Vertical Motion Seismometer.

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The instrument for recording the vertical component of earthquake motion described below, has been in use for some years in the Seismological Observatory of the Imperial University of Tōkyō and in the Central Meteological Observatory of the same place besides a few other stations in Japan, and has given records of moderate earthquakes as good as, if not better than those given by preexistent instruments. The first working instrument was presented to the general meeting of the Physico-mathematical Society of Tōkyō on June 6th 1898.

The principle of its construction is similar to that of the majority of similar instruments hitherto in use, except that it is free from disturbances due to coexisting components of motion other than vertical and is more compact in its form. It consists of a weight M suspended by means of two spiral springs SS′ in a state of neutral equilibrium (See Fig. 2), so that it is in relative rest when its bearings are subjected to quick motions.

For recording infinitesimal displacements, one of the springs only is sufficient, if the motion be purely vertical. From Fig. 1, we see that the weight M will be in stable equilibrium when the spring is wound until its couple is equal to that exerted by the weight of the mass M about the axis A. It will perform small oscillations about this position, the free period depending upon the inertia of the mass and the restitutional force of the spring. If we now fix a small vertical bar l to the axle A and put a small vertically sliding weight m on it, the system will be brought into a state of unstable equilibrium when m is sufficiently

raised. Its height can be so adjusted that its action just neutralizes the restitutional force of the spring, thus bringing the system into neutral equilibrium. The size of this sliding weight is provisionally calculated by observing the deflection produced when a small weight is added to M, i.e. hung to P: and its position is finally adjusted by carefully sliding it up and down.

The neutral equilibrium of M thus produced,

(1) is limited to a very small extent of displacement; for finite displacement the equilibrium is stable when M is moved downward and unstable when it is moved upward, the arm L being supposed to be horizontal:

(2) is disturbed by the horizontal motion of the ground perpendicular to the axis A of the spring in as much as the center of inertia of the whole mass suspended by the spring is above the level plane through the axle: and

(3) is affected by tilting of the ground.

All these difficulties are overcome by suspending the weight by two springs of equal strength, one on each side, as in Fig. 2, each spring taking one-half of the weight of M which may be twice as heavy as in the previous case. The weight of M is supported by means of an axle fixed to it and passing through a pair of holes in one of the arms (LL′) and through a pair of slots in the other. In order to distribute the couple of the weight equally to the two springs, they are previously tested separately by winding up with a weight ($\frac{1}{2}$ kilogram) one half as heavy as the actual one and the amount of winding is noted by means of graduations made on the box containing the spring; at the same time the sliding weights are adjusted; and when the instrument is set up with the actual weight (1 kilog), the springs are wound to those readings. Thus adjusted, the equilibrium is neutral even if the weight be moved horizontally along the line AA′, for the simple reason that the algebraic sum of the couples which it exerts on the two springs remains constant, as can easily be verified experimentally.

By this construction,

(1) The range of vertical displacement for neutral equilibrium is increased, for now the horizontal distance between the axles AA′ remains constant whatever height the weight M may have, while the restitutional couples of the springs are neutralized by the sliding weight *mm′*. The instruments in actual use record vertical displacements of 3 cm. without much error, in a special instrument designed to record very strong earthquakes, the distance AA′ is 50 cm., and 6 cm. of vertical displacement can be recorded.

(2) The effect of horizontal shocks is practically reduced to nothing as the weights *mm′* act in opposite senses with regard to such motion.

(3) Tilting of the ground also produces equal and opposite effects on the two sliding weights, and so does not affect M. The disturbance hereby produced is of the second order of magnitude depending upon the cosine of tilt and is practically negligeble when it is less than 2 or 3 degrees of arc. The instrument can be put upon a pencil and rocked back and forth without sensibly altering the relative position of M.

The fine adjustment of the tension of the springs is effected by horizontally sliding the catch gripping each box: the ends of those catches are cut into screws one righthanded and the other lefthanded and they are joined by a connecting rod with nuts at each end, the rod itself being held in position by supports *gg′*; thus both of the springs are wound or unwound by equal amounts by simply turning this connecting rod.

The index for recording the motion simply or multiplied, consists of an aluminium lever balanced at its point of support as in instruments hitherto in use: in order to reduce its mass to a minimum, it is to be placed on the cross end of the drum recorder as in Fig. 3, if such be used, and on the curved side if roller recorder be used as in Fig. 4.

The frictional resistances of the instrument, besides that arising from the index which is common to all instruments, is here chiefly confined to the axle of M. and can be reduced by making this axle as fine as possible, and making the holes conical and slots knife-edged. The pivots at A and A′ do not bear any stress in the normal state of the instrument; they only serve to keep the distance AA′ constant. In instruments meant to

record small earthquakes only, those pivots can be entirely dispensed with, and the weight M supported by two pairs of holes or pivots from both of the arms instead of as now by holes and slots.

Feb. 22nd. 1901 Physical Laboratory
Imperial University Tōkyō.

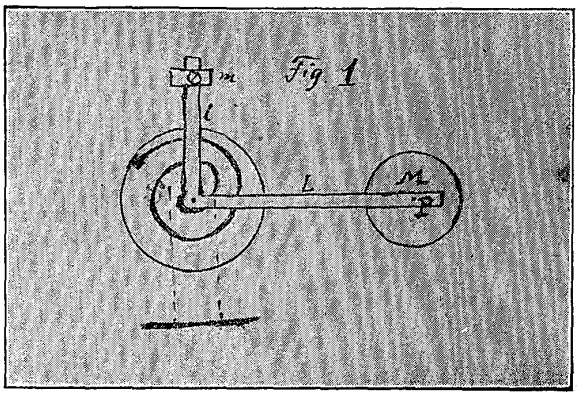

Fig. 1

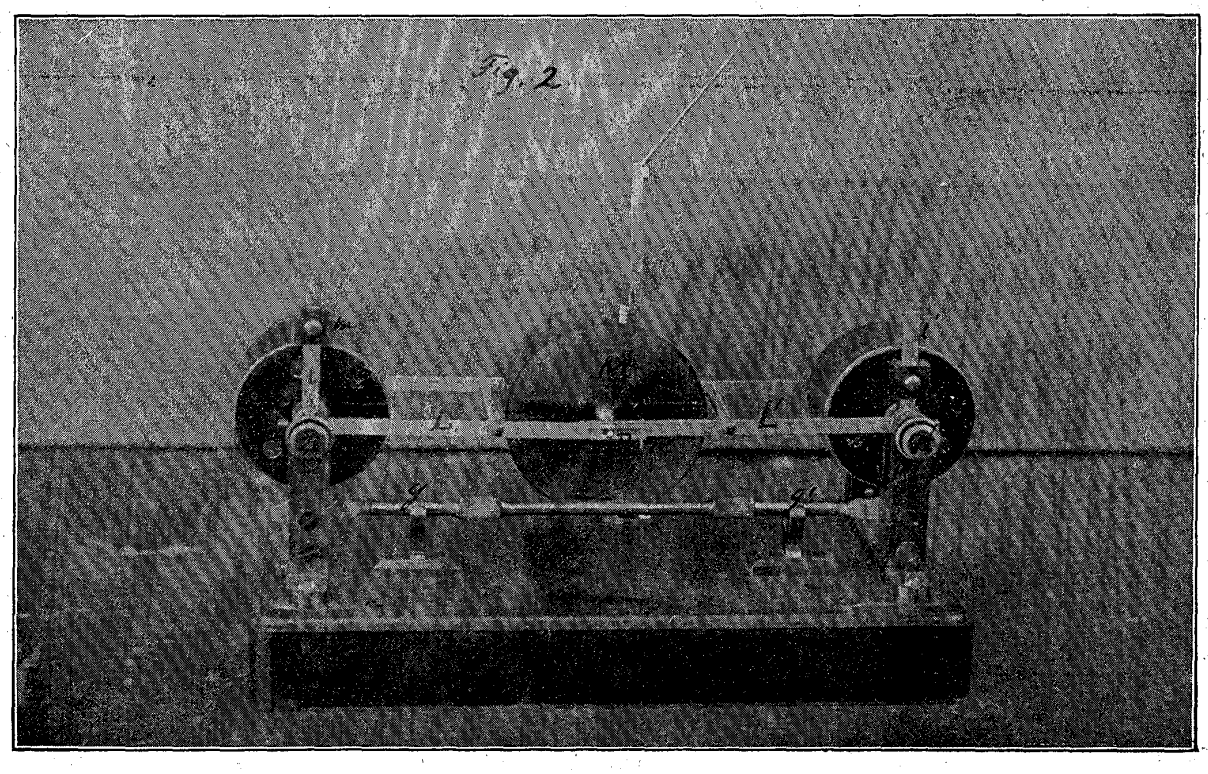

Fig. 2

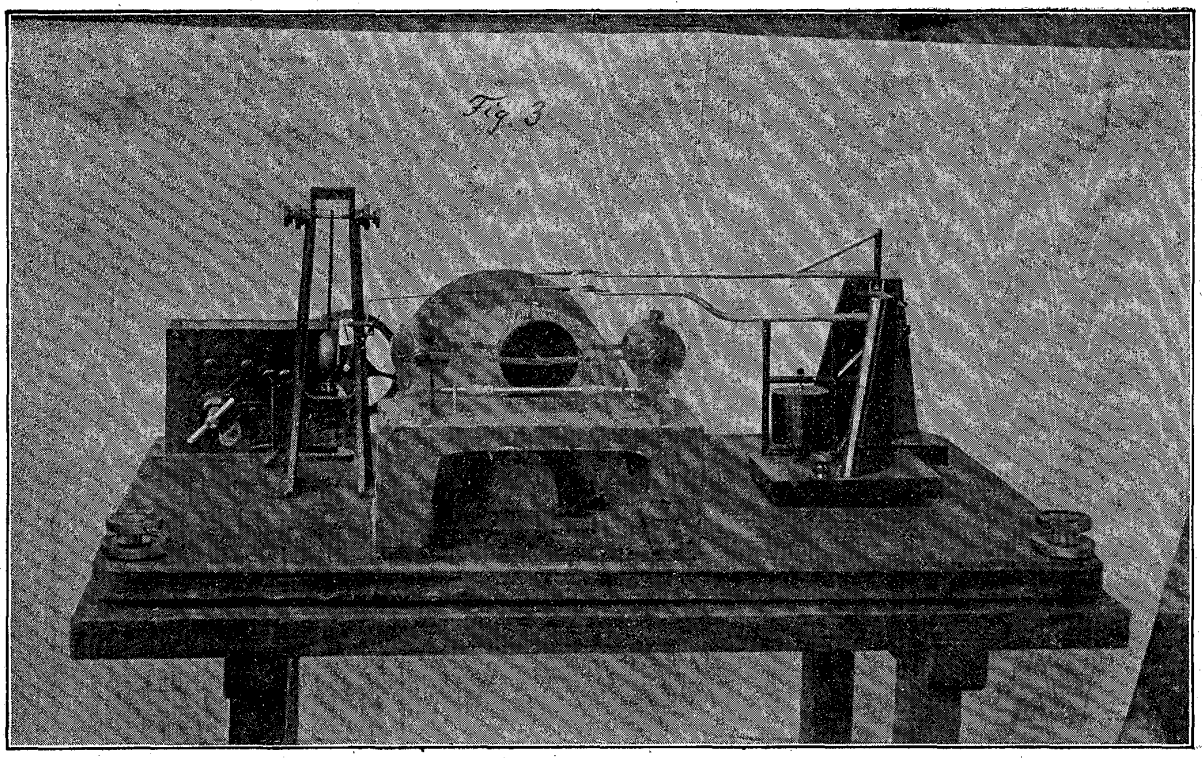

Fig. 3

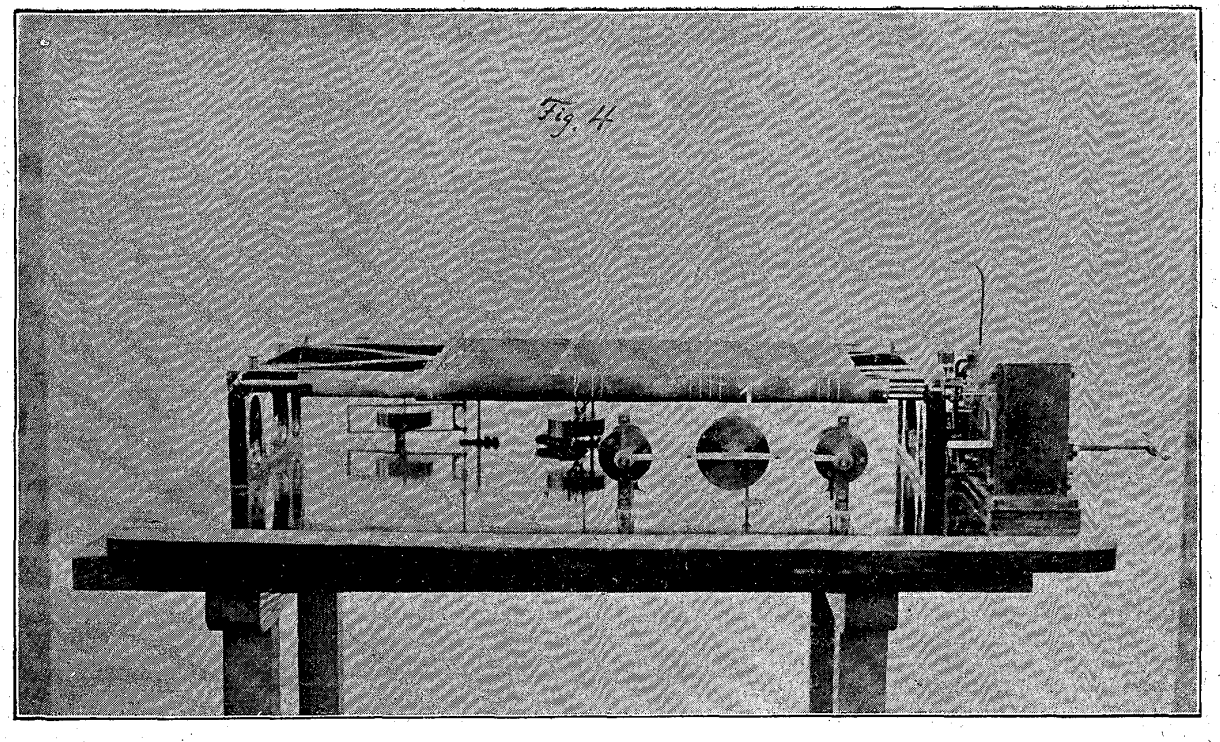

Fig. 4