REPORT ON THE C. I. W. MARINE EARTH INDUCTOR.

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The apparatus was installed on board the *Carnegie* at Papeete, Tahiti, in October, 1912, as follows: The inductor was mounted on the new gimbal stand (Plate I, Fig. 1) in the after observatory, C¹; the galvanometer, in order to eliminate any possible magnetic effect, was fastened by a bolt passing through the hard rubber base of the instrument to a substantial shelf against a wood wall about thirty feet aft of the inductor; communication between the observers at the earth inductor and the galvanometer was established by means of a simple signaling device. The writer, after having taken part in the experimental work at Washington, was assigned as observer on board the *Carnegie* and was placed in charge of the earth-inductor work by Mr. Peters, in command of the vessel, who afforded him every possible facility.

The chief difficulty at sea has been the maintenance of the adjustment of the galvanometer, owing to some minor imperfections which can easily be remedied.² It has been found possible to adjust readily the system at shore stations so that a tip of 20° in any direction, with a scale distance of 58 cm., causes a change of not more than 1 mm. in the galvanometer zero. The failure to maintain balance at sea is also partly due to the temperature and humidity changes. Fortunately, after some practice, it has been found possible to make the adjustment for balance on board, even when the sea is moderately rough, within three to fifteen minutes, depending upon how badly the coil was out of balance and upon the character of the ship's motion. In moderately rough seas, the wandering of the zero is reduced to a range of 5 to 10 mm. when the galvanometer is used with a 100-ohm shunt. Owing to the lack of symmetry in the balancing arrangements, it is difficult to throw the center of gravity of the coil into the line of suspension. By manipulation, it has been found easier to place the center of gravity in a plane at right angles to the coil than in the plane of the coil; for this reason the galvanometer has been mounted with the plane of its coil fore and aft.

The *general scheme of observation* used on board the *Carnegie* between Papeete, Tahiti, and Coronel, Chile, during October 15 to November 26, 1912, was as follows: The galvanometer was

¹ *Terr. Mag.*, v. XV, 1910, plate III, station C, opposite p. 62.

² *Terr. Mag.*, v. XVIII, 1913, p. 44.

shunted so that its turning points could be read satisfactorily. The horizontal circle of the inductor was set with the rotation axis in the magnetic meridian. The vertical circle was then set approximately one degree less than the actual magnetic inclination and the coil was spun, in a righthand direction, at the fixed speed adopted for the particular observations, and the turning points of the galvanometer were noted. The coil was next spun in the opposite direction at the same speed and similar galvanometer readings were made. Similar readings followed for the vertical circle set about one degree above the approximate reading of the magnetic inclination. From these readings the sensibility of the instrument was determined as also, by linear interpolation, the setting for which the mid-point will be independent of the direction of spin. Thus, if A was the first vertical circle setting, the reading of the vertical circle for the position of balance, assuming no appreciable variation in thermoelectromotive force due to possible changes in temperature at the commutator, would be $A + \left(\frac{D_1}{D_1 - D_2} \right) \Delta$, where D_1 is the difference between the galvanometer readings for righthand and lefthand rotation at the first vertical circle setting, D_2 the corresponding quantity for the second setting of the vertical circle, and Δ the difference between the two settings of the vertical circle. Usually the observation began with the vertical circle east of the magnetic meridian, so that a second determination similar to the one outlined above was then made with the vertical circle west. From these two interpolated positions of balance the angle of dip may be determined readily by combination of the results. The speeds used in rotating the coil have been within the limits of 60 to 120 turns of the crank per minute; by reason of the multiplication of the gear system, this is equivalent to from 250 to 500 revolutions per minute of the coil.

As the interpolation term may be subject to error because of any change in the sensibility of the galvanometer, or in the quality of insulation, or in the resistance of the various contacts and portions of the circuit, a sharp lookout was kept for any leakage, this being indicated by a decrease in the sensibility of the galvanometer. To prevent this, all insulated surfaces were greased with vaseline or good kerosene and wiped off and regreased frequently. The term may also be subject to error if there is variation in the thermoelectromotive force, due to changes of the temperature at the commutator during the observation. The commutator was, there-

fore, kept well lubricated with vaseline, in order to reduce the possibility of such variation.

For the above scheme of observation four persons have been generally used: two at the galvanometer, one to read and the other to record; two at the earth inductor, one to make the circle settings and to rotate the coil, the other to record the settings and to keep the meridional plane of the instrument in the magnetic meridional plane. The last operation is of the same importance as in the use of the dip circle, and is maintained by reference to a standard Ritchie compass, where simultaneous observations are being made by another observer in connection with the horizontal intensity observations.

In the first work on board ship it was attempted to form mental means of the galvanometer deflections. This was found to be fairly satisfactory when the sea was smooth, but impracticable under ordinary conditions, on account of the swinging of the gimbal. The method finally adopted was to read ten pairs of turning points for each operation of the earth inductor. It has been found that four determinations of the dip, namely, circle east and circle west, with the gimbal rings both direct and reversed, are necessary in order to give a result that can be repeated within one or two minutes of arc (this statement applying for dips from 45° to 55° and total intensity from 0.4 to 0.5 C. G. S.). The whole operation as outlined requires from 13 to 16 minutes.

At times the successive determinations have agreed exactly, more frequently they have differed by a few hundredths of a degree, and occasionally they have varied by three or four tenths of a degree. The cause or causes of the occasional large variations are being investigated. The earth-inductor observations have been made on nearly every day the dip circle was used, sometimes before and after, and sometimes in the middle of the dip-circle work, so that the earth-inductor values and those of the dip circle apply to the same times and positions. On two different occasions the whole afternoon was given to determination of dip by the earth inductor. Of six determinations, all applying to the same position and time on one of these days, the extreme difference from the mean in the case of one value was $0^{\circ}.25$, of a second value $0^{\circ}.18$, while the other values differed by less than $0^{\circ}.1$ from the mean. The second day's work gave eight determinations, none of which differed from the mean by as much as $0^{\circ}.1$. This work was done while the ship was becalmed so that the only motion was rolling. It is hoped that the mean values of the magnetic inclination determined at sea with the inductor may be depended upon finally within an absolute accuracy of three minutes of arc, or less.

On the "Carnegie," Coronel, Chile, Nov. 26, '12.