ON A NEW SEISMOGRAPH FOR HORIZONTAL MOTION.

By J. A. Ewing B.Sc., F.R.S.E.,
Professor of Mechanical Engineering in the University of Tokio.

Read Dec. 22nd, 1880.

[Abstract.]

The new seismograph is designed to record on a magnified scale two rectangular components of the successive horizontal movements which take place during an earthquake, in conjunction with the time.

Two horizontal levers, set at right angles to each other, are pivotted on vertical axes which are rigidly fixed relatively to the earth. At the short end of each there is a massive bob of metal whose inertia keeps it at rest during the disturbance. The long end of each presses gently on a smoked-glass plate which is kept revolving continously by clock-work. During an earthquake the vertical axes move with the earth, while the bobs of the levers remain steady (as regards motion transverse to the lever) and thus the long ends move radially on the revolving plate through distances which are a certain multiple of the earth's motion, the particular multiple depending on the relative length of the long and short arms of the levers.

The peculiar characteristic of the instrument is this, that the bobs are not rigidly fixed to the levers but jointed in such a way as to allow of relative rotation about a vertical axis, so that when a lever moves angularly about its fixed axis the bob does not rotate with it. Further, each lever is so proportioned that the supporting axis is the centre of percussion relatively to the axis of the bob, which is the corresponding centre of rotation. This insures that when a displacement occurs the inertia of the moving part of the lever does not have the effect of giving the bob any impulse whatever—so that it does not tend to move either in the direction of the displacement or in the opposite direction. The record which is given is therefore a true record of the displacement, and after it is given there is no disposition on the part of the lever either to go on moving in the same direction or to return to its original position until the return displacement occurs. On account of this characteristic property the instrument has been called the *Astatic* horizontal lever seismograph.

The accompanying figures show as much of the apparatus as need be shown for the purpose of explaining its action. Fig. 1 gives a side view of one of the two (similar) levers. The figure is drawn to a scale of about one-third of full size. AA is the supporting axis, the lever being pivotted between a conical point at the bottom and a set screw at the top, which is carried by an inverted stirrup forming one piece with the base plate. In the figure, one side of this stirrup has been removed so that the form of the lever may be seen. The lever consists of a brass piece BB and a long pointer C. At the end of BB the bob D is pivotted. If consists of a solid brass cylinder supported by the short arm of the lever and free to rotate about the axis EE. The pointer C is hinged to the part B in a manner that permits C to move up and down but not sideways, relatively to B. This enables C to rise and fall, following the inequalities in the height of the glass plate which are inevitable during its revolution. The pointer C consists of a single straw tipped

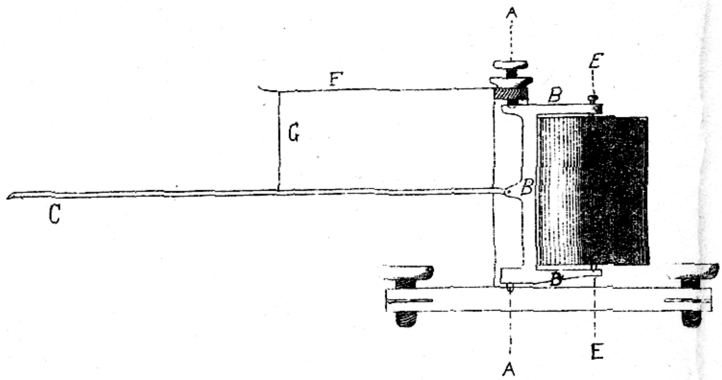

Fig 1

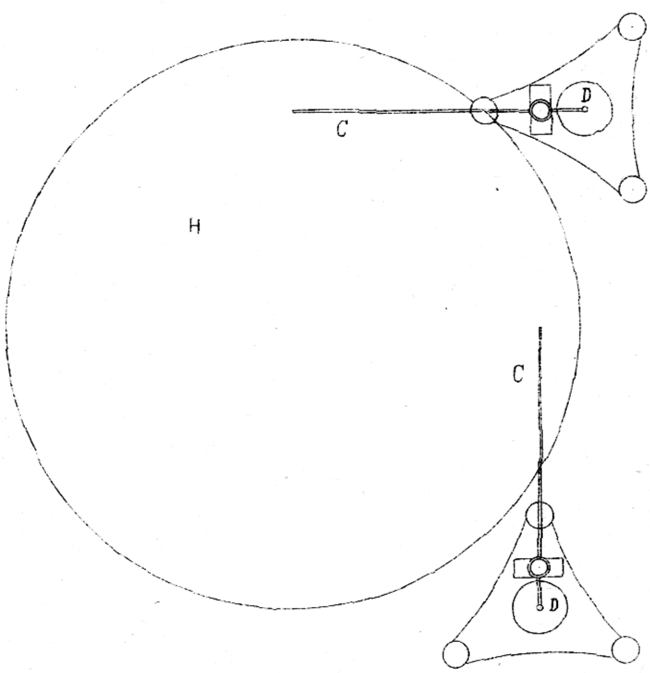

Fig 2

Prof. Ewing's Horizontal Lever Seismograph at its end with a small piece of sharp steel which presses against the revolving plate. In order to diminish the pressure of C on the plate a part of the weight of the straw is borne by a fine steel spring F which stands out from the top of the stirrup, and which is connected to C by a silk fibre G.

The lever consisting of B and C together is proportioned so that the axes AA and EE stand to each other in the relation of centre of percussion and centre of rotation. Hence when, during an earthquake, a displacement of AA occurs transverse to the lever, EE is the axis of instantaneous rotation, and there is therefore no force applied to the bob D to set it in motion in any manner. It remains at rest and the pointer C travels radially over the glass plate through a distance which in the present case is six times as great as the actual displacement of the surface of the earth. This is the ideal action of the instrument, which is to some extent interfered with by friction at the axes AA and EE. By a proper construction of the supporting points the error due to friction may be made insignificantly small.

Each lever stands on the top of a post firmly stuck in the earth and cut off short a few inches above the surface. The base plate is supported by three levelling screws, by means of which the axis AA can be adjusted so as to be vertical. Under the feet of the screws are a pyramidal hole, a V slot, and a plane surface, and the base plate is firmly pressed against these by a single screw bolt in the centre, which is not shown in the drawing. The whole arrangements form what Thomson and Tait have called a geometrical clamp (see T. and T. Nat. Phil. Vol. I. second edition § 198). It gives absolute definiteness of support without the necessity of any nice fitting. Fig. 2 (whose scale is half that of fig. 1) shows in plan the glass plate and the levers in their position relatively to it. The pointers touch the plate at different distances from the centre, and they are placed so that records caused by their movements are drawn in the direction of the radius.

The method by which the glass plate is supported is not shown in the drawing. It is attached to a stout post by means of another geometrical clamp and is kept revolving continuously about a vertical axis through its centre by clockwork. So long as no earthquake occurs each lever draws the same circle over and over again on the plate. When a shock comes an undulating line is drawn the amplitudes of whose waves show the extent and their lengths the periods of the successive movements of the earth.

From the two rectangular components, determined in this way, the magnitude and direction of the actual horizontal motion can of course be found without difficulty.

A contrivance has recently been added to mark times on the plate during an earthquake: this was found to be desirable on account of irregularity in the rotation of the plate. It consists of a short pendulum the bob of which is held deflected from its lowest position by an electro-magnet through which a current passes continually except when it is interrupted by a shock. Then the pendulum is set free and makes a mark on the plate at each swing until it comes to rest. This gives a scale of equal times by reference to which the period of each wave may be determined.

To test the amount of the frictional error the following experiment has been made.

The whole apparatus was put on a shaky table whose movements could be made to imitate those of an earthquake. The two levers, instead of being placed in their usual positions were put side by side, and the bob of one of them was held fixed by a bracket from a neighbouring wall. It was therefore perfectly steady during the artificial earthquakes which were made by shaking the table. When the table was shaken (the glass plate revolving at the same time) two records were given, side by side; one by the lever whose bob was fixed, the other by the lever whose bob was free. If the bob of the second lever had remained stationary the records would have agreed exactly; if not, then the difference between them would show the extent and nature of the frictional error of the apparatus.

The result was very satisfactory. The two records did agree more closely than could have been hoped for, especially when the motions of the table were such that the records resembled those given by actual earthquakes. From this experiment it may be concluded that the indications of the instrument are correct to a close degree of approximation.

An instrument differing only in a few insignificant constructive details from the one just described has been erected in the Engineering Laboratory of the Tokio University and has already given records of a number of earthquakes. A short account of the observations made by its means during the month of November 1880 was communicated to the Asiatic Society of Japan at a meeting held on December 14th. The records already obtained (with one exception) agree in showing that the shocks began very gradually—so much so that one could not say to which side the first deviation took place. All of these lasted for some time and consisted of a very large number of successive undulations—in one case as many as 150 complete waves could be counted, which extended over one and a half minutes of time. The total motion from one side to the other was never more than one-third of a millimetre. The periodic time of the waves varied in different earthquakes, and even in a single earthquake the successive waves differed considerably in this respect as well as in amplitude.

---

* Trrns. As. Soc. Jap. Vol. IX Par. I pp 40-41.