DETERMINATIONS OF GRAVITY.

With the earlier instruments used in gravity determinations, the labor involved in their use was so great that investigations were neglected for half a century. These investigations have been revived within a few years. A short pendulum, one-quarter meter in length, was first employed by Lieut.-Col. Von Sternick, in Austria. Commandant De Forges developed a one-half meter pendulum a little later. More recently Dr. T. C. Mendenhall, superintendent of the United States Coast and Geodetic Survey, designed a one-half second pendulum, which has been much used. In fact, pendulums of this kind have been used in all the recent investigations of the survey. It is by prolonged, patient and careful investigation that the earth's figure is being determined by ascertaining the force of gravity at different points on the earth's surface by means of this pendulum in connection with other apparatus.

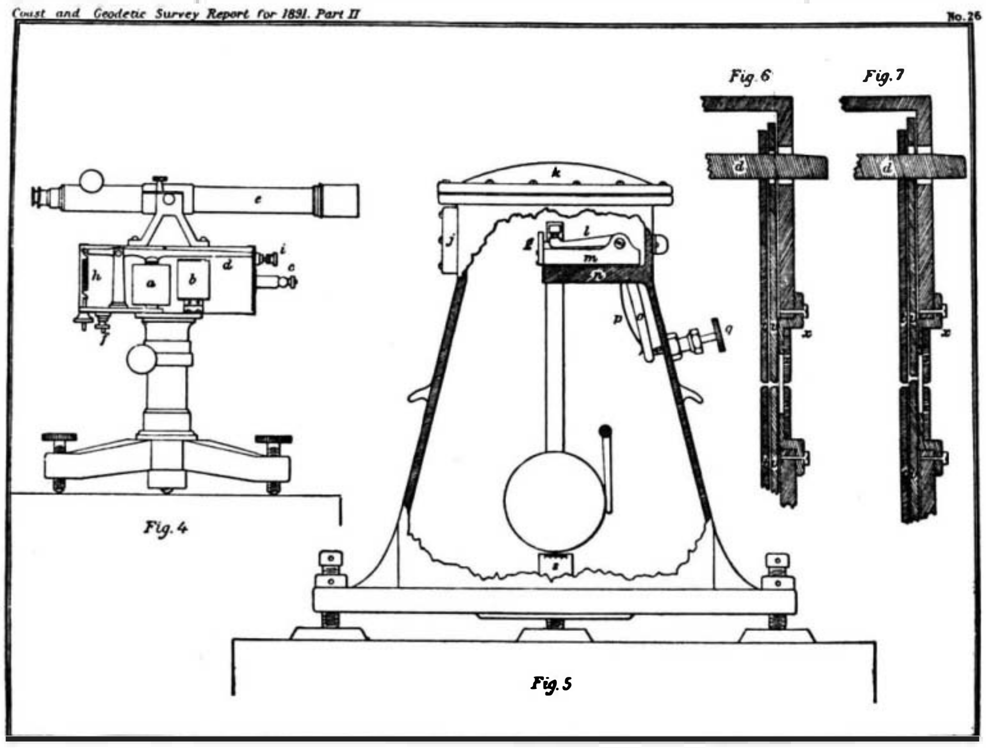
This interesting apparatus is shown in the annexed engravings, in which Fig. 1 represents the pendulum inclosed in an air-tight chamber, the flashing apparatus, observing telescope, the vacuum pump for reducing the air pressure in the pendulum chamber, and the chronometer for controlling the electric circuit so as to produce a flash at stated intervals.

Three pendulums constitute a set. If discrepancies appear in the results, the one at fault may be detected. Each pendulum is designated by a letter, showing the set to which it belongs, and its individual number. The pendulums are made of an alloy of aluminum 10 per cent and copper 90 per cent, a composition which has a very high resistance to corrosion. The pendulums are highly polished, but not lacquered. Each weighs approximately 1,200 grammes, and is about 248 millimeters in length from the center of the bob to the knife edge. The stem and bob are designed so as to offer little resistance to air when in motion. The bob is solid and is 9 centimeters in diameter and 4·5 centimeters thick at the center, its faces being spherical surfaces. The knife edge is a continuous piece of agate passing through the head of the pendulum and firmly secured to it. The edges are formed by the meeting of carefully ground faces at an angle of about 110°. These edges bear upon agate planes, on which the pendulum swings. The two pieces of agate forming these planes are rigidly embedded in a heavy brass plate, m (Fig 5). A small mirror is set in each side of the pendulum head. These mirrors are carefully adjusted, so that from any of the pendulums with either face front, the image of the slit will be reflected into the same portion of the field of the observing telescope. These pendulums are handled with great care, a double jointed handle being provided for lifting them from the case in which they are carried, and placing them in position in the air-tight chamber.

In the flash light apparatus a light metal box is mounted on a stand having both vertical and azimuthal movements, and clamps, and carries above an ordinary observing telescope, which may be focused for objects as near as four feet (Fig. 4). This box contains an electro-magnet, a, whose coils are connected with a chronometer circuit through the binding post, f, and whose armature carries a long arm, d, projecting through an opening in the end of the box. This arm moves two shutters, t and v, which are arranged to emit a flash of light from the box when the circuit is broken, but not when it is closed. The light passes through slits in the shutters and through a slit in the end of the box when the several slits coincide. The light for the flash is furnished by a small oil lamp attached to one side of the box, the light from which is reflected by a mirror in the box, and concentrated by a lens on the slit. After placing the apparatus upon its support, which may be a rock or a pier, the chamber is leveled and the pendulum is put in position. The cap is placed on the chamber, the air pump is attached, and the pressure in the chamber is reduced to about 50 centimeters, as indicated by the manometer on the side of the chamber. The chamber is provided with a starting lever, by means of which the pendulum is carefully drawn aside and allowed to rest for an instant. Then, as nearly as possible in coincidence with the beat of the chronometer, the external arm of the lever is pushed back to its place, thus leaving the pendulum free to vibrate through the desired arc.

The pendulum is capable of continuing its vibration for twenty-four hours after receiving an impulse, but four hours is sufficient for any observation.

A small mirror is placed on the pendulum support parallel and as near to the mirror on the pendulum head as possible without interfering with the motion of the pendulum. The flash apparatus is placed one or two meters from these mirrors and in a line normal to them. A flash of light is produced every second, as determined by the break circuit chronometer. When properly adjusted, the flash is reflected from both mirrors, and assuming the pendulum to be at rest, two lines of light are seen as one in the telescope. Now, suppose the pendulum to be in motion, the flash which occurs for an instant each second will be reflected from the moving and stationary mirrors. If the movable mirror should happen to be in the plane of its original adjustment when the flash occurs, the appearance in the telescope will be precisely the same as when the pendulum is at rest. If the period of the pendulum be precisely one-half that of the chronometer, it will return to this position in just one second, and the appearance will be continually repeated. If, however, the pendulum be slightly slow or fast in relation to the chronometer, the mirror will not be precisely in this position at the end of one second, and the image from the mirror will be a little above or below that of the image from the stationary mirror. In another second the distance separating them will be still greater, and this will go on until the moving image is no longer seen in the field of the telescope. After a time, however (say five minutes), the pendulum will have gained or lost one oscillation on the beat of the chronometer, and a few seconds before the period for this has elapsed, the image reappears in the field and approaches coincidence, to again recede on the other side.

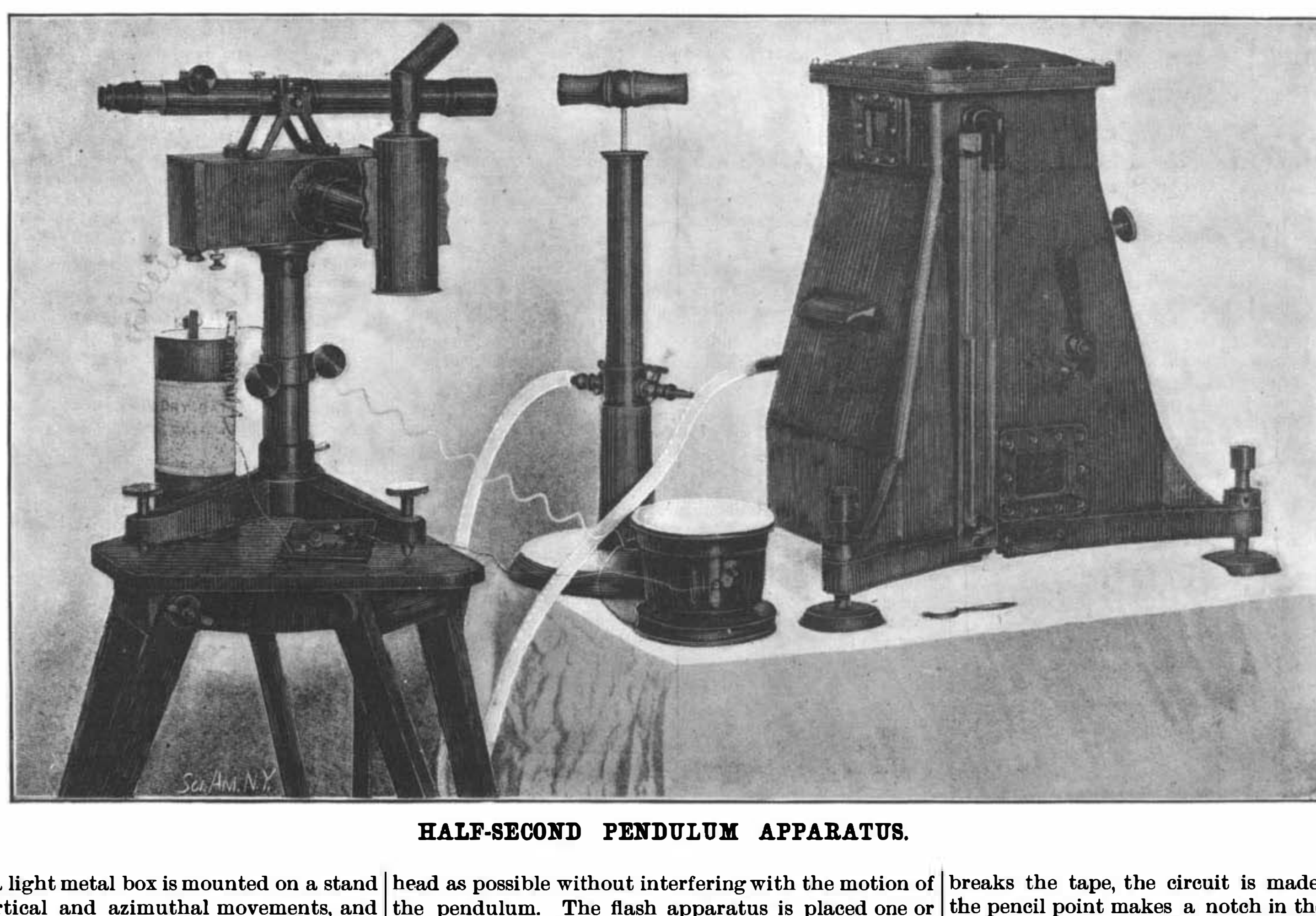


RECEIVER AND FLASH APPARATUS PARTLY IN SECTION.

It is only necessary to observe the instant of this coincidence of the two images. After having ascertained the "coincidence interval" and observed the first coincidence, the happening of any one in the future can be quite closely predicted. An error of one second made in observing the coincidence either at the beginning or end of the swing will produce in the result an error less than one part in 2,500,000. It has been found possible to get a fair rate from an observation from a single pair of coincidences, the time consumed being less than five minutes.

The rate of the chronometer is checked by frequent astronomical observations, and the variations of gravity are determined by the comparison of the pendulum vibrations with the flashes controlled by the chronometer, as already described.

Measurements of the force of gravity relative to the base station, Washington, were made at twenty-six stations, the field work occupying one hundred and fifty days.*



HALF-SECOND PENDULUM APPARATUS.

An Electric Chronograph.

An electric chronograph, on which Profs. Crehore and Austin have been working for some time, was put into operation recently in the races of the Interscholastic Association, of Boston, says the Electrical Engineer. The clock records the time from the report of the starting revolver to the breaking of the tape. Falling weights set in motion a heavy frictionless, rotating wheel. The record of time is made by a pencil on a roll of paper wound about the shaft cylinder. The explosion of the pistol releases the weights and sets the wheel in motion, and at the same time presses the lead on the paper. When the winner breaks the tape, the circuit is made and broken, and the pencil point makes a notch in the record. The instrument is calibrated by an astronomical clock, the recorded revolutions all read by tables and the time deduced in seconds and fractions with the greatest possible accuracy.

* For the information here given we are indebted to the report of Dr. T. C. Mendenhall and a paper read before the Philosophical Society of Washington by George Rockwell Putnam.