little from the "crossed" position, light will pass through it, and its intensity increases until the planes of the prisms are parallel, when it again diminishes, and if one of the prisms is rotated, there will be darkness twice every revolution.

To accomplish the end that is obtained by rotating the analyzer without actually doing so, a transparent medium which can rotate the plane of polarization is placed between the polarizer and analyzer, and made subject to the control of an electric current. The medium used in these experiments was liquid carbon bisulphide, contained in a glass tube with plane glass ends. This was selected because it is very clear and colorless and possesses the necessary rotary property to a considerable extent when situated in a magnetic field of force, the rotary power being in proportion to the intensity of the magnetic field.

To produce a magnetic field in the carbon bisulphide a coil of wire is wound around the glass tube, and an electric current passes through the coil. The prisms being crossed, so that no light emerges from the analyzer, a current is sent through the coil on the tube, causing the rotation of the plane of polarization.

This is equivalent to rotating the polarizer; hence a light now emerges from the analyzer. When the current is broken the medium loses its rotary power and there is again complete darkness. This arrangement makes an effectual shutter for the beam without moving any mass of matter.

A view of the laboratory apparatus is shown in Fig. 1. Fig. 2 shows diagrammatically a complete arrangement of the electrical circuits and apparatus,

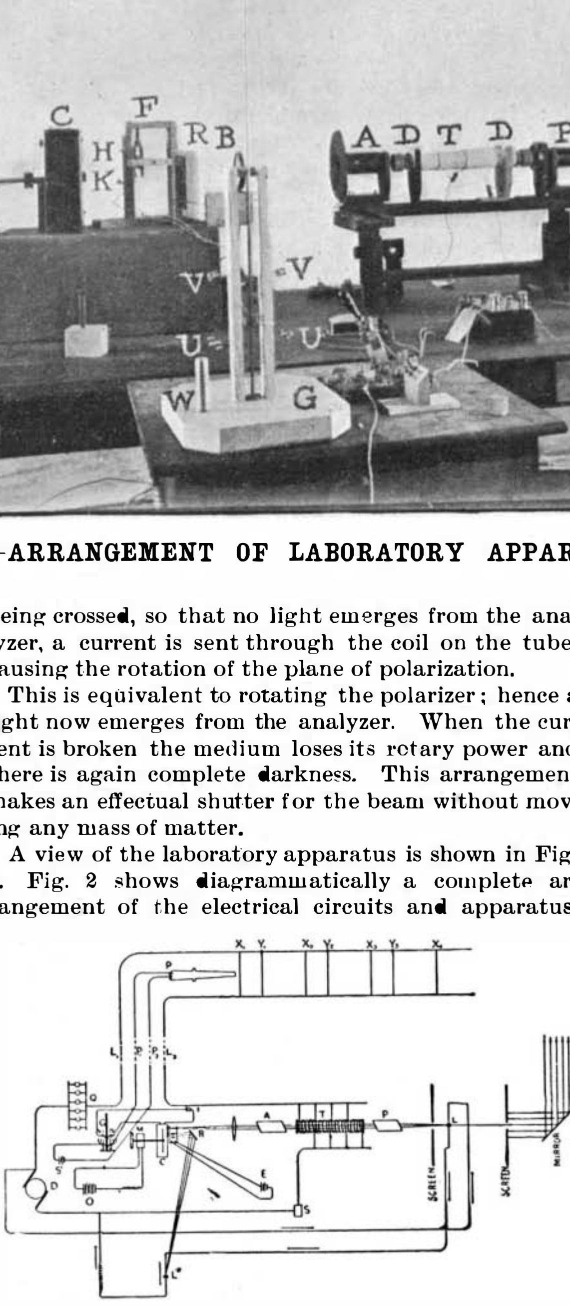


Fig. 2.—ARRANGEMENT OF ELECTRICAL CIRCUITS.

and Fig. 3 shows the apparatus on the proving ground. Corresponding letters represent like parts in the figures.

The arc lamps, L and L', are used as sources of light. P is the polarizer; T, the transmitter tube containing carbon bisulphide and wound with magnet wire; A is the analyzer, in front of which is a lens to condense a beam of light upon the camera, C. The motor, M, revolves the sensitive plate in the camera. The speed of the plate is obtained at the moment of firing by the shadow of one prong of a tuning fork cast by a beam from the lamp, L', reflected from a mirror, R, upon the sensitive plate, the tuning fork being run electrically by the cells, E. At X', X^2, X^3, etc., placed at regular intervals from the gun, are wire screens which are cut one after the other by the projectile.

At Y', Y^2, Y^3, etc. are placed devices for mechanically restoring the current. Before firing, the current passes only through the screen, X', because of an insulating plug placed between the jaws of the device which interrupts the connections between X', X^2, X^3, etc. When the projectile strikes a wire attached to this insulating plug, the plug is pulled out and the jaws spring together, thus establishing the circuit through X^2.

The receiver is a photographic means of recording the intermittent beam of light through the analyzer, and consists of a camera containing a sensitized plate, which is shown in position ready for use at C (Fig. 1).

The electrical tuning fork is shown at F (Fig. 1). Four storage cells were used to energize the motor, and greater uniformity in speed was obtained by placing a heavy iron-toothed gear wheel as a flywheel on the motor shaft, as shown at N (Fig. 1). This wheel also served another purpose in offering a convenient and ready means of determining the proper speed of rotation for a given setting of the camera slide. The wheel contained 56 teeth, and by simply holding on its periphery the edge of a card, with the motor running at an unknown speed, the corresponding note would be given out, and when this was compared with a tuning fork in the other hand of the observer, it indicated at once whether the speed of the motor should be increased or diminished.

The velocity of the projectile is obtained from the measurement of three quantities, the distance between screens, ω the angular velocity of the plate, and θ the angle through which the plate revolves while the projectile passes between screens. This gives the expressions for the velocity $v = \omega \frac{S}{\theta}$. The angle θ upon the plate can be measured with considerable accuracy. In an average case with a distance of 40 feet between screens, angle θ is 108°·0969,

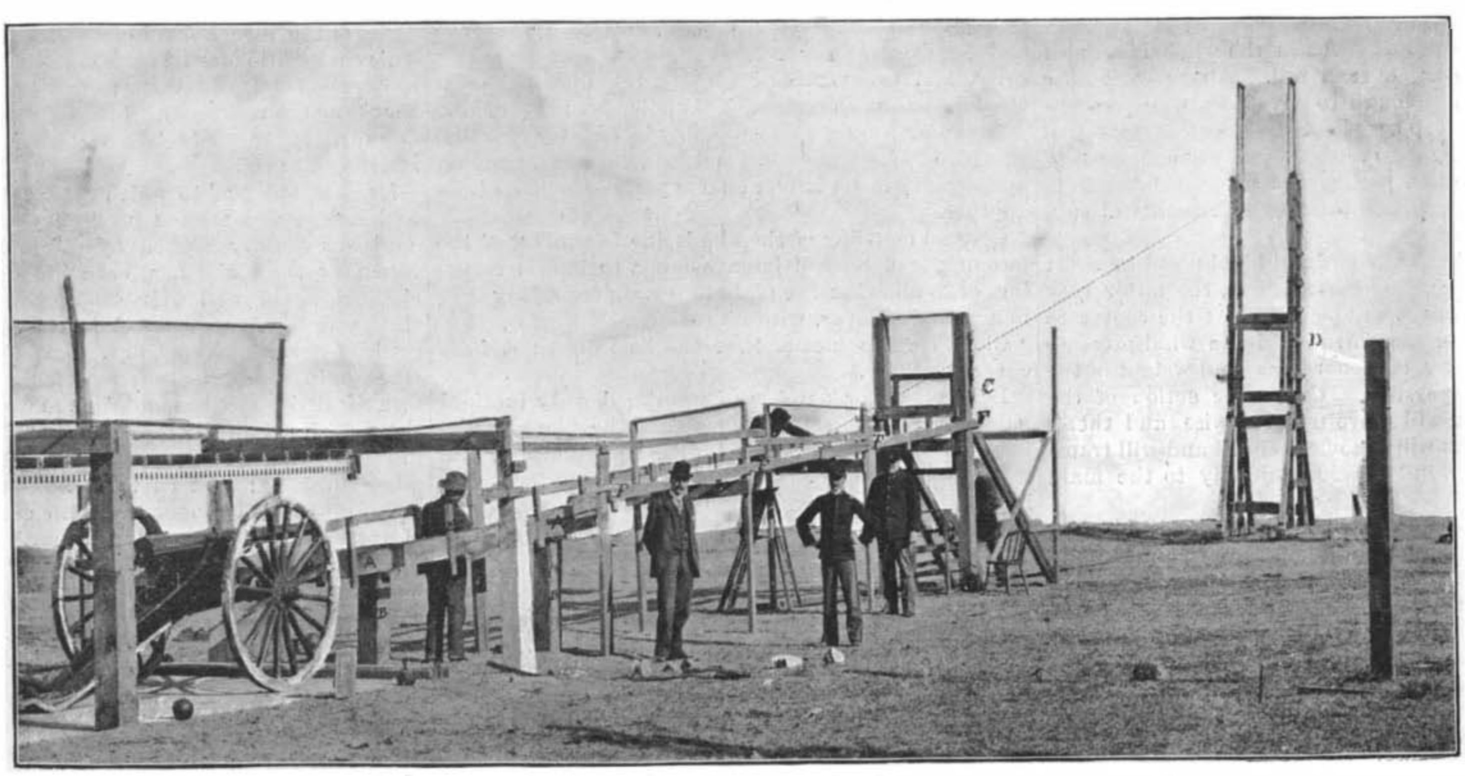


Fig. 3.—APPARATUS FOR RECORDING THE SPEED OF PROJECTILES.

* For the information here given we are indebted to Dr. Albert C. Crehore, Assistant Professor of Physics, Dartmouth College, and Dr. George O. Squier, First Lieutenant, U. S. A., Instructor U. S. Artillery School.

with a probable error from nine measurements of 0·0074 or an error of one part in 14,630. The angular velocity ω can with proper instruments be obtained with great accuracy.

The principal ballistic result obtained from the experiments may be said to be the locating of a maximum point in the velocity curve outside of the gun. This maximum point is, in the present experiment, at 6 or 7 feet from the muzzle of the gun—certainly more than 5 feet and less than 10—or about 25 calibers in front of the muzzle. The increase in velocity from the muzzle to the maximum point is large, more than 40 foot seconds. The muzzle velocity being about 1,600 feet, this increase is about 2·5 per cent of the whole.

The decrease in velocity beyond the maximum point is comparatively gradual, obeying the true law of the resistance of the air, so that the projectile must travel about a hundred feet before the velocity is reduced to that which it actually had at the muzzle.

This maximum point introduces an error in the present method of obtaining muzzle velocities, in which the velocity is measured at a distance of 100 to 200 feet and reduced back to the muzzle by formulas. The Franklin Institute has awarded the John Scott Legacy medal and premium to Lieut. Squier and Prof. Crehore for this apparatus.*

*This apparatus is described at greater length and with additional illustrations in SUPPLEMENT, No. 1054.

THE ROYAL OBSERVATORY AND HOW THEY TELL THE TIME AT GREENWICH.

BY DR. D. DUNBAR.

Greenwich, situate on the winding Thames, five miles east-southeast from London, in the County of Kent, possesses a large amount of historical interest. It is the birthplace of many illustrious persons, among them Henry the Eighth, Edward the Sixth, Queen Mary, Queen Elizabeth, and several children of James the First. But it is not of departed kings and queens we propose now to speak, nor of the social attractions of Greenwich. It is a place of great resort, specially on a bright bank holiday.

The observatory building is familiar to every inhabitant of the town, and well known to scientific men all over the world. It stands on the spot once occupied by the tower built by Duke Humphrey. At one time the observatory was furnished with a deep well for the observation of stars in the daytime, but the great improvement in telescopes rendered this unnecessary, and it is now arched over. An apparatus has been erected on the eastern turret of the observatory for the purpose of enabling the captains of vessels leaving the river to ascertain by it the rate of their chronometers, thus obviating the necessity of applying at the observatory. It consists of a large ball of wood lined with leather, which, in order to give preliminary notice, is raised at five minutes before one P. M., half way up a pole, by which it is surmounted, at two minutes before one is raised to the top, and at one o'clock precisely the ball drops. By means of an electric current from the observatory accurate time signals are distributed every hour by the post office telegraphs to a large number of towns, and clocks in the metropolis and country are synchonized. There is in the wall of the observatory a large twenty-four hour clock face, that is, with hours marked from one to twenty-four, to include a day and night; where the time is exhibited at any hour when the park is open for any one who chooses to climb the pleasant hill and look at it.

THE ROYAL OBSERVATORY AT GREENWICH.

The observatory is an oblong edifice, divided into four apartments. It is a quiet, retired spot well walled around, some 150 feet above the average height of the river. The roar of London sounds muffled and distant, and only seems to emphasize the sense of calmness and silence in this abode of science. Here, above the trees of the old park, and on the rim of the mighty city, the astronomers keep the time for half the world. Greenwich time is the standard for the British nation, for British ships at sea, and for the ships of most other countries as well.

We were received by Mr. W. H. M. Christie, Astronomer Royal, and placed in charge of the senior computor, Mr. H. Furnel, to be escorted over the apartments. We soon find that his acquaintance with the interesting and delicate instruments that are explained in turn is much greater than our limited powers of comprehension. But Mr. Furnel, who has become a student of the stars, is a patient gentleman who goes to much trouble in his endeavors to initiate a layman in the mysteries of the heavens.

The main question of this paper is how they tell the time at Greenwich, and we shall endeavor to explain this in popular rather than in scientific language.

The fixing of the standard of time depends on astronomical observations. When the sun is exactly south—on the meridian, as it is called—the hour is twelve o'clock noon. As the movement of the sun apparently fluctuates, astronomers call this apparent noon. At Greenwich Observatory to the study of the sun is added that of the stars for accurately recording the time.

The way of it is this. There are two finely made clocks—the solar clock, keeping the solar time, and the sidereal clock, regulated by observations of the stars. The sidereal clock is kept as the standard, and every night or day the weather permits, any error is determined by comparison of the clocks. The error of the solar clock is then corrected.

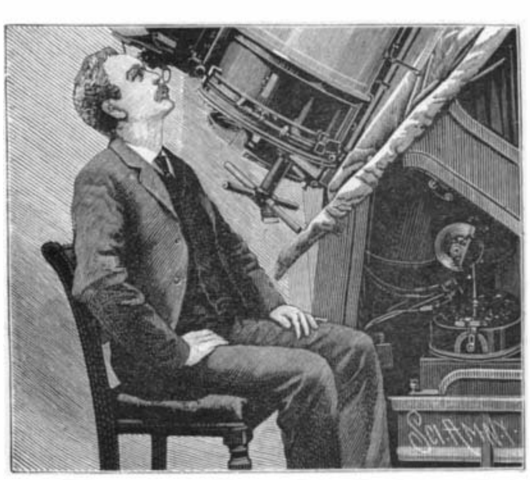
The standard time, therefore, is kept for the nation at Greenwich by constant observation of certain stars, checked by observations of the sun. There are some two hundred and fifty stars calendared at Greenwich, which are known as clock stars. The observations are made with a fine instrument called the transit or meridian circle. Greenwich has the honor of having been the first observatory in the world where a large transit circle was mounted, viz., in 1850. Briefly, it is a large and fine telescope, mounted between two uprights, and pointing exactly to the center line—the meridian—of the heavens, as seen at Greenwich. As the telescope is so hung that it will swing round in, a complete circle between the uprights, it can view any point in this center line of the heavens. The roof of the room in which the telescope is placed can be opened by a sliding or trap door above it, and thus can expose any point of the meridian.

This center line is supposed to be drawn across the heavens from pole to pole of the earth, through the Greenwich zenith; and it is when on this center line in their journey from east to west that the sun and stars are said to be on the meridian. When the sun is on this line, the hour is midday at Greenwich.

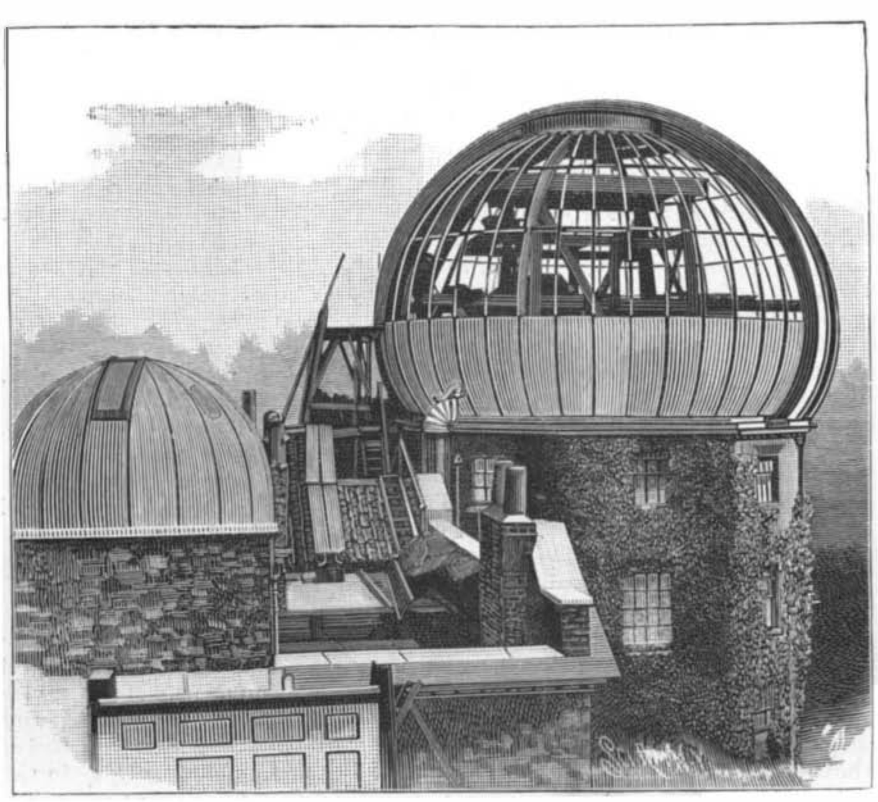
In the eyepiece of the telescope are five wires, one of which is exactly on the middle. When, therefore, the star passes this line, it is at the highest, or crossing the meridian. This, however, is not exactly the same as the actual time, because no transit telescope is probably exactly on the meridian line, and the error is corrected by various calculations.

Connected by electricity with the transit circle is a "chronograph," which at Greenwich is on the other side of the courtyard.

The chronograph is a cylinder on which paper is fixed, and on paper is registered the times of the stars'



THE GUIDER AND PHOTOGRAPHER AT WORK.



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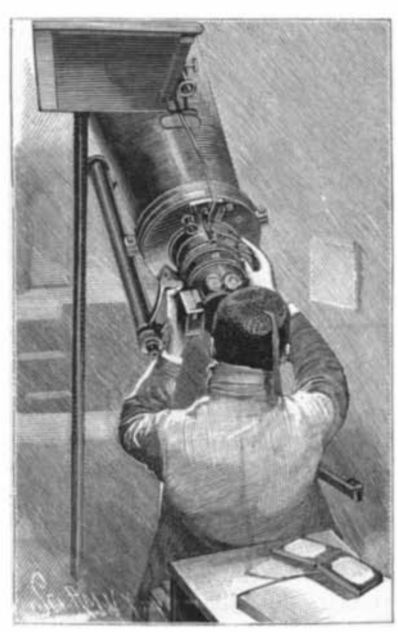

TAKING AN OBSERVATION.