of construction, as well as of the other errors introduced in the measurement of the horizontal intensity, are given in sufficient detail.

It is shown that the errors in reading the circle and the scale, when sufficiently large angles are used, and the error in the constant of the coil are quite negligible; and that the only other error necessary to consider, viz., that introduced in the measurement of the current traversing the coils, can also be made entirely negligible. In consequence the horizontal intensity of the earth's magnetic field can be determined with an error less than 1 part in 10,000, which is the precision desired, while the magneticians consider 1 part in 5,000 adequate.

With this instrument it is possible to make several complete determinations of the horizontal intensity in one minute; while at least from half an hour to an hour is required with the magnetometer method.

In addition to the preliminary experimental tests, two considerable series of simultaneous determinations of the horizontal intensity have been made with the sine galvanometer and a standard C.I.W. magnetometer by Messrs. Fleming, Fisk, Peters, Ives, and the author. The intensity variations determined from the galvanometer readings have also been compared with those obtained from simultaneous magnetograms of the Cheltenham Observatory. An account of this work will be published shortly by others. The intensities as determined by the different instruments agreed within 1 part in 25,000, though the errors of the electrical standards used, are not known with a precision such as to justify the expectation of an agreement much beyond one part in 4,000 between the absolute value, even if it were not for the limitations of the magnetometer method.

The complete paper will appear shortly in the *Researches* of this Department.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
CARNEGIE INSTITUTION OF WASHINGTON.

RESULTS OF COMPARISONS OF INSTRUMENTS FOR MEASURING THE EARTH'S MAGNETIC ELEMENTS.

BY LOUIS A. BAUER AND J. A. FLEMING.

DURING the period 1905 to 1921 the Department of Terrestrial Magnetism of the Carnegie Institution of Washington has had the opportunity to carry out intercomparisons of magnetic instruments all over the globe. These intercomparisons have been made at the chief magnetic observatories and at various stations of the Department of Terrestrial Magnetism. Thus the intercomparisons apply not alone to the magnetic instruments as designed and constructed by the Department of Terrestrial Magnetism, but also to magnetic instruments of various designs in use by the chief magnetic services. The resulting data besides yielding the information required for the correlation and reduction of magnetic observations made by existing organizations, have likewise yielded results having important bearings upon the principles and methods of magnetic measurements.

One of the most interesting series of such comparisons was that made recently at the standardizing observatory of the Department of Terrestrial Magnetism between our previously adopted standard magnetometer and a sine galvanometer, designed by Dr. Barnett and constructed in the workshop of the Department. With the latter instrument the value of the horizontal intensity of the earth's magnetic field is determined by an electric method, whereas with the standard magnetometer the same magnetic element is obtained by the usual magnetic method. The results of the comparisons between the two instruments showed satisfactory agreement in the values of the horizontal intensity obtained by the two independent methods.

CARNEGIE INSTITUTION.

FURTHER RESULTS OF LINE INTEGRALS OF THE EARTH'S MAGNETIC FORCE.

BY LOUIS A. BAUER AND W. J. PETERS.

A PAPER was presented by the first author at the joint Chicago meeting of Section B of the American Association for the Advancement of Science and the American Physical Society, on December 30, 1920, giving results respecting possible vertical electric currents cutting the earth's surface. The results were obtained on the basis of the magnetic data accumulated by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

The present paper gives additional results as derived from recent computations of line integrals around circuits formed by the tracks of the magnetic-survey vessel, the "Carnegie," and the trips of land expeditions sent out by the Department of Terrestrial Magnetism.

One of the most interesting circuits was that formed by Cruise III of the "Carnegie" in the North Atlantic Ocean, in 1914 extending from New York to 80° north, off the northwest coast of Spitzbergen. This circuit embraces an area of 4,441,176 square kilometers. The result of the line integral around this circuit was such as would be produced by currents of positive electricity passing through the air perpendicularly through the earth's surface of average strength one twentieth of an ampere per square kilometer. For the sake of comparison it may be recalled that the line integral around the United States, as based upon the most recent magnetic data, gives a result which could be produced by currents of positive electricity passing from the air perpendicularly through the earth's surface, having an average strength of about one-thirtieth of an ampere per square kilometer.

From the foregoing it is seen that the results of two line integrals, one over an ocean area exclusively, and the other over a land area exclusively, are of the same sign and are practically of the same magnitude. On the other hand, the vertical currents as disclosed by atmospheric-electric observations, according to present methods over the regions of the two line integrals agree, however, in direction with the results of the magnetic line integrals. Quantitatively, there is a pronounced discordance. The strength of the vertical conduction currents