18. *A New Method for Regulating Electric Currents and its Application to Measurements of Geomagnetic Field.*

By Izumi YOKOYAMA,

Earthquake Research Institute.

(Read April 21, 1953.—Received June 20, 1953.)

1. Introduction.

Among the various observations in geophysics, one of the most precise measurements is to determine the geomagnetic field with the sufficient accuracy, i. e. with the error less than 0.1 *minutes* of arc in declination and inclination and 1 *gamma* in intensity. In 1948 a portable electromagnetic magnetometer using a rotating coil as a detector for measuring the three elements of the geomagnetic field with the aforementioned preciseness was completed by I. Tsubokawa[1] of the Geographical Survey Institute and named "G. S. I. first order magnetometer".

Recently the Earthquake Research Institute has commenced to utilize the G. S. I. second order magnetometer which was also completed by Tsubokawa with the intention of simplifying the first order one at the least cost of the preciseness. For the sake of the magnetic surveys we ourselves aimed at, such as those at volcanoes and earthquake zones in case of emergencies, we devised a new method for regulating electric currents in place of the astatic galvanometer which was found to be rather inconvenient in field works.

2. A new method for regulating electric currents.

The G. S. I. type magnetometer consists of a small rotating coil as a detector and a Helmholtz-Gaugain coil to generate a constant magnetic field which are mounted on the horizontal axis of a theodolite. The axis of rotation of the detector, the central axis of the Helmholtz-Gaugain coil and the horizontal axis of the theodolite are arranged at right angles to one another. The electromotive force generated in the detector can be sensitively detected by a high gain amplifier with a magic-eye. The declination and inclination are simultaneously measured by adjusting

1) I. TSUBOKAWA, *Bull. G. S. I.*, **2** (1951), 325.

successively the horizontal and vertical directions of the axis of rotation of the detector so that the output of the amplifier becomes null, letting no current pass through the Helmholtz-Gaugain coil. The geomagnetic intensity can be measured by finding the direction of the resultant of the geomagnetic field and the constant induced field by the Helmholtz-Gaugain coil. The schematic diagram is shown in Fig. 1.

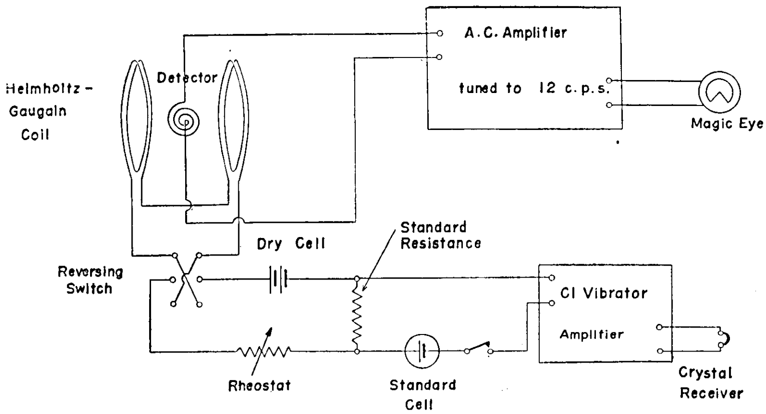

Fig. 1. Schematic diagram of the G. S. I. type magnetometer.

The electric currents passing through the Helmholtz-Gaugain coil are regulated to be constant by adjusting the rheostats so as to nullify the current in the standard-cell's circuit. Then the voltage-drop in the standard-resistance becomes strictly equal to the voltage of the standard-cell and the value of the electric current may be known exactly from the values of the standard-resistance and electromotive force of the standard-cell both being corrected by the temperature coefficients.

The balance of the standard-cell's circuit is detected by a new method in place of an astatic galvanometer of the sensitivity 10^{-6} *volt*. The circuit-diagram of the new method is shown in Fig. 2. The direct-voltage is converted into an alternating one of 1,000 c. p. s. by intermittent contact of the osmium point of the so-called "CI vibrator" which is excited by a circuit containing a small carbon-microphone, an electromagnet, and dry batteries. The voltage of the 1,000 c. p. s. alternating-current which is the same amplitude with the applied direct current, is implied in an ordinary audio-amplifier. According to the result of the experiment, the gain of the amplifier is about 40 *db* when we use 67.5 *volts* as B electric source. The output of the amplifier is connected to a high-impedance crystal receiver made of rochelle salt. The observer hears a sound of

1,000 c. p. s. modulated by the electric current in the standard-cell's circuit and no signal when the balance is completed. As our sense of hearing is most sensitive in the neighbourhood of 1,000 c. p. s., the above-mentioned method of detection is efficient and appropriate. The rheostat in Fig. 1 is able to control about one part in 100,000 and this detector is sensible of the change in this one part near the state of balancing as a result of the experiment. The magnet included in CI vibrator, whose magnetic field we had apprehension of, has been ascertained to have no appreciable influence upon the detector of the magnetometer at a distance of about 3 *meters*.

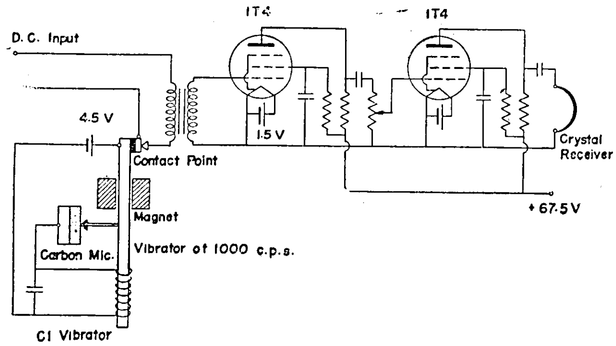

Fig. 2. Circuit-diagram of the CI vibrator-amplifier.

3. Observations of geomagnetic field using this method at the Kakioka Magnetic Observatory.

In order to determine the coil constant of the G. S. I. second order magnetometer and examine the accuracy of observations, the comparison measurement with the standard magnetometer of the Kakioka Magnetic Observatory was carried out in Oct., 1952. The above-mentioned method for regulating electric currents of the Helmholtz-Gaugain coil was applied to determining the horizontal intensity. The time required for one complete observation is less than 10 *minutes*. The results of the observation are shown in Table I and graphically represented in Fig. 3 compared with the values obtained from the magnetogram of the Observatory. The variometer-room is about 40 *meters* distant from the absolute observatory in which our observation was made. From these values, the instrumental errors and the probable errors of single observation are deduced as shown in Tables II and III, the magnetogram of the observatory being considered true. Table IV shows the other probable errors of single observation deduced from the fluctuations of the reading values independent of the magnetogram, on the assumption that the directions of the horizontal and vertical axes of the theodolite are invariable by revolving and that the respective

Table I.
Results of the comparison measurement.

Time	Declination		Inclination		Horizontal Intensity	
	Observed value	Magneto-gram	Observed value	Magneto-gram	Observed value	Magneto-gram
1952, Oct. 2nd						
09h 50m	6°24'.2w	6°24'.1w	49°23'.0	49°22'.6	30054γ	30051γ
11 46	27.6	27.8	23.2	22.4	63	66
13 28	25.4	25.6	23.3	22.5	72	69
14 40	24.1	23.4	23.3	22.7	64	65
15 59	21.5	21.9	23.9	23.1	63	61
17 01	22.5	22.5	23.9	23.1	64	62
17 37	22.5	22.4	23.9	23.2	62	60
20 39	22.4	22.6	24.1	23.4	59	58
21 16	22.4	22.7	24.5	23.5	53	55
21 51	22.6	22.6	24.8	23.8	48	50
22 32	22.0	21.9	24.8	23.8	46	50
23 08	21.2	21.2	24.2	23.5	63	64
23 48	21.4	21.4	24.4	23.6	59	59
3rd						
00 32	21.7	21.7	24.4	23.6	61	60
01 10	21.4	21.4	24.5	23.6	62	61
07 46	22.5	22.3	24.3	23.6	46	46
08 31	22.9	22.8	24.0	23.5	50	50
09 18	24.3	24.0	23.8	23.2	48	53
09 58	25.8	25.1	23.5	23.0	45	52
10 36	27.1	26.5	23.6	23.2	45	47
11 22	28.2	27.6	24.1	23.6	42	43
12 06	28.5	27.7	24.3	23.8	43	45
14 35	25.2	24.8	24.4	23.8	50	50
15 18	24.7	24.3	24.2	23.9	45	46
15 56	23.8	23.6	24.2	23.9	53	47
4th						
09 17	23.9	24.2	24.8	24.4	16	17
10 06	26.4	26.4	24.5	24.1	34	32
11 10	26.5	26.3	24.3	23.5	46	44
11 48	26.2	26.1	23.7	23.3	52	51
16 28	25.7	25.6	28.6	27.7	29966	29965
17 04	24.3	24.1	28.5	27.8	977	971
17 32	23.7	23.8	28.3	27.8	989	982

Table II.
Instrumental error.

Westerly Declination	Inclination	Horizontal Intensity
-0′.13	-0′.65	*

* Coil constant was determined by the least square method.

Table III.
Probable error of a single observation deduced from the comparison with the magnetogram.

Declination	Inclination	Horizontal Intensity
0′.20	0′.13	1.5γ

Table IV.
Probable error of a single observation deduced from the fluctuations of reading values.

Declination	Inclination	Horizontal Intensity
0′.22	0′.16	1.6γ

components of geomagnetic field are constant during the time of observation.[2)]

As shown in Table II, the instrumental error in inclination is of not negligible quantity. This may be attributed to the following origins:

1) The systematic errors of the magnetometer due to errors in graduations of circles or some magnetic deposits.
2) The difference of the main field between the variometer-room and the absolute observatory.
3) The systematic errors of the standard magnetometer — the values of inclination corresponding to magnetogram in Table I are computed from the magnetograms of horizontal and vertical components.

Referring to Tables III and IV, it may be said that the probable errors of single observation are respectively less than 0′.20 in declination, 0′.15 in inclination and 1.5γ in intensity.

2) *loc. cit.*, 1), 357.

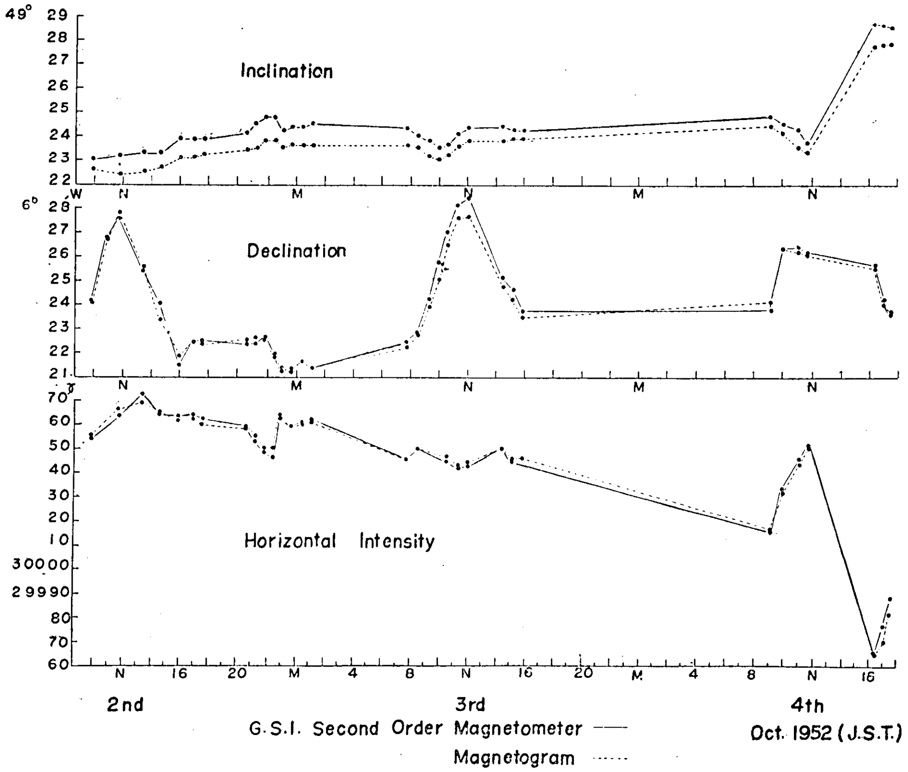

Fig. 3. Results of the comparison measurement.

4. Conclusion.

As a result of the comparison measurement with the standard magnetometer, it was found that the new method for regulating the electric currents applied to measurements of geomagnetic field is almost as highly sensitive as the astatic galvanometer and furthermore that it lightens the observer's burden in field works. The G. S. I. second order magnetometer was also found to be very excellent in its simplicity and rapidity of operation and in its high accuracy.

In conclusion, the writer wishes to express his hearty thanks to Dr. T. Rikitake for his helpful support. The writer also wishes to record his indebtedness to Mr. I. Tsubokawa of the Geographical Survey Institute. The writer's hearty thanks are also due to Mr. T. Oguchi who assisted the writer in the comparison measurement.

18. 電流を制御する新しい試み及びその地磁気測定への応用

地震研究所 横 山 泉

今迄，地磁気を電磁的に測定する場合，ヘルムホルツ・コイルに通ずる電流をポテンシオメーター的に制御するに際して，無定位電流計が用いられた．これは野外観測においては種々の煩わしさを伴うものであった．今回，この無定位電流計の代りに CI 発振器を利用した直流増幅器を用いた．柿岡における比較観測の結果から，この新しい方法は十分な精度を有するものであり，又，観測者の負担を大いに減ずるものであることが判った．