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ONDERWERP:
SUBJECT: MEASUREMENT OF THE MAGNETIC PROPERTIES OF MAGNETITE ACCORDING TO THE TWIN ISTHMUS METHOD.

AFDELING:
DIVISION: CHEMISTRY

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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

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MEASUREMENT OF THE MAGNETIC PROPERTIES OF MAGNETITE ACCORDING TO THE TWIN ISTHMUS METHOD.

1. INTRODUCTION.

If one wants to study the magnetic properties of magnetite such as coercive force, remanence, saturation magnetisation and susceptibility, the hysteresis loop and the normal magnetisation curve have to be determined. These properties determine the behaviour of magnetite materials such as the powder used in heavy medium coal washers.

The susceptibility and the magnetite content of magnetite samples are the properties that determine the attractive force necessary to recover the magnetite at the plant separator.

From the coercive force the magnetic hardness can be derived on which the ease or difficulty of magnetisation and demagnetisation of these powders in the washing plant depends. The first aspect will make collection in the magnetic separator more difficult, and the apparatus may behave as if it were overloaded. The last aspect could cause an unstable suspension in the washer.

A knowledge of the coercive force, which is proportional to the specific surface of the magnetite powder, permits conclusions regarding the mean grain size of the powder.

2. DESCRIPTION OF METHOD.

For these measurements the twin isthmus method according to V.H. Gottschalk and C.W. Davis[1] is used. Two identical capsules (See Figure 2, 3 and 4), one empty and one containing the magnetite powder to be measured, are inserted parallel to one another into a gap of the iron core of an electromagnet (See Figure 1 and 2), so that the powder forms a closed magnetic circuit with the iron core of the electromagnet. Both capsules are provided with identical secondary

windings.../

windings. The primary windings are those of the electromagnet.

When the field strength is changed suddenly from one value to another, the resulting change of induction can be measured by means of the deflection of a ballistic galvanometer connected to one of the secondary windings. The galvanometer throw caused by the secondary windings of the empty capsule is proportional to the field strength of the air gap, the throw caused by the windings of the filled capsule is proportional to the magnetic induction of the magnetite. When the two secondary windings are connected in series and opposed*, the throw gives the difference between the induction and the field strength which is the magnetisation.

For calibrating the field strength in the air gap against the exciting current of the electromagnet, the secondary windings of the two empty capsules are connected in series and added** so as to increase the galvanometer throw.

For the measurement of the ballistic galvanometer constant K a mutual induction standard was used.

3. DESCRIPTION OF THE TWIN ISTHMUS APPARATUS.

(a) The Electromagnet.

The two capsules (Figure 3 and 4) can be inserted into the air gap of the electromagnet (See Figure 1 and 2) and kept in place by means of two wedges (See Figure 2) constructed from the same transformer plates used for the core of the electromagnet (containing 57 transformer laminations each 0.89 mm thick).

To ensure that the capsules are always kept in the same position an adjusting plate (made from non-magnetic material) is fastened beneath the air gap (See Figure 1 and 2). The common bottom plate (made of soft iron) of the two capsules (Figure 2 and 3) and the two wedges rest on this plate. Simultaneously this plate has the function of keeping the length of the air gap constant.

The.../

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* This means that the induced voltages are opposed.

** This means that the induced voltages are added.

The common bottom plate of the two capsules is supplied with an adjusting rod (See Figure 3) which must touch the adjusting plate. This serves to position the capsules inside the air gap. Capsule No. 2 opposite the adjusting rod is always placed at the top to prevent the cooling oil (see later) from penetrating into this capsule. For this reason this No. 2 capsule is selected to contain the magnetite powder.

The windings of the two coils of the electromagnet are designed in such a way so that with an exciting current of 4.5A a field strength of approximately 3350 oersteds is obtained without overdue heating of the magnet (approximately 980 windings of 16 gauge wire on each coil).

Because the heat generated by the electromagnet affects the exciting current, the magnet was placed in transformer oil (Figure 2) which is cooled by passing water through a copper spiral.

(b) Primary Current Circuit.

In Figure 5 the primary current circuit is shown. Two heavy motor car batteries in series, each of 12 volt, are the current source. The exciting current can be rapidly changed from one fixed value to another by the following means: fixed resistances R_2 to R_{10} are connected in series and 10 single throw knife switches serve to short-circuit the resistances as desired. The current can thus be increased or reduced step by step. R_1 is variable and is used to readjust the current when necessary. In Table Al the special specifications and current intensities used are tabulated.

Table Al.../

TABLE A1.

SPECIFICATION OF RESISTORS AND CURRENTS USED IN PRIMARY CURRENT CIRCUIT.

TYPE OF RESISTOR	RESISTORS	MAXIMUM CURRENT	RESISTANCE USED IN OHMS	CURRENT USED IN A
RHEUSTAT	R_1	8.5A		4.3
	R_2	8.5A	6.0	3.2
	R_3	8.5A	3.75	2.1
	R_4	1.4A	14.0	1.45
	R_5	1.4A	12.0	0.82
	R_6	1.4A	33.5	0.40
	R_7	1.1A	104	0.14
ADJUSTABLE WIRE WOUND RESISTORS	R_8		200	0.063
	R_9		250	0.038
	R_{10}		2050	0.011

In Figure 5 M_p represents the primary windings of the electromagnet and R_p the primary windings of the mutual induction standard which is used for measuring the ballistic galvanometer constant. The mercury change-over switch S serves to switch the electromagnet on for magnetic measurements or the mutual induction standard for standardising. The mercury commutator K is used to reverse the current in the electromagnet. This switch can be operated by a motor with a switching period of 6-7 commutations/sec., specially for demagnetisation purposes before measuring normal magnetisation curves. It was tried to suppress the vigorous sparking during switching by connecting condensers across the switch, but no success was achieved. Therefore, no suppression for the sparking was used. Gottschalk and Davis[2] found no difference in galvanometer deflections with or without the condensers.

To demagnetise the samples the electrolytic variable resistance N must be connected by means of the switch T. The resistance N consists of 5 glass cylinders each containing one

litre.../

litre of an electrolyte with one copper electrode at the bottom and a movable one. By increasing the distance between them, the resistance is increased. The first cylinder contains a saturated NaCl solution, the second about 30%, the third 10%, the fourth 3% NaCl and the fifth distilled water.

By means of this facility it is possible to reduce the exciting current while reversing from 5 to 0.00003A. This current must often be checked and if necessary the solutions in the first four cylinders must be diluted and the distilled water of the fifth renewed.

The current is measured with a Multizet amperemeter (Siemens, VAΩ-meter), using the following ranges: 10, 3, 1, 0.3 and 0.1A.

(c) Twin Isthmus Capsules.

The capsules are shown in Figure 2, 3 and 4. They are built according to Figure 24 in Dean and Davis's publication[3]. The construction of these capsules guarantee that the volume of the contained mineral powder is invariable and known to within a fraction of 1 percent from the geometrical dimensions. The internal dimensions of the two capsules used, are tabulated in Table A2.

TABLE A2.

THE INTERNAL DIMENSIONS OF THE TWO CAPSULES.

CAPSULE NO.	DIAMETER (cm)	HEIGHT (cm)	VOLUME (cc)	USED	PURPOSE
1	1.618	1.394	2.87	empty	field strenght
2	1.626	1.393	2.89	filled	induction

All figures tabled were obtained by measurements which were repeated 10 times by means of a micrometer. The knowledge of the volumina is necessary for the determination of the packing densities of the powder samples. The common bottom plate and the two top lids are made of soft iron and the cylinders of brass. Because a common bottom plate is used for the two capsules it is easier to adjust the capsules in the yoke of the electromagnet as described above. Repetitions of the magnetic measurements after removing and replacing the capsules gave good agreement. See column 11 of Table B4a,

column 10.../

column 10 of Table B5a, column 11, 12 and 13 of Table B6a and their descriptions on pages 17 and 18.

The external dimensions and the number of windings of the secondary coils which are necessary for the calculation of the magnetisations of the powder samples and of the field strength are tabulated in Table A3.

TABLE A3.

THE EXTERNAL DIMENSIONS AND THE NUMBER OF WINDINGS OF THE SECONDARY COILS.

CAPSULE NO.	EXTERNAL DIAMETER OF BRASS CYLINDER mm	DIAMETER OF BRASS CYLINDER AND LAYERS OF WIRE WINDINGS mm	NUMBER OF WINDINGS OF				RESISTANCE OF SECONDARY IN OHM
			1st LAYER	+2nd LAYER	+3rd LAYER	+4th LAYER	
1	20.12	21.09	62	124	185	245	32.2
2	20.10	21.07	62	124	184	245	32.5
Mean	20.11	21.08					

The diameters were measured 6 times by means of sliding callipers. To obtain the mean area of the windings of the two capsules the mean external area of the two brass cylinders (3.176 cm^2) and the mean area of the two cylinders plus the 4 layers of windings on each cylinder (3.490 cm^2) were calculated. The mean area value of the windings must be

between.../

between these two values and near to the mean (3.333 cm^2) of these values.

(d) Secondary Current Circuit.

In Figure 6 the circuit of the secondary current is shown. $G = 300\,\Omega$ is the internal resistance of the one coil used of the "Double Coil Galvanometer" Type: K_c (Kipp and Zonen), which has a time of indication of 7 seconds in the case of critical damping and a critical damping resistance $D = 19900\,\Omega$. This resistance D was adjusted by means of two magnetic shunts supplied with the instrument.

The sensitivity of the galvanometer can be reduced to $^1/_n$ by means of a variable shunt S and the variable resistance E, so that the critical damping resistance D of the galvanometer is maintained. Gottschalk and Davis[4] stated the following formulae:

$$E = (D - G - R) - (C + r)/n \quad \text{and}$$

$$S = (C + r)\ (n - 1)$$

R is a fixed resistance of $10000\,\Omega$, r is the sum of the resistances of the two secondary windings T of the capsules equal to $64.7\,\Omega$ (See Table A3) and C is a variable resistance chosen so that $C + r = 9600\,\Omega$ and may be kept constant by using secondaries of different resistances.

In Table A4 settings of S and E for a desired multiplier n of the galvanometer throw are tabulated.

TABLE A4.

SETTINGS FOR MULTIPLIER.

n	S	E
1	∞	0
2	9600	4800
3	4800	6400
11	960	8727
13	800	8861
25	400	9226
33	300	9309
49	200	9404
65	150	9452
97	100	9501
121	80	9520
241	40	9560
481	20	9580
961	10	9590

The galvanometer G can be protected by means of the switch K_1 when changing the setting of the primary current.

By means of the switch K_3 the secondary coils TT of the two capsules can be replaced by the secondary windings of the mutual induction standard R_s for measuring the ballistic galvanometer constant. Because the toggle switch K_3 caused trouble during the measurements, it was removed and the switching is now done by simply disconnecting and connecting by means of clamping the respective secondaries to the resistance C. See Appendix 1.

4. CALIBRATION OF THE APPARATUS.

(a) Measurement of the Ballistic Galvanometer Constant.

α) Mutual Induction Standard.

The method used is described by W. Jellinghaus[5]. The mutual induction standard (Hartmann and Braun) used has a mutual inductivity L of 0.01 henry, each of the two coils a resistance of 7 Ω and can take a maximum current of 1A. Because C + r must be equal to 9600 Ω, C = 9600 - 7 = 9593 Ω.

The measuring circuit is obtained by connecting the two coils of the mutual induction, R_p (Figure 5) and R_s (Figure 6) into the primary as well as the secondary circuit by means of the switches S (Figure 5) and K_3 (Figure 6) respectively. With this arrangement the critical damping resistance D is maintained.

The galvanometer throw β in cm is produced in one direction or in the other by either opening or closing the primary current by means of the mercury switch S in Figure 5. With this procedure the ballistic galvanometer constant K can be calculated by means of the formula:

$$K = \frac{Li}{n\beta} \left[\frac{\text{maxwell}}{\text{cm}}\right]$$

i = 0.061A is the primary current, measured by means of the Multizet with an accuracy of ± 1%. It was felt that a higher accuracy was not necessary. i must be adjusted during calibration by means of the resistance Q (Figure 5) while the knife switches S up to S_7 must be open. n is the multiplier.

The light beam of the galvanometer has a length of 3 m and a maximum deflection of 25 cm. Consequently no correction for the tangent of the deflection angle is necessary.

In.../

In Table B1 an example is given of the measurement of K. β is in general about 13 cm. The accuracy of the reading of the galvanometer throw of 13 cm is about 0.05 cm. The standard deviation of the mean is ± 0.13%. Because the time of indication of 7 seconds is independent of the magnetude of the throw, its absolute accuracy decreases with increasing size. With a maximum throw of 25 cm, the accuracy is only ± 0.15 mm.

β) Standard Solenoid

The standard solenoid built by the Institute consists of the primary coil of 90.0 cm length and 897 windings of enamelled copper wire of 20 gauge wound over a marble cylinder of 31.97 mm diameter; the secondary coil of 6.00 cm length wound in the middle of the primary coil over a cardboard cover of 34.48 mm diameter. Enamelled copper wire of No. 42 S.W.G. gauge was used. The coil consists of two layers of 424 and 416 windings respectively. The outside diameter of the coil is 34.99 mm and its resistance is equal to 187.9 Ω. From these figures the mean area of the windings equal to q = 9.477 cm² was calculated.

The procedure for measuring the ballistic galvanometer constant K is the same as for the mutual induction standard which was replaced by the standard solenoid only and C is the equal to 9600 - 188 = 9412 Ω.

The formulae for the calculation of K were taken from F. Kohlrausch[6]

$$H = \frac{n_1 i}{\sqrt{4r^2 + l^2}} \quad [\mathrm{A\ cm^{-1}}]$$

being valid for the middle of a long coil, and

$$B_0 = \mu_0 H = \frac{K'}{n_2 q}\beta \qquad \left[\frac{\mathrm{Vs}}{\mathrm{cm}^2}\right]$$

From these two formulae K' can be evaluated.

$$K' = \frac{\mu_0 \; n_1 \; n_2 \; i \; q}{\beta l \sqrt{1 + \left(\frac{2r}{l}\right)^2}} = \frac{\mu_0 \; n_1 \; n_2 \; r^2 \pi \; i}{\beta l \sqrt{1 + \left(\frac{2r}{l}\right)^2}} \; \left[\frac{\mathrm{Vs}}{\mathrm{cm}}\right]$$

For simplicity, K' is the ballistic galvanometer constant expressed in $\frac{\mathrm{Vs}}{\mathrm{cm}}$ and K the constant expressed in maxwell/cm

K = 10⁸.../

$$K = 10^{8} \frac{\mu_0 n_1 n_2 r^2 \pi i}{\beta l \sqrt{1 + (\frac{2r}{l})^2}} \quad [\frac{\text{maxwell}}{\text{cm}}]$$

This formula differs by the factor $\frac{1}{2}$ from the formula, given by Kohlrausch[7], because we did not reverse but only switched the primary current on and off.

The symbols have the following meaning:-

B_0 = Induction in $[\frac{Vs}{cm^2}]$
μ_0 = Magnetic field constant = $4\pi \times 10^{-9} \frac{Vs}{Acm}$
n_1 = Number of windings of primary coil (= 897 windings)
n_2 = Number of windings of secondary coil (=840 windings)
i = Primary current (=0.619A)
q = Winding surface of secondary coil (9.477 cm^2)
β = Galvanometer throw (in cm)
l = Length of primary coil (90.00 cm)
$2r$ = Diameter of primary coil (3.299 cm)

When introducing these values

$$K = 9.9631 \times 10^{-4} \frac{i}{\beta} [\frac{Vs}{cm}] = 9.9631 \times 10^{+4} \frac{i}{\beta} \text{ maxwell/cm}$$

By comparing the galvanometer constant K_1 obtained by means of the mutual induction standard, and the constant K_2 obtained by the standard solenoid, the ratio $K_1 / K_2 = 0.909$, which means that K_2 is 9.99% higher than K_1. This can be caused by the presence of some ferro-or para-magnetic material in the marble core of the solenoid standard, which is not taken in account in the formula. It was noticed that the core is not pure white but contains grey spots. Therefore, it was decided to use only the mutual induction standard of Hartmann and Braun for measuring the galvanometer constant.

(b) Calibration of the Twin Isthmus Apparatus.

For measuring the magnetic field strength inside the isthmus capsules as a function of the exciting current the coils of the capsules were added (See page 2) to double the galvanometer throw and with both capsules empty.

The exciting current was measured with a multi-range amperemeter (Multizet, already mentioned). Therefore, the current for the ten switch positions (See Figure 5) must be determined before the magnetic measurements could be started, because it is impossible to change from one range to another without interrupting the exciting current. During these determinations the galvanometer was short-circuited. (Switch K_1. Figure 6).

α) Calibration.../

α) Calibration for Hysteresis Loop.

After measuring the exciting current for the 10 switch positions the following procedure was followed. The 10 switches were closed (Figure 5) and then successively opened, starting with S_1 and thereafter successively closed, starting with S_{10}. This was repeated about 10 times with the galvanometer short-circuited.

The procedure for the measurement of the hysteresis loop is as follows: Before starting with the measurement the reversing switch K (Figure 5) is positioned in such a way that the galvanometer throw when reducing the current is always to the left. This measurement is started with the highest possible current of about 4.5A. All knife switches are closed. By opening the knife switch S_1, a sudden reduction of the exciting current and, therefore, of the field strength takes place and the resulting galvanometer throw is measured. This is repeated until all the switches are open. Then switch K is reversed to keep the galvanometer throw to the left when closing the switches successively starting with S_{10}.

However, since the galvanometer is not absolutely symmetrical (See page 16 and Table B1), the whole measuring series is repeated with galvanometer throws to the right. During measurements the multiplier n has to be decreased and increased again; so that a maximum advantage of the galvanometer throw on the galvanometer scale is obtained.

In Table B2a and B2b and Figure 7 (mean of the two tables) the more recent calibration of the isthmus capsules for the hysteresis loop after renewal of the two wedges (See Figure 2) is given as an example.

Column 1 gives the values of the exciting current, column 2 the multiplier used. The measuring cycle including the galvanometer throws to the left (column 3) and to the right (column 4) was repeated once (column 5 and 6). The mean of these 4 measurements (column 7) multiplied with the multiplier n (column 2) gives the true galvanometer deflection (column 8). $\bar{\beta}$ (column 9) is obtained by subtracting the respective true deflection (column 8) from half the sum of the whole column 8. The required field strength H in oersted (column 10) is obtained by multiplying the values of column 9 with the standardisation factor F, which is calculated according to the formula

H = .../

$$H = \frac{B_n}{\mu_0} = \frac{K'\bar{\beta}}{\mu_0 n_2 q}\left[\frac{A}{cm}\right] = \frac{10^9}{4\pi} x \frac{K'\bar{\beta}}{n_2 q}\left[\frac{A}{cm}\right] = \frac{4\pi}{10} x \frac{10^9}{4\pi} x \frac{K'\bar{\beta}}{n_2 q} \text{ oersted}$$

$$H = 10^8 \ x \ \frac{K'\bar{\beta}}{n_2 q} = \frac{K\bar{\beta}}{n_2 q} = F\bar{\beta} \text{ oersted}$$

the formula was used already for calibration of the galvanometer constant K by means of the standard solenoid (See page 9 and F. Kohlrausch^{8}). The field strength H is obtained in oersted if K is introduced in maxwell/cm and q in cm².

By introducing n_2 = 245 (number of windings of one of the isthmus coils,(Table A3, page 6), q = 2 x 3.333 = 6.666 cm² (twice the mean area of the secondary winding, because the secondaries are added, see page 6),

$$F = \frac{K}{n_2 q} = \frac{K}{245x2x3.333} = \frac{K}{1633.24} \text{ oersted/cm}$$

K must be determined every day before starting with the magnetic measurement.

In the standard step by step method of determining hysteresis loops the error is cumulative; the test for accuracy is the sum of the mean throws, which should be the same as the normal induction throw obtained with the maximum magnetising current.

From Table B2a and B2b it can be seen that there is a bigger difference in the two first and the two last throws of each column (column 3 to 8).

This is due to the remanence of the iron core of the electromagnet. After having produced the maximum field strength (3450 oersted), a magnetic field of 17 oersted still periods in the air gap and the empty capsule when the current is switched off. This field is only annihilated when an opposing current of 0.0104A is passed through the magnet coils (see Figure 8).

As shown in appendix 2 this method of calibration was checked by measuring the field strength by means of a Bismuth spiral.

β) Calibration for Normal Magnetisation Curve.

After determination of the current for the different switch positions, the core of the electromagnet, the common bottom plate and the two lids of the capsules (See Figure 1) were demagnetised by using the electrolytic variable resistance N (See Figure 5). To use a demagnetisation current of about

5.5A.../

5.5A, which is higher than the current of about 4.5A used later on for measurements an additional 6 V car battery was connected to the 24 V batteries normally used. The demagnetisation was done by increasing the electrolytic resistance and reversing the current by means of the motor-driven switch K (Figure 5). During the demagnetisation the galvanometer must be short-circuited (switch K_1, Figure 6).

After demagnetisation and removal of the additional battery, the calibration was started using the lowest current by closing only the knife switch S_{10} (Figure 5). After 10-20 reversals (switch K, Figure 5) the galvanometer throw was measured twice in each direction. This procedure was repeated by increasing the current, which is accomplished by closing one switch after the other (S_9.....S_1, Figure 5). Each observation must be preceded with the 10-20 reversals. During the measurements the multiplier n had to be increased.

An example for the more recent calibration of the isthmus capsules for normal magnetisation curves after renewal of the two wedges is given in Table B3a and B3b. Up to column 8 the columns are the same as in Table B2a and B2b. The required field strength H in oersted (column 9) is obtained by multiplying the values $\overline{\beta}$ of column 8 with the standardisation factor F'. Because here the method of reversals is used, when measuring the normal magnetisation curve, the factor F' is half that of factor F used for the calibration of the hysteresis loop.

$$F' = \frac{1}{2} F = \frac{K}{2x1633.24} = \frac{K}{3266.48} \text{ oersted/cm}$$

See appendix 3.

5. MAGNETIC MEASUREMENTS OF MAGNETITE POWDERS.

For measuring the hysteresis loop and the normal magnetisation curve of magnetite powder, the powder is filled into one of the two capsules (capsule No. 2 was always used, see page 3). The filling must be done in such a way that the grains cannot turn when reversing the magnetic field during measurements. For this purpose the powder is packed and compressed with a rod in small quantaties at a time until the capsule is filled and the surface is then smoothed by tapping.

Because the specific magnetisation is a function of the packing density, special care must be taken to obtain the same density. To achieve a definite packing density for fine as well as coarse powders, a non-magnetic material such as

Al_2O_3 must be added, its amount depending on the fineness of the magnetite.

The procedure is as follows; according to the invariable volume of the capsule (see page 5) the respective weight of magnetite is filled into it and then Al_2O_3 is added until the lid fits tightly. Then the capsule is emptied and its content weighed and mixed. The weighing is done to determine the amount of Al_2O_3 necessary for a specific density and grain size. Al_2O_3 from British Drughouse (Laboratory Reagent) was used (for + 270 mesh magnetite powder the coarse Al_2O_3 for steel analysis and for -270 mesh powder the fine calcined Al_2O_3).

The measuring procedure is the same as in the case of calibration except that the secondaries are opposed.

There is, however, a difference in the evaluation: the formula

$$I = \frac{K'\beta}{n_2\ q_m}\left[\frac{Vs}{cm^2}\right] = \frac{K\beta}{n_2\ q_m}\ \text{gauss} = f\beta\ \text{gauss}$$

is applied, which with some alteration is also used for the calibration of the capsules. But in this case q_m is the area of cross section of the column of powder in the capsule and not twice the mean area of a secondary winding. In this case I is the magnetisation, using the following definition:

$$B = \mu_0 H + I$$

where the induction B and the magnetisation I are measured in $\frac{Vs}{cm^2}$ and the field strength in $\frac{A}{cm}$. In this case, because the windings of the filled and those of the empty capsules are opposed, I is measured.

The internal diameter d, the area of cross section q_m and the standardisation factor

$$f = \frac{K}{n_2\,q_m}\quad \text{gauss/cm}$$

for hysteresis loop measurements for capsules No. 1 and No. 2 are given in Table A5. For the measurement of the normal magnetisation curve the standardisation factor $f' = \frac{1}{2}f$, because here the measurement was done by means of reversals, is also included in Table A5.

Table A5.../

TABLE A5.

DIAMETER AND SURFACE AREA OF MAGNETITE POWDER AND STANDARDISATION FACTORS.

CAPSULE NO.	d	q_m	n_2	f	f'
1	1.618 cm	2.06 cm^2	245	K/503.7	K/1007.4
2	1.626 cm	2.08 cm^2	245	K/508.6	K/1017.2

In the tables B4a, B4b, B5a, B5b, B6a, B6b and their descriptions on pages 17-18 examples are given for the measurements of hysteresis loops and normal magnetisation curves. From the tables it can be seen that the galvanometer throws to the left and to the right are not symmetrical.

Measurements of magnetites were also done with the secondaries added and opposed. The difference between galvanometer throws of added and opposed secondaries is equal to a throw of secondaries added but with empty capsules.

$$\underbrace{\underbrace{(B + \mu_0 H + \mu_0 H)}_{\text{Added}} - \underbrace{(B + \mu_0 H - \mu_0 H)}_{\text{Opposed}}}_{\text{One Capsule filled}} = \underbrace{\underbrace{(2\mu_0 H)}_{\text{Empty Capsules Added}}}_{\text{During calibration}}$$

Comparing the results obtained by the measurements of added and opposed secondaries with the results during calibration, differences in the throws of about 1-3% were found, which shows that the method used gives satisfactory results.

6. RESULTS OF CALIBRATION AND MEASUREMENTS OF MAGNETITE POWDERS.

In the following tables some examples are given to show actual figures of measurements, accuracy and reproducibility when measurements were repeated.

Table B1.../

TABLE B1.

BALLISTIC GALVANOMETER CONSTANT. STANDARDISATION BY MEANS OF THE MUTUAL INDUCTION STANDARD.

READING LEFT	DEFLECTION IN cm	READING ZERO	DEFLECTION IN cm	READING RIGHT
13.25	12.75	26.00		
		26.05	12.70	38.75
13.40	12.70	26.10		
		26.15	12.65	38.80
13.40	12.75	26.15		
		26.20	12.65	38.85
13.40	12.80	26.20		
		26.20	12.70	38.90
13.45	12.80	26.25		
		26.25	12.70	38.95
	12.76		12.68	

Mean: 12.72 cm.

Standard deviation of single measurements: $\pm 0.054 \sim 0.42\%$
Standard deviation of mean : $\pm 0.017 \sim 0.13\%$

Asymmetry of the galvanometer throw = 0.08 cm = 0.6% to the left.

Ballistic galvanometer

$$\text{constant} = K = \frac{Li}{n\beta} \quad [\text{maxwell/cm}]$$

$$= \frac{0.01 \times 0.061 \times 10^8}{2 \times 12.72} \quad \text{maxwell/cm}$$

$$= \frac{4796}{2} \quad \text{maxwell/cm}$$

$$= \underline{\underline{2398 \pm 3}} \quad \text{maxwell/cm}$$

Here an example is given of the measurements of the ballistic galvanometer constant. As can be seen from the table, the measurements were started with a deflection to the left. The damping of the galvanometer was adjusted in such a way that no oscillation took place and, therefore, after the deflection the galvanometer stopped at the zero point.

From the figures of the zero point it can be seen that the zero point is not constant during this test. However,

this.../

this was only the case each day at the beginning of the magnetic measurements. The beginning of the magnetic measurements each day is the determination of the galvanometer constant.

The asymmetry of the galvanometer throw is here 0.6% to the left which is commonly the case with all tests.

TABLES B2.

In these two tables a and b calibrations of the isthmus apparatus for hysteresis loops after renewing the two wedges are given. Although there are small discrepancies in the exciting current of the respective measuring points (column 1) the respective resulting field strengths (column 10) of the two tables can be compared and their differences are tabulated as precentages in column 11 of Table B2a. Column 11 shows good agreement between the two calibration measurements excepting naturally the very small values.

The galvanometer constant and the asymmetry of the galvanometer are also given. The latter changes from measuring series to measuring series.

The mean of these two calibration curves is plotted in Figure 8.

TABLES B3.

In the two tables a and b calibrations of the isthmus apparatus for normal magnetisation curves after renewing the wedges are given. The percentages of the differences between the respective field strengths (column 9) of the two measuring series are shown in column 10 of Table B3a. The values of this column are satisfactorily small.

The mean of these two calibration curves **is** plotted in Figure 9.

The Tables B2a (hysteris loop) and B3a (normal magnetisation curve) belong to the same measuring series, having the same galvanometer constant. The same applies in the case of Tables B2b and B3b. In both cases the hysteresis loop values of field strength (column 10) at the highest exciting current (column 1) used, are 0.5% and 1.1% smaller than the respective normal magnetisation values (column 9). These values should coincide but this is never the case in all the measurements.

TABLES B4.

In the two tables a and b the hysteris loops of Gladstone magnetite (intermediate size) are given.

TABLES B5.../

TABLES B5.

In the two tables a and b the respective normal magnetisation curves of the Tables B4a and b are given. The 4 measurements were done on the same day, for that reason they have the same ballistic galvanometer constant. After the measuring series tabulated in Tables B4a and B5a had been completed, the sample was removed from the capsule, mixed by means of a spatula and refilled again.

The differences in percentage before and after refilling are tabulated for the hysteresis loop measurements in column 11 of Table B4a and for the normal magnetisation curve measurements in column 10 of Table B5a. The deviations are satisfactorily small.

In both cases before and after refilling the capsule the hysteresis loop values of magnetisation (column 10) at the highest exciting current (column 1) used, are 0.4% and 0.5% smaller than the respective normal magnetisation values (column 9). These values should coincide but this is never the case in all the measurements. With 58 measurements of normal magnetisation curves and hysteresis loops, done on different magnetite powders, it was found that the mean difference between their saturation magnetisations is 1.4 ± 1.0%.

TABLES B6.

In the 3 Tables a, b and c hysteresis loops of Alanwood magnetite -270 +325 mesh (-53 +44μ) are tabulated. The three measurements were done on three different days, thus, three different galvanometer constants were found. After measuring the hysteresis loop given in Table a, the exciting current of the electromagnet was switched off over night, without removing the capsules from the air gap. Then after measuring the hysteresis loop a second time (Table b) the sample was removed from the capsule, mixed by means of a spatula and refilled again and the hysteresis loop was measured a third time (Table c). The differences in percentages between the 3 measuring series are tabulated in the columns 11, 12 and 13 of the Table B6a. These are satisfactorily small.

The results of these 3 measuring series are plotted in <u>Figure 10</u>.

TABLE B7.

To test the symmetry of the isthmus apparatus with

regard.../

regard to the two capsules, the secondaries of the two empty capsules were opposed. If the symmetry of the apparatus is complete no deflection of the galvanometer should be expected when suddenly changing the exciting current. Table B7 shows that actually deflections could be measured. They are, however, so small that specially when they had been measured at small exciting currents, no quantitative conclusions can be made. Nevertheless these deflections show that some asymmetry of the apparatus is present. In column 10 the apparent "field strength" is calculated. Comparing these values with those of the Tables B2a and b, column 10, it can be concluded that the asymmetry of the apparatus lies within the fault of the method.

TABLES B8.

To be sure that the method of measuring the normal magnetisation curve is trustworthy and the preceding demagnetisation, described on pages 12-13, is complete, the results of this method applied for a pill of Ermelo magnetite, tabulated in Table B8a are compared with results obtained by the following method.

After demagnetisation, the measuring series was started with the highest exciting current. The exciting current was reduced to the next step followed by a second demagnetisation and measurement. This procedure was continued and the results tabulated in Table B8b. The difference in percentage between the two methods are given in column 10 of Table B8a, showing a very good agreement.

7. APPENDIX.

APPENDIX 1.

It was observed that the zero point of the ballistic galvanometer after a throw to the left and to the right did not coincide although the two throws were the same. The discrepancy can be as much as 10mm. It was found that when different kinds of copper wire, soldered connections specially at the toggle switch K_3 (See Figure 6) and the large precision decade resistance box of Hartmann and Braun (specially when earthing its case) are not used, the two mentioned zero points of the galvanometer coincide. Therefore, instead of the large decade set the small set of Tinsley was installed and all connections were clamped. The toggle switch K_3 was removed and the switching was done by simply disconnecting and connecting by means of clamping the respective secondary to the resistance C (See Figure 6).

The.../

The set-up was checked by the following method, where the mutual standard induction was used. The galvanometer throw had to be the same when introducing the multiplier n = 1 and switching on and off the primary current by means of the mercury switch S (Figure 5) or when using n = 2 and reversing the current by means of the mercury switch K. In the beginning the galvanometer throws were not always equal. The reason for this was found to be a non-simultaneous switching of the primary current by means of the reversing switch K. After replacing K with a new one, the throws were the same.

APPENDIX 2.

Because with some measurements doubts arose whether it was necessary to multiply the results obtained with the factor 2, it was decided to check the calibration of the capsules with another method. The method of the bismuth spiral was applied.

It was impossible to insert this spiral into one of the empty capsules, therefore, it was placed in front of the two capsules. To assure that the field strength at this point is the same as in the capsules, the following adjustment was done according to Figure 7. To achieve that the air gap at this place is the same as in the capsules, one of the iron lids of the capsules was placed here, where it remained because of the magnetic field.

After this adjustment, the field strength obtained by an exciting current of 3.92A was measured twice by means of the bismuth spiral giving the following results 3160 and 3130 oersteds, the mean is 3145 oersted. From the calibration curve, measured by means of the ballistic galvanometer, 3180 oersted was interpolated for the same exciting current. This good agreement between the two different measuring methods assures that for this calculation the correct factor was used.

APPENDIX 3.

A recalculation of the standardisation factor 31.64 oersted/cm as quoted in Dean and Davis, Table 20, page 63[9], according to the formula

$$F' = \frac{K}{2n_2 q} \text{ oersted/cm}$$

used in this report was done. This check was necessary to ascertain whether this calculation led to the same result as obtained by Gottschalk and Davis. Because here the method of reversals was used, when measuring the normal magnetisation

curve.../

curve, the factor $\frac{1}{2}$ must be introduced into the formula.

On page 63 the galvanometer constant K' is equal to 0.0174 microcoulomb/cm = 0.01740 x 10^{-6} coulomb/cm $[\frac{As}{cm}]$. By multiplying K' with the critical damping resistance of the galvanometer circuit D = 23932Ω, the galvanometer constant K = 416.42 x 10^2 maxwell/cm is obtained. By introducing this value of K, $n_2 = 95$ and q = 2 x 3.46, the value of F' = 31.67 oersted/cm is obtained, the same value as in Table 20 in Dean and Davis.

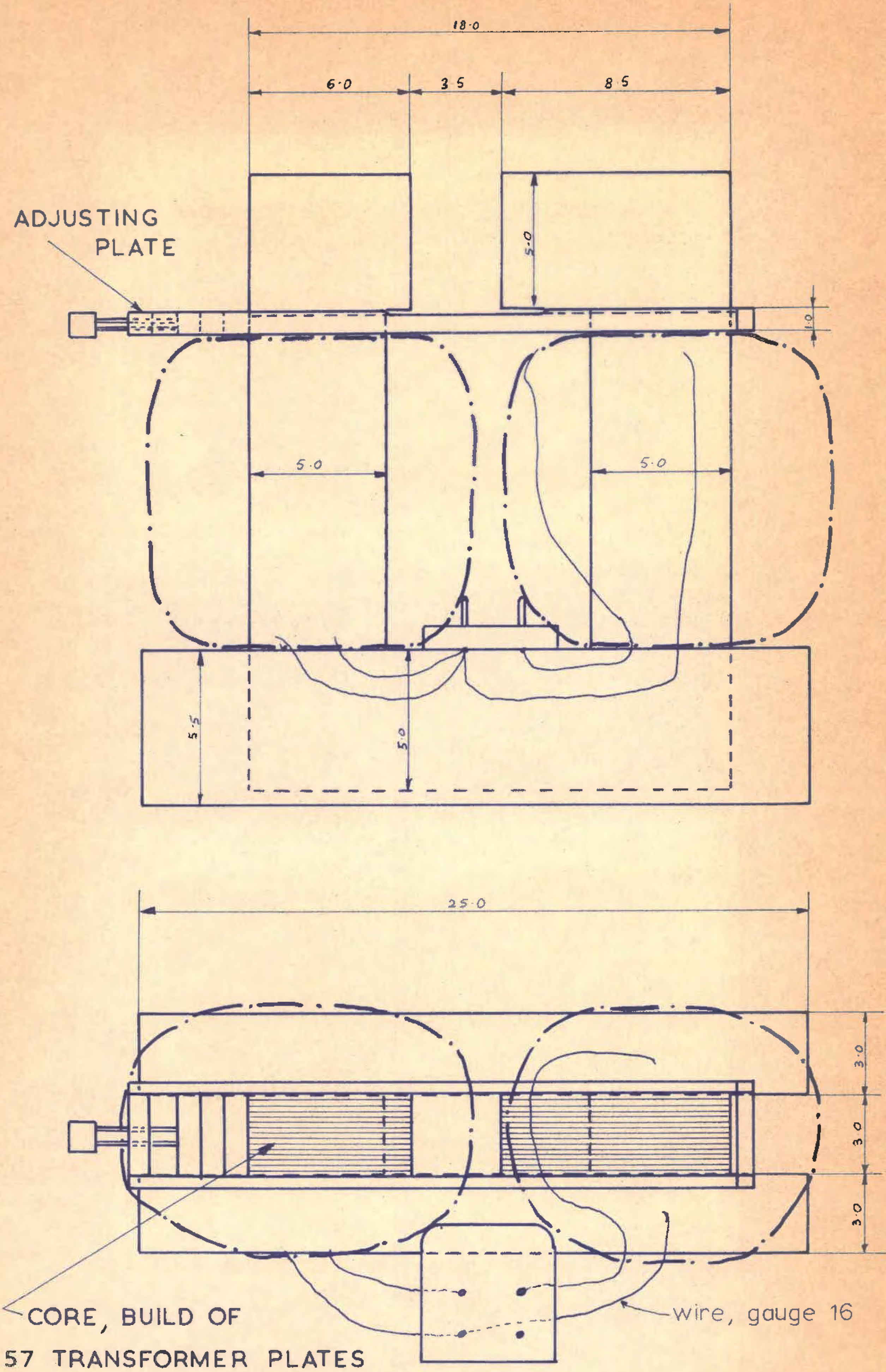
W.T.E. VON WOLFF.
Principal Research Officer.

I.I.M. KESSLER.
Research Officer.

PRETORIA.
13th July, 1966.

REFERENCES.

1. V.H. Gottschalk and C.W. Davis.
    - (a) Bureau of Mines Report of Investigation 3268, February, 1935.
    - (b) In R.S. Dean and C.W. Davis, Magnetic Separation of Ores, Bureau of Mines Bulletin 425, Washington 1941, p.58.
2. R.S. Dean and C.W. Davis, Magnetic Separation of Ores, p.59.
3. R.S. Dean and C.W. Davis, Magnetic Separation of Ores, p.61.
4. R.S. Dean and C.W. Davis, Magnetic Separation of Ores, p.62.
5. W. Jellinghaus, Magnetische Messungen an Ferromagnetischen Stoffen, Walter de Gruyter, Berlin, 1952, p.38-39.
6. F. Kohlrausch, Praktische Physik, Vol. 2, 20th Edition, Teubner Stuttgart 1956, p.199, p.218 and 219.
7. F. Kohlrausch, Praktische Physik, Vol. 2, 20th Edition, equation on page 219.
8. F. Kohlrausch, Praktische Physik, Vol. 2, 20th Edition, equation on page 218.
9. R.S. Dean and C.W. Davis, Magnetic Separation of Ores, p.63.



ADJUSTING PLATE

CORE, BUILD OF 57 TRANSFORMER PLATES 0·89 mm. THICK

wire, gauge 16

Scale: 1-2 cm

FIG. I : ELECTRO MAGNET

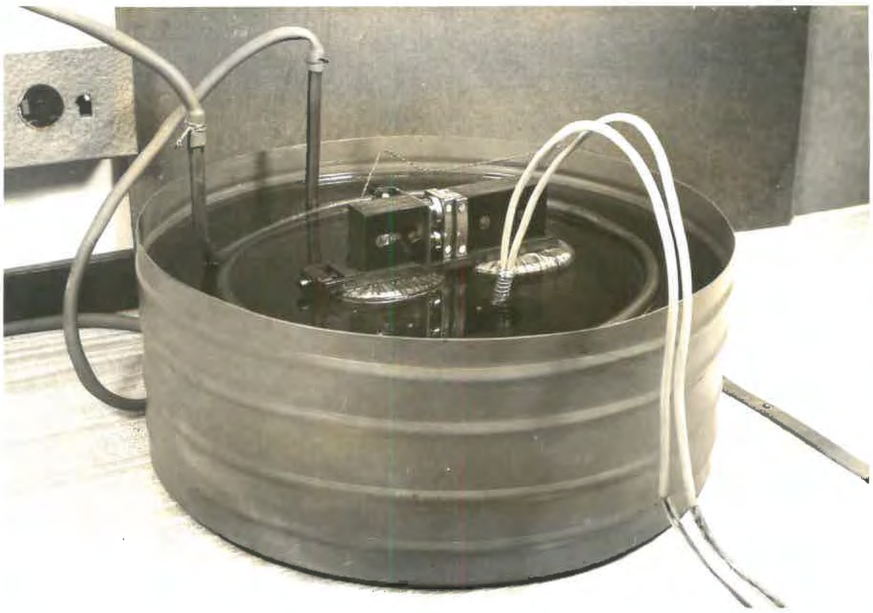


FIGURE 2.

Twin Isthmus Apparatus including the Electromagnet; the two capsules and the two wedges are in the air gap. The Apparatus stands in transformer oil cooled by passing water through a spiral.

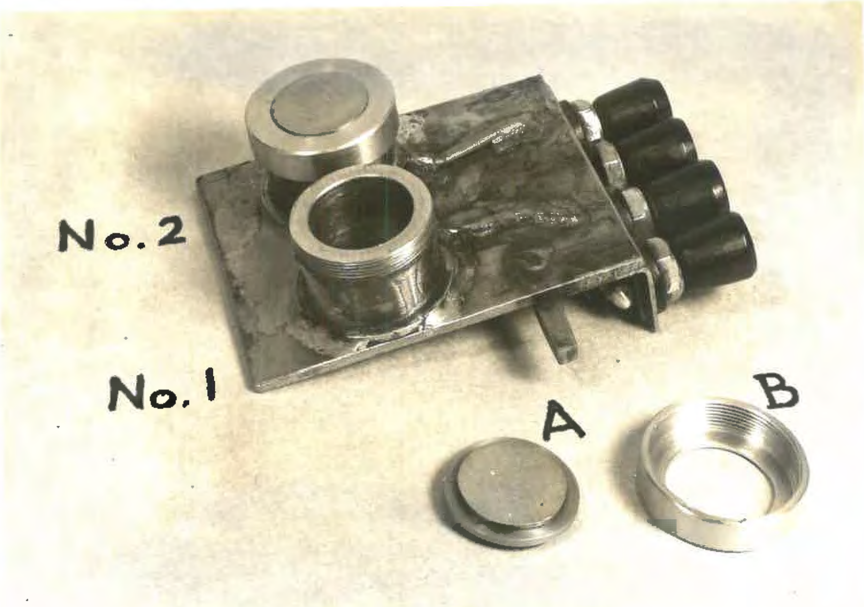
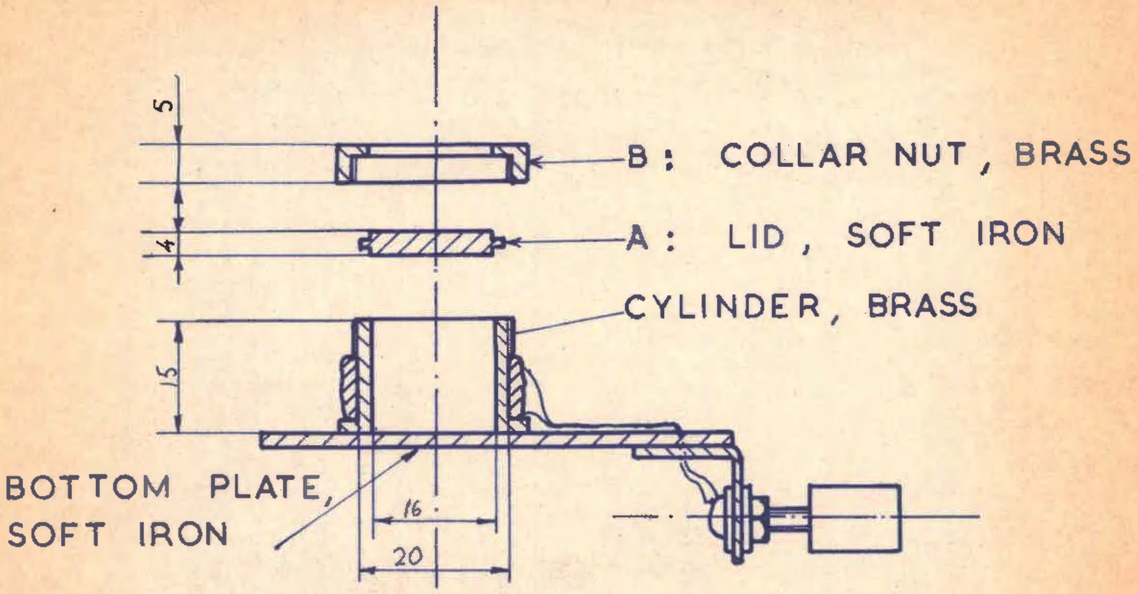
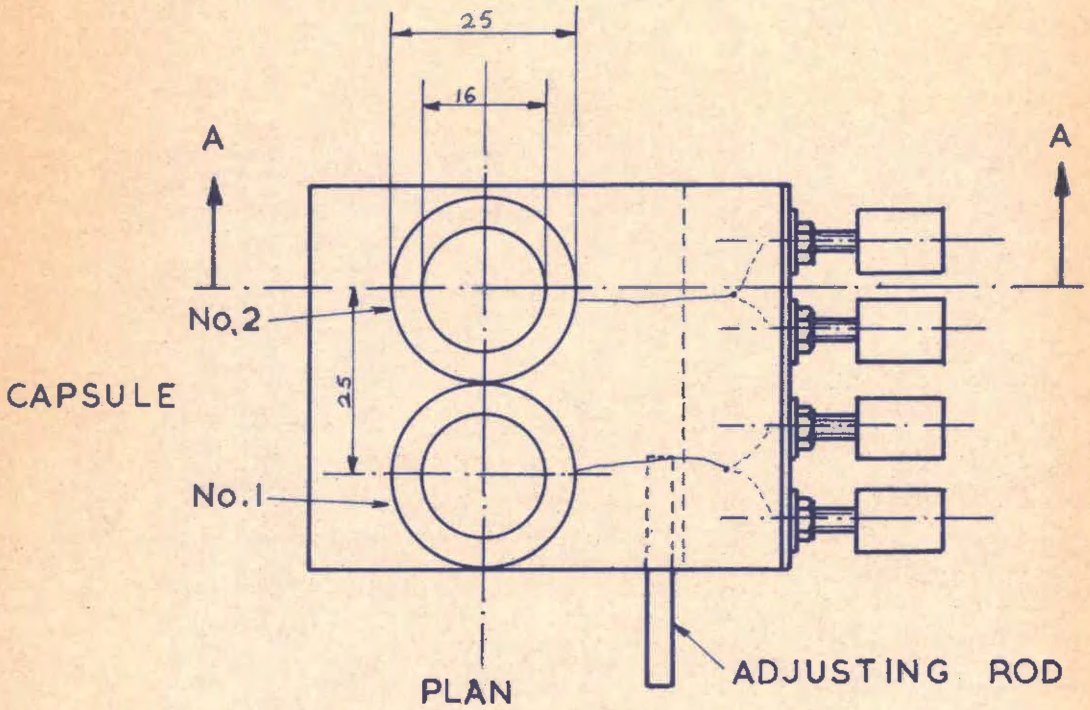


FIGURE 3.

Capsule No. 1 and No. 2, the common plate with the adjusting rod and the four terminals of the two secondary windings. From capsule No. 1 the lid A and the fastening collar unit B are removed. Capsule No, 2 always contains the powder to be measured.



SECTION: AA



PLAN

SCALE: 1-1 mm

FIG. 4 :DOUBLE ISTHMUS CAPSULES

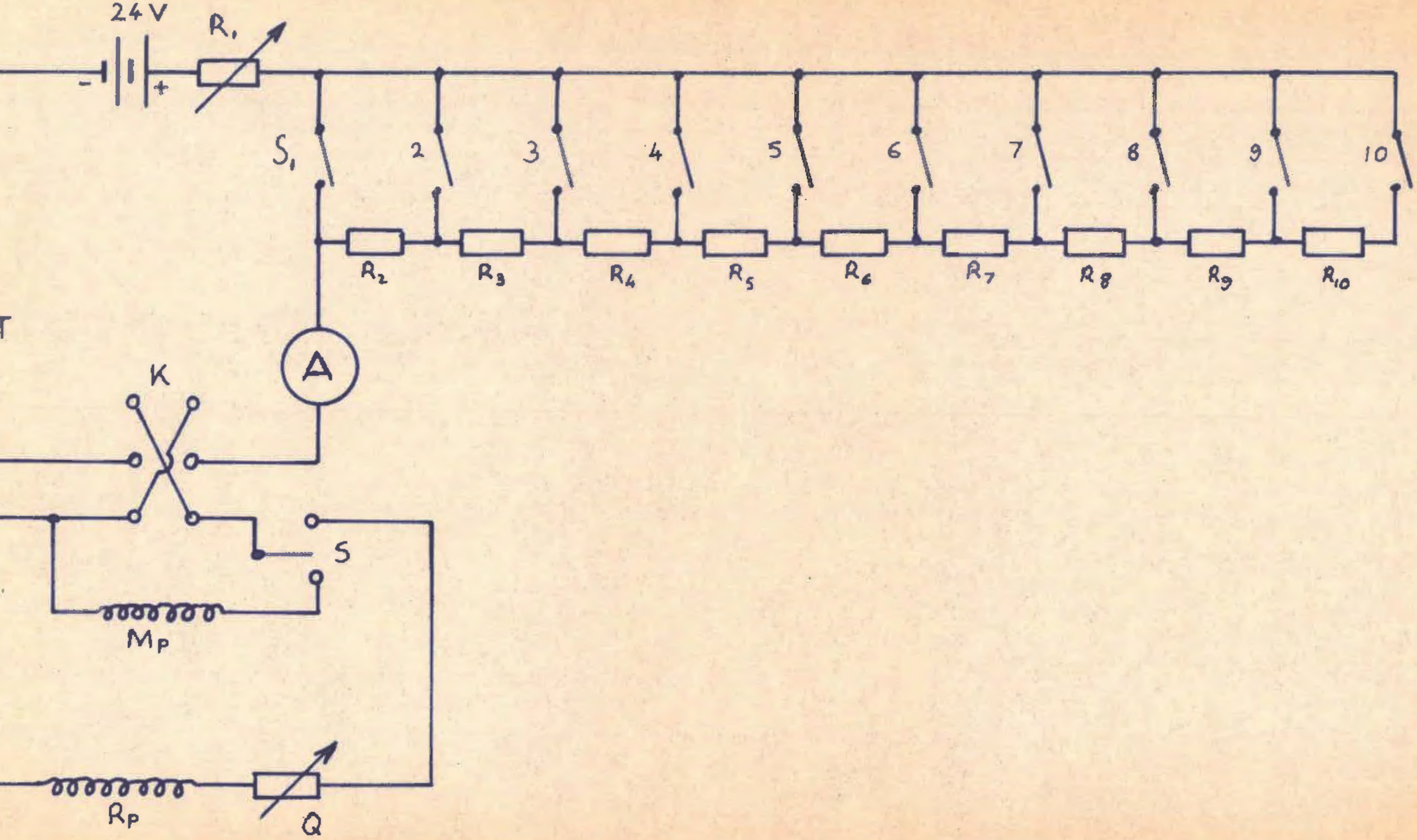


FIG. 5 : PRIMARY CIRCUIT

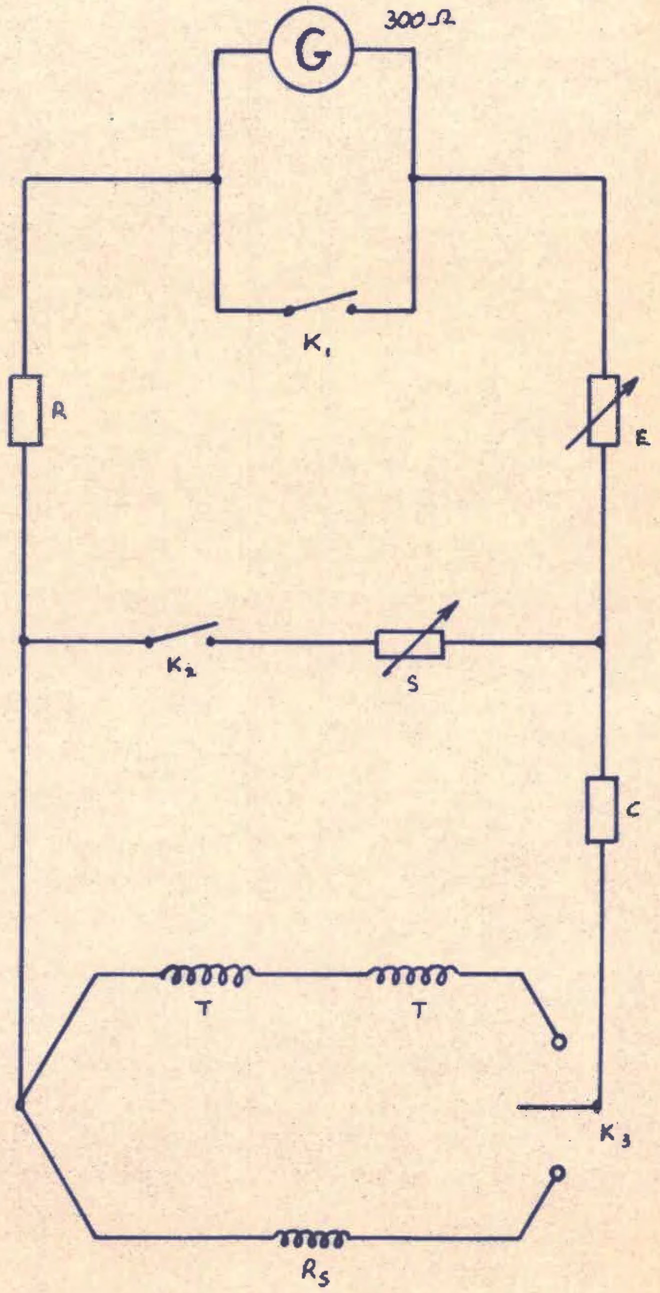
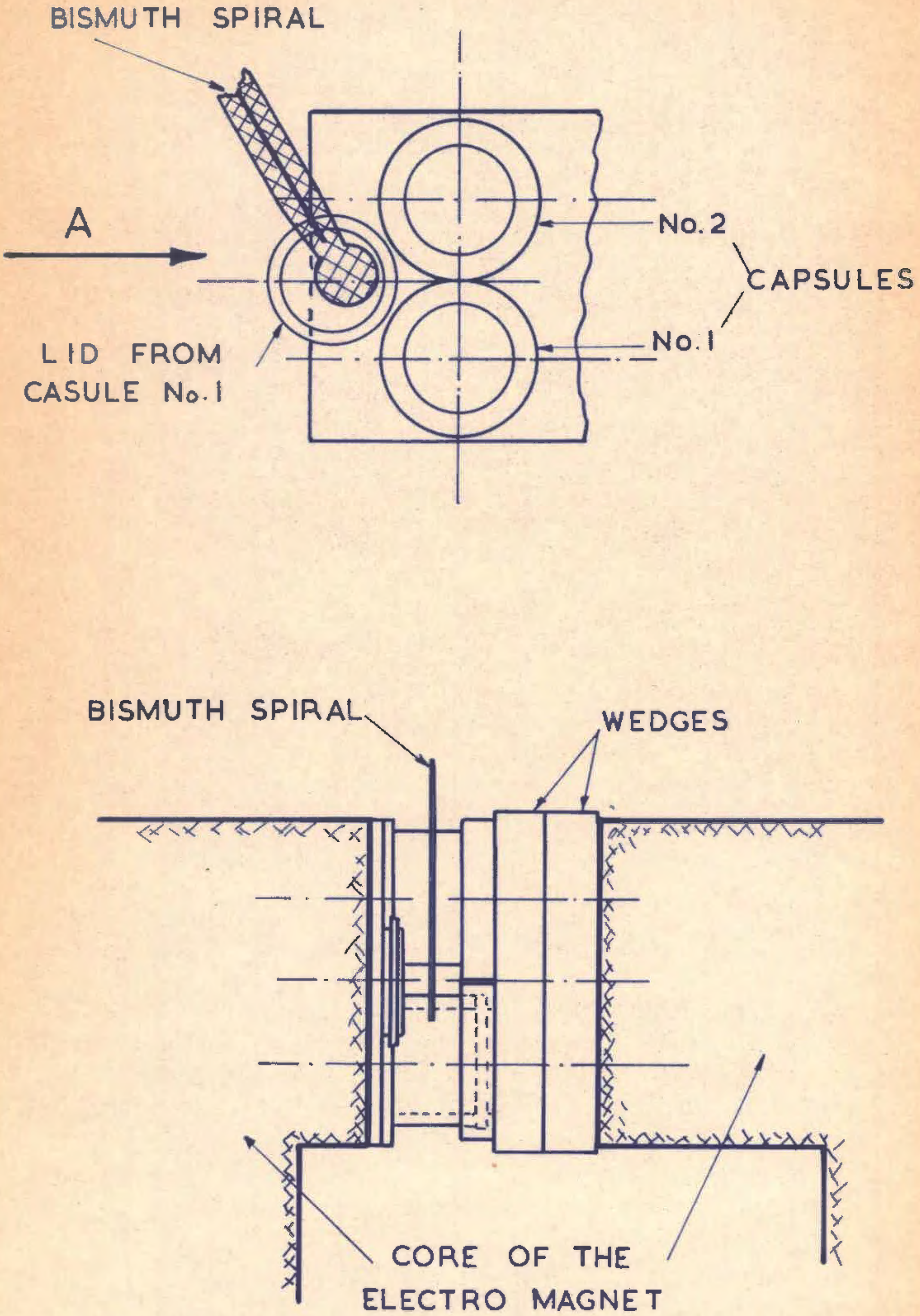


FIG. 6 : SECONDARY CIRCUIT



VIEW: A

FIG. 7: ARRANGEMENT FOR MEASURING THE FIELDSTREGTH BY MEANS OF A BISMUTH SPIRAL

SCALE: 1-1

CALIBRATION O
HYSTERESIS
(THE BALLISTIC GALVA

1	2	3	4	5	6	7
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THROW IN cm				
		LEFT	RIGHT	LEFT	RIGHT	MEA
4.42	13	17.80	17.65	17.75	17.75	17.7
3.25	33	10.05	9.90	10.15	10.05	10.0
2.19	33	10.50	10.50	10.55	10.50	10.5
1.54	33	16.50	16.55	16.50	16.50	16.5
0.83	33	13.55	13.50	13.45	13.50	13.5
0.40	33	8.80	8.75	8.80	8.85	8.8
0.141	33	2.65	2.55	2.60	2.60	2.6
0.062	13	2.15	2.10	2.20	2.10	2.1
0.0376	2	15.10	15.10	15.05	15.15	15.1
0.0108	2	6.00	6.15	6.10	6.05	6.0
0						
0						
0.0108	2	6.05	6.05	6.05	6.10	6.0
0.0376	2	15.05	15.05	15.15	15.05	15.0
0.062	13	2.15	2.15	2.20	2.10	2.1
0.142	33	2.80	2.45	2.75	2.55	2.6
0.40	33	8.80	8.75	8.70	8.75	8.7
0.831	33	13.50	13.50	13.45	13.60	13.5
1.54	33	16.65	16.60	16.55	16.55	16.5
2.20	33	10.50	10.50	10.50	10.55	10.5
3.27	33	10.25	10.30	10.35	10.30	10.3
4.42	13	18.55	18.75	18.50	18.65	18.6
		207.40	206.85	207.35	207.25	
Asymmetry of throws*		0.55 = 0.27%		0.10 = 0.05%		

---

*Difference between columns 3 and 4 or 5 and 6 respecti

BLE B2a.

HE ISTHMUS CAPSULES FOR
P (SECONDARIES ADDED).
ETER CONSTANT IS K = 2392.16)

8	9	10	11
n x MEAN	$\overline{\beta} = \frac{1}{2}$ SUM- n x MEAN	CALCULATED FIELD STRENGTH IN OERSTED $H = F\overline{\beta}$	PERCENTAGE DIFFERENCE BETWEEN MEAN AND THE TWO SINGLE MEASUREMENTS OF TABLE B2a AND B2b (COLUMN 10)
230.62	2356.76	3451.9	0.1%
331.32	2126.14	3114.1	0.1%
346.83	1794.82	2628.8	0.4%
544.83	1447.99	2120.8	0.3%
445.50	903.16	1322.8	0.04%
290.40	457.66	670.3	0.5%
85.80	167.26	244.9	0.1%
27.82	81.46	119.3	0.8%
30.20	53.64	78.3	1.3%
12.15	23.44	34.3	2.9%
	11.29	16.5	2.9%
12.12	-0.83	-1.2	95.1%
30.15	-30.98	-45.3	1.1%
27.95	-58.93	-86.3	0.6%
87.12	-146.05	-213.9	0.5%
288.75	-434.80	-636.8	0.08%
445.83	-880.63	-1289.8	0.2%
547.47	-1428.10	-2091.7	0.2%
346.83	-1774.93	-2599.7	0.3%
339.90	-2114.83	-3097.5	0.3%
241.93	-2356.76	-3451.9	0.1%

4713.52

r.

T

REPETITION OF THE
CAPSULES FOR HYSTERE
(THE BALLISTIC GALVANO

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER TH		
		LEFT	RIGHT	LEFT
4.34	13	17.85	17.85	17.80
3.20	33	10.20	10.50	10.35
2.12	33	10.35	10.40	10.30
1.51	33	16.30	16.35	16.30
0.82	33	13.40	13.40	13.30
0.398	33	8.85	8.90	8.85
0.141	33	2.70	2.65	2.70
0.062	13	2.20	2.20	2.15
0.0375	2	15.20	15.00	15.25
0.0108	2	6.20	6.15	6.20
0				
0				
0.0108	2	6.10	6.15	6.10
0.0376	2	15.05	15.05	15.05
0.062	13	2.15	2.20	2.15
0.142	33	2.60	2.75	2.70
0.399	33	8.75	8.75	8.70
0.822	33	13.45	13.45	13.45
1.52	33	16.60	16.55	16.55
2.13	33	10.40	10.45	10.45
3.22	33	10.70	10.70	10.70
4.37	13	18.05	17.95	18.20
		207.10	207.40	207.25
Asymmetry of throws*		-0.30 = 0.14%		0 = 0

*Difference between columns 3 and 4 or 5 a

ABLE B2b.

CALIBRATION OF THE ISTHMUS
SIS LOOP (SECONDARIES ADDED).
METER CONSTANT IS K = 2386.54).

6	7	8	9	10
ROW IN cm		n x MEAN	$\overline{\beta} = \frac{1}{2}$ SUM- n x MEAN	CALCULATED FIELD STRENGTH IN OERSTED H = F$\overline{\beta}$
RIGHT	MEAN			
17.45	17.74	230.62	2357.39	3444.7
10.60	10.41	343.20	2126.77	3167.7
10.35	10.35	341.55	1783.57	2606.2
16.20	16.29	537.57	1442.02	2107.1
13.35	13.36	440.88	904.45	1321.6
8.75	8.84	291.72	463.57	677.4
2.70	2.69	88.77	171.85	251.1
2.15	2.18	28.28	83.08	121.4
15.15	15.15	30.30	54.80	80.1
6.10	6.16	12.32	24.50	35.8
			12.18	17.8
6.05	6.10	12.20	-0.02	-0.03
15.05	15.05	30.10	-30.12	-44.0
2.20	2.18	28.28	-58.40	-85.3
2.80	2.71	89.43	-147.83	-216.0
8.80	8.75	288.75	-436.58	-637.9
13.40	13.44	443.52	-880.10	-1286.0
16.35	16.51	544.83	-1424.93	-2082.2
10.35	10.41	343.20	-1768.13	-2583.6
10.75	10.71	353.43	-2121.56	-3100.1
18.35	18.14	235.82	-2357.38	-3444.7
		4714.77		

206.90

.35
.17%

nd 6 respectively.

CALIBRATION OF THE ISTHMUS CAPSULES F
(THE BALLISTIC GALV

1	2	3	4	5	6	7
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THROW ON REVERSAI OF CURRENT IN cm				
		LEFT	RIGHT	LEFT	RIGHT	MEA
0.0108	2	10.95	11.00	11.00	11.00	10.
0.0376	11	7.15	7.10	7.15	7.15	7
0.062	13	10.25	10.40	10.30	10.30	10
0.141	33	9.40	9.30	9.35	9.45	9
0.40	49	17.85	17.95	17.90	17.90	17
0.825	97	18.35	18.35	18.30	18.30	18
1.525	121	23.75	23.90	23.75	23.85	23
2.18	481	7.60	7.45	7.30	7.70	7
3.20	481	8.80	8.85	8.80	8.90	8
4.38	481	9.90	9.85	9.85	9.80	9

124.00 124.15 123.70 124.35

Asymmetry of throws* -0.15 = 0.12% 0.35 0.28%

*Difference between columns 3 and 4 or 5 and 6 respec

ABLE B3a.

NORMAL MAGNETISATION CURVE (SECONDARIES ADDED).

OMETER CONSTANT IS K = 2392.16).

8	9	10
n x MEAN = $\overline{\beta}$	CALCULATED FIELD STRENGTH IN OERSTED $H = F'\overline{\beta}$	PERCENTAGE DIFFERENCE BETWEEN MEAN AND THE TWO SINGLE MEASUREMENTS OF TABLE B3a AND B3b (COLUMN 9)
21.98	16.1	0.03%
78.54	57.5	0.02%
134.03	98.2	0.05%
309.38	226.6	0.4%
877.10	642.3	0.9%
1777.53	1301.8	0.2%
2881.01	2109.9	0.3%
3612.31	2645.4	0.6%
4252.04	3113.9	0.2%
4737.85	3469.7	0.2%

ely.

TABLE

REPETITION OF THE CALIB
CAPSULES FOR NORMAL MAGNETISATI
(THE BALLISTIC GALVANOMETER

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THROW OF CURRENT IN		
		LEFT	RIGHT	LEFT
0.0108	2	11.00	11.05	11.00
0.0378	11	7.20	7.15	7.20
0.062	13	10.30	10.40	10.30
0.141	33	9.30	9.35	9.30
0.40	49	18.10	18.25	18.35
0.828	97	18.25	18.25	18.35
1.53	121	23.70	23.75	23.75
2.18	481	7.50	7.40	7.45
3.26	481	8.85	8.95	8.90
4.42	481	9.85	9.95	9.95
		124.05	124.50	124.55

Asymmetry of throws* -0.45 = 0.36% 0 = 0

---

*Difference between columns 3 and 4 or 5 a

3b. .

ATION OF THE ISTHMUS
N CURVE (SECONDARIES ADDED).
CONSTANT IS K = 2386.54).

6	7	8	9
ON REVERSAL cm		n x MEAN = $\bar{\beta}$	CALCULATED FIELD STRENGTH IN OERSTED H = F'$\bar{\beta}$
RIGHT	MEAN		
11.05	11.03	22.05	16.1
7.10	7.16	78.76	57.5
10.30	10.33	134.23	98.1
9.35	9.33	307.73	224.8
18.35	18.26	894.74	653.7
18.35	18.30	1789.52	1307.5
23.75	23.74	2872.54	2098.7
7.40	7.44	3578.64	2614.6
8.90	8.90	4280.90	3127.7
9.90	9.91	4766.71	3482.6

124.45

.10
.08%

nd 6 respectively.

MEASUREMENTS FOR THE HYSTERESIS L

WEIGHT OF MAGNETITE : 7.5

(THE BALLISTIC GALVANOMET

1	2	3	4	5	6	
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THROW IN cm				
		LEFT	RIGHT	LEFT	RIGHT	MEA
4.20	1	3.45	3.30	3.40	3.35	3.
3.18	1	6.80	6.75	6.75	6.70	6.
2.18	1	11.75	11.65	11.70	11.70	11.
1.50	2	19.95	19.75	19.90	19.85	19.
0.788	13	6.85	6.75	6.80	6.80	6.
0.392	13	11.45	11.45	11.40	11.35	11.
0.141	13	6.15	6.15	6.15	6.10	6.
0.064	2	16.00	16.05	16.00	16.10	16.
0.0382	2	20.25	20.20	20.20	20.25	20.
0.0111	2	9.30	9.25	9.35	9.20	9.
0						
0						
0.011	2	10.25	10.20	10.20	10.20	10.
0.0382	11	5.25	5.25	5.25	5.30	5.
0.064	11	4.55	4.50	4.50	4.45	4.
0.141	13	8.60	8.50	8.65	8.55	8.
0.392	13	13.75	13.75	13.70	13.65	13.
0.793	13	7.70	7.60	7.75	7.65	7.
1.51	13	3.35	3.30	3.30	3.35	3.
2.20	1	12.30	12.40	12.35	12.45	12.
3.20	1	7.25	7.25	7.20	7.30	7.
4.20	1	3.70	3.75	3.70	3.70	3.

		3	4	5	6
		188.65	187.80	188.25	188.00
Asymmetry of throws*		0.85 = 0.45%		0.25 = 0.13%	

---

*Difference between columns 3 and 4 or 5 and 6 respect

TABLE B4a.

OP OF GLADESTONE MAGNETITE (INTERMEDIATE SIZE).
34g MIXED WITH 0.7794g Al_2O_3 (COARSE).
R CONSTANT IS K = 2372.62 MAXWELL/cm).

	8	9	10	11
	n x MEAN	$\overline{\beta} = \frac{1}{2}$ SUM-n x MEAN	CALCULATED MAGNETISATION IN GAUSS $I = F\overline{\beta}$	PERCENTAGE DIFFERENCE BETWEEN MEAN AND THE TWO SINGLE MEASUREMENTS OF TABLE B4a AND B4b (COLUMN 10)
8	3.38	526.51	2456.1	0.1%
5	6.75	523.13	2440.3	0.1%
0	11.70	516.38	2408.8	0.1%
6	39.72	504.68	2354.2	0.1%
0	88.40	464.96	2168.9	0.2%
1	148.33	376.56	1756.6	0.1%
4	79.82	228.23	1064.7	0.2%
4	32.08	148.41	692.3	0.4%
3	40.45	116.33	542.7	0.6%
8	18.55	75.88	353.9	0.9%
		57.33	267.4	1.1%
1	20.42	36.91	172.2	2.1%
6	57.86	-20.95	-97.7	2.0%
0	49.50	-70.45	-328.6	0.8%
3	111.48	-181.93	-848.7	0.2%
1	178.23	-360.16	-1680.1	0.2%
3	99.78	-459.94	-2145.5	0.1%
3	43.23	-503.17	-2347.2	0.1%
3	12.38	-515.55	-2404.9	0.1%
5	7.25	-522.80	-2438.8	0.1%
1	3.71	-526.51	-2456.1	0.1%
	1053.02			

ely.

MEASUREMENTS FOR TH
MAGNETITE (INTERME
SAMPLE WAS TAKEN OUT OF
(THE BALLISTIC GALVANOMETE

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER		
		LEFT	RIGHT	LEF
4.25	1	3.45	3.35	3.
3.22	1	6.75	6.80	6.
2.22	1	11.60	11.70	11.
1.51	2	19.70	19.80	19.
0.797	13	6.80	6.90	6.
0.394	13	11.55	11.55	11.
0.142	13	6.15	6.20	6.
0.064	2	16.05	16.00	16.
0.0384	2	20.15	20.30	20.
0.0112	2	9.25	9.40	9.
0				
0				
0.0112	2	10.20	10.30	10.
0.0384	11	5.25	5.25	5.
0.064	11	4.55	4.55	4.
0.142	13	8.45	8.60	8.
0.395	13	13.75	13.85	13.
0.8	13	7.65	7.70	7.
1.53	13	3.35	3.30	3.
2.20	1	12.25	12.25	12.
3.22	1	7.30	7.25	7.
4.26	1	3.80	3.75	3.

188.00 188.80 188.

Asymmetry of throws* -0.80
= 0.43% =

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*Difference between columns 3 and 4 or 5

ABLE B4b.

HYSTERESIS LOOP OF GLADESTONE
TE SIZE) REPEATED, AFTER THE
APSULE, MIXED AND REFILLED AGAIN.
CONSTANT IS K = 2372.62 MAXWELL/cm).

6	7	8	9	10
ROW IN cm		n x MEAN	$\overline{\beta} = \frac{1}{2}$ SUM- n x MEAN	CALCULATED MAGNETISATION IN GAUSS $I = F\overline{\beta}$
RIGHT	MEAN			
3.40	3.40	3.40	527.89	2462.5
6.75	6.78	6.78	524.49	2446.6
11.70	11.66	11.66	517.71	2415.0
19.75	19.75	39.50	506.05	2360.6
6.85	6.85	89.05	466.55	2176.4
11.50	11.55	150.15	377.50	1760.9
6.15	6.18	80.28	227.35	1060.5
16.10	16.04	32.08	147.07	686.1
20.25	20.23	40.45	114.99	536.4
9.35	9.33	18.65	74.54	347.7
			55.89	260.7
10.25	10.25	20.50	35.39	165.1
5.15	5.21	57.31	-21.92	-102.3
4.45	4.51	49.61	-71.53	-333.7
8.55	8.53	110.83	-182.36	-844.2
13.80	13.80	179.40	-361.76	-1687.5
7.60	7.66	99.58	-461.34	-2152.1
3.35	3.33	43.23	-504.57	-2353.7
12.25	12.24	12.24	-516.81	-2410.8
7.30	7.31	7.31	-524.12	-2444.9
3.70	3.76	3.76	-527.88	-2462.5
		1055.77		

188.20

.20
.11%

nd 6 respectively.

MEASUREMENTS FOR THE NORMAL MAGNETISATION

WEIGHT OF MAGNETITE = 7.523

(THE BALLISTIC GALVANOMETER

1	2	3	4	5	6	7
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THROW ON REVERSAL CURRENT IN cm				
		LEFT	RIGHT	LEFT	RIGHT	MEAN
0.011	2	12.50	12.40	12.50	12.55	12.4
0.0385	11	9.70	9.65	9.75	9.70	9.7
0.064	11	16.90	17.00	16.90	17.05	16.9
0.143	33	11.60	11.70	11.65	11.70	11.6
0.394	33	22.10	22.15	22.15	22.15	22.1
0.798	49	18.85	18.85	18.80	18.90	18.8
1.51	65	15.45	15.60	15.50	15.55	15.5
2.20	97	10.65	10.70	10.65	10.65	10.6
3.20	97	10.85	10.80	10.85	10.85	10.8
4.20	97	10.85	10.95	10.85	10.95	10.9
		139.45	139.80	139.60	140.05	
Asymmetry of throws*		-0.35 = 0.25%		-0.45 = 0.32%		

*Difference between columns 3 and 4 or 5 and 6 respect

TABLE B5a.

CURVE OF GLADESTONE MAGNETITE (INTERMEDIATE SIZE).
4g MIXED WITH 0.7794g Al_2O_3 (COARSE).
CONSTANT IS K = 2372.62 MAXWELL/cm).

	8	9	10
	n x MEAN = $\overline{\beta}$	CALCULATED MAGNETISATION IN GAUSS $I = F'\overline{\beta}$	PERCENTAGE DIFFERENCE BETWEEN MEAN AND THE TWO SINGLE MEASUREMENTS OF TABLE B5a AND B5b (COLUMN 9)
9	24.98	58.3	0.4%
0	106.70	248.9	0.4%
6	186.56	435.1	0.5%
6	384.78	897.5	0.1%
4	730.62	1704.1	0.3%
5	923.65	2154.3	0.2%
3	1009.13	2353.7	0.3%
6	1034.02	2411.8	0.2%
4	1051.48	2452.5	0.2%
0	1057.30	2466.1	0.2%

vely.

TABL

REPETITION OF THE MEASUREMEN
CURVE OF GLADESTONE MAGNETIT
SAMPLE WAS TAKEN OUT OF THE C
(THE BALLISTIC GALVANOMETER CON

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THR CURRENT IN		
		LEFT	RIGHT	LEF
0.0112	2	12.55	12.55	12.
0.0389	11	9.75	9.85	9.
0.064	11	17.05	17.10	17.
0.144	33	11.65	11.75	11.
0.400	33	22.25	22.35	22.
0.81	49	18.85	18.95	18.
1.54	65	15.60	15.60	15.
2.22	97	10.70	10.70	10.
3.23	97	10.85	10.90	10.
4.28	97	10.90	11.00	10.
		140.15	140.75	140.

Asymmetry of throws* -0.60 = 0.43% =

*Difference between column 3 and 4 or 5

B5b.

FOR THE NORMAL MAGNETISATION
(INTERMEDIATE SIZE) AFTER THE
SULE, MIXED AND REFILLED AGAIN.
ANT IS K = 2372.62 MAXWELL/cm).

6	7	8	9
ON REVERSAL		n x MEAN = $\overline{\beta}$	CALCULATED MAGNETISATION IN GAUSS $I = F'\overline{\beta}$
RIGHT	MEAN		
12.65	12.60	25.20	58.8
9.80	9.78	107.53	250.8
17.20	17.11	188.21	438.9
11.70	11.69	385.77	899.8
22.35	22.28	735.08	1714.5
18.95	18.91	926.59	2161.2
15.65	15.61	1014.65	2366.6
10.70	10.71	1038.87	2423.1
10.95	10.89	1056.33	2463.8
10.95	10.94	1061.18	2475.1

140.90

.65
.46%

d 6 respectively.

MEASUREMENTS FOR THE HYSTERESI
WEIGHT OF MAGNETITE
(THE BALLISTIC GALVANOMET

1	2	3	4	5	6	7	
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THROW IN cm					n
		LEFT	RIGHT	LEFT	RIGHT	MEAN	
4.20	1	3.40	3.75	3.45	3.70	3.58	
3.20	1	7.10	6.55	7.20	6.50	6.84	
2.20	1	13.35	13.70	13.45	13.65	13.54	
1.54	2	21.55	22.25	21.65	22.05	21.88	
0.83	13	7.75	7.95	7.80	7.95	7.86	1
0.398	13	12.55	12.55	12.55	12.50	12.54	1
0.142	13	6.90	6.55	6.75	6.65	6.71	
0.063	11	3.20	3.20	3.25	3.15	3.20	
0.0382	11	3.95	3.65	3.85	3.75	3.80	
0.0109	2	11.35	10.85	11.25	10.95	11.10	
0							
0.0109	2	12.15	11.60	12.05	11.75	11.89	2
0.0382	11	5.60	5.70	5.65	5.65	5.65	6
0.063	11	4.55	4.50	4.50	4.55	4.53	4
0.142	13	8.40	9.05	8.50	9.00	8.74	11
0.396	13	14.55	14.60	14.60	14.60	14.59	18
0.830	13	8.65	8.70	8.70	8.75	8.70	11
1.54	13	3.50	3.35	3.45	3.40	3.43	4
2.22	1	14.25	13.95	14.15	14.05	14.10	1
3.22	1	7.95	7.60	7.85	7.65	7.76	
4.20	1	4.10	4.60	4.25	4.45	4.35	
							114

	174.80	174.65	174.90	174.70
Asymmetry of throws*	0.15 = 0.09%		0.20 = 0.11%	

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*Difference between column 3 and 4 or 5 and 6 respectively.

TABLE B6a.

LOOP OF ALANWOOD MAGNETITE -270 +325 MESH.
7.5220g MIXED WITH 0.2669g Al_2O_3.
CONSTANT IS K = 2340.29 MAXWELL/cm).

8	9	10	11		
			PERCENTAGE DIFFERENCE BETWEEN MEAN AND THE TWO SINGLE MEASUREMENTS OF		
MEAN	$\overline{\beta} = \frac{1}{2}$ SUM- n x MEAN	CALCULATED MAGNETISATION IN GAUSS $I = F\overline{\beta}$	TABLE B6a AND TABLE B6b (COLUMN 10)	TABLE B6b AND TABLE B6c (COLUMN 10)	TABLE B6a AND TABLE B6c (COLUMN 10)
3.58	571.09	2628.2	0.1%	0.2%	0.3%
6.84	567.51	2611.8	0.1%	0.2%	0.3%
3.54	560.67	2580.3	0.08%	0.2%	0.3%
3.75	547.13	2517.9	0.1%	0.2%	0.3%
2.18	503.38	2316.6	0.3%	0.1%	0.4%
3.02	401.20	1846.4	1.0%	0.05%	0.6%
7.23	238.18	1096.1	0.9%	0.04%	0.9%
5.20	150.95	694.7	1.0%	0.5%	1.5%
1.80	115.75	532.7	1.2%	0.5%	1.6%
2.20	73.95	340.3	0.9%	2.0%	2.2%
	51.75	238.2	1.2%	0.6%	2.3%
3.78	27.97	128.7	3.4%	0.4%	3.8%
2.15	-34.18	-157.3	0.6%	0.6%	1.3%
9.78	-83.96	-386.4	1.8%	0.1%	1.7%
3.62	-197.58	-909.3	1.2%	0.2%	1.4%
9.67	-387.25	-1782.2	0.6%	0.1%	0.8%
3.10	-500.35	-2302.7	0.3%	0.1%	0.4%
4.53	-544.88	-2507.6	0.1%	0.2%	0.3%
4.10	-558.98	-2572.5	0.1%	0.2%	0.3%
7.76	-566.74	-2608.2	0.1%	0.2%	0.3%
4.35	-571.09	-2628.2	0.1%	0.2%	0.3%
2.18					

T

REPETITION OF THE MEASUR
ALANWOOD MAGNETITE -270 +3
OUT OF THE CAPSULE OR THE
THE ELECTRO-MAGNET
WEIGHT OF SAMPLE 7.52
(THE BALLISTIC GALVANOMETER

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER TH		
		LEFT	RIGHT	LEFT
4.20	1	3.30	3.55	3.35
3.21	1	6.85	7.30	6.95
2.22	1	12.95	13.15	12.95
1.55	2	20.45	21.10	20.35
0.838	13	7.60	7.75	7.65
0.40	13	12.55	12.50	12.50
0.144	13	6.95	6.50	6.90
0.064	11	3.35	3.05	3.25
0.0387	11	4.15	3.90	4.10
0.011	2	10.60	10.35	10.55
0				
0				
0.01	2	11.45	11.40	11.50
0.0386	11	5.70	5.95	5.75
0.064	11	4.60	4.80	4.65
0.144	13	8.50	9.15	8.55
0.40	13	14.55	14.50	14.50
0.84	13	8.50	8.40	8.50
1.55	13	3.40	3.25	3.35
2.25	1	13.90	14.05	13.95
3.26	1	7.60	7.35	7.55
4.27	1	4.05	3.65	4.00
		171.00	171.65	170.8

Asymmetry of throws*		-0.65 = 0.38%		- =

*Difference between columns 3 and 4 or 5

ABLE B6b.

EMENTS FOR THE HYSTERESIS LOOP OF
25 MESH WITHOUT REMOVING THE SAMPLE
CAPSULE OUT OF THE AIR GAP; ONLY
WAS SWITCHED OFF FOR A TIME.
20g MIXED WITH 0.2669g Al_2O_3.
CONSTANT IS K = 2356.12 MAXWELL/cm).

6	7	8	9	10
ROW IN cm		n x MEAN	$\overline{\beta} = \frac{1}{2}$ SUM- n x MEAN	CALCULATED MAGNETISATION IN GAUSS $I = F\overline{\beta}$
RIGHT	MEAN			
3.50	3.43	3.43	568.26	2632.4
7.05	7.06	7.06	564.83	2616.5
13.20	13.06	13.06	557.77	2583.8
21.05	20.74	41.48	544.71	2523.3
7.70	7.68	99.78	503.23	2331.2
12.50	12.51	162.63	403.45	1868.9
6.65	6.75	87.75	240.82	1115.6
3.15	3.20	35.20	153.07	709.1
3.95	4.03	44.28	117.87	546.0
10.40	10.48	20.95	73.59	340.9
			52.64	243.9
11.50	11.48	22.95	29.69	137.5
5.90	5.83	64.08	-34.39	-159.3
4.85	4.73	51.98	-86.37	-400.1
9.10	8.83	114.73	-201.10	-931.6
14.50	14.51	188.63	-389.73	-1805.4
8.45	8.46	109.98	-499.71	-2314.8
3.30	3.33	43.23	-542.94	-2515.1
14.00	13.98	13.98	-556.92	-2579.9
7.40	7.48	7.48	-564.40	-2614.5
3.75	3.86	3.86	-568.26	-2632.4
		1136.52		

171.91

.06
.04%

nd 6 respectively.

REPETITION OF THE MEA
ALANWOOD MAGNETITE -270
FROM THE CAPSULE,
WEIGHT OF SAMPLE 7
(THE BALLISTIC GALVANOMET

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER		
		LEFT	RIGHT	LE
4.20	1	3.30	3.65	3.
3.21	1	6.80	7.30	6.
2.22	1	12.90	13.35	12.
1.55	2	20.90	21.40	20.
0.842	13	7.70	7.85	7.
0.40	13	12.60	12.55	12.
0.145	13	6.90	6.40	6.
0.065	11	3.35	3.15	3.
0.039	11	3.75	3.90	3.
0.011	2	11.90	11.55	11.
0				
0				
0.011	2	11.90	11.65	11.
0.039	11	5.70	6.05	5.
0.064	11	4.55	4.80	4.
0.145	13	8.65	9.20	8.
0.40	13	14.65	14.55	14.
0.845	13	8.55	8.45	8.
1.55	13	3.55	3.30	3.
2.22	1	13.95	13.95	13.
3.20	1	7.65	7.25	7.
4.20	1	4.00	3.75	4.
		173.25	174.05	173.

Asymmetry of throws* $\underbrace{173.25 \quad 174.05}_{-0.80}$

-0.80
= 0.46% =

*Difference between columns 3 and 4 or 5

TABLE B6c.

REMENTS FOR THE HYSTERESIS LOOP OF
325 MESH, AFTER REMOVING THE SAMPLE
IXING AND REFILLING IT AGAIN.
220g MIXED WITH 0.2669g Al_2O_3.
CONSTANT IS K = 2347.96 MAXWELL/cm).

	6	7	8	9	10
	HROW IN cm		n x MEAN	$\overline{\beta} = \frac{1}{2}$ SUM- n x MEAN	CALCULATED MAGNETISATION IN GAUSS $I = F\overline{\beta}$
	RIGHT	MEAN			
5	3.60	3.48	3.48	572.24	2641.7
5	7.40	7.06	7.06	568.76	2625.6
5	13.25	13.11	13.11	561.70	2592.9
5	21.40	21.14	42.28	548.59	2532.5
5	7.80	7.78	101.08	506.31	2337.3
5	12.55	12.56	163.28	405.23	1870.7
5	6.65	6.68	86.78	241.95	1116.9
0	3.25	3.26	35.86	155.17	716.3
5	3.90	3.85	42.35	119.31	550.8
5	11.65	11.74	23.48	76.96	355.3
				53.48	246.9
0	11.60	11.76	23.52	29.96	138.3
0	6.00	5.89	64.79	-34.83	-160.8
5	4.75	4.69	51.59	-86.42	-398.9
5	9.10	8.93	116.03	-202.45	-934.6
0	14.65	14.59	189.67	-392.12	-1810.2
0	8.50	8.50	110.50	-502.62	-2320.3
5	3.35	3.41	44.33	-546.95	-2524.9
5	13.90	13.94	13.94	-560.89	-2589.3
5	7.40	7.44	7.44	-568.33	-2623.6
0	3.85	3.90	3.90	-572.23	-2641.6
			1144.47		

0 174.55,

-1.55
0.90%

and 6 respectively.

T

MEASUREMENTS FOR THE HYSTERESIS LOOP

(THE BALLISTIC GALVANOMETER

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER T		
		LEFT	RIGHT	LEFT
4.20	1	0	1.90	0.4
3.18	1	0.80	1.20	0.7
2.20	1	1.05	1.40	1.1
1.53	1	1.30	1.60	1.3
0.828	1	1.60	1.20	1.1
0.397	1	1.75	0.85	0.7
0.143	1	0.35	0.25	0.3
0.063	1	1.80	0	0.7
0.0385	1	0	0	0
0.0112	1	0.75	-1.45	1.0
0				
0				
0.0109	1	0	1.25	-0.7
0.0383	1	0	0.15	0
0.063	1	0.15	0.15	0
0.143	1	0.45	0.35	0
0.397	1	1.15	0.90	0.9
0.83	1	1.70	1.20	1.3
1.54	1	1.55	1.25	1.4
2.20	1	1.45	1.10	1.4
3.20	1	1.25	0.70	1.3
4.22	1	1.40	0.45	1.0

ABLE B7

F THE TWO EMPTY CAPSULES (SECONDARIES OPPOSED).

CONSTANT IS K = 2355.20 MAXWELL/cm).

6	7	8	9	10
ROW IN cm		n x MEAN	$\overline{\beta} = \frac{1}{2}$ SUM- n x MEAN	CALCULATED FIELD STRENGTH IN OERSTED H = F$\overline{\beta}$
RIGHT	MEAN			
0.85	0.80	0.80	7.26	33.62
1.15	0.98	0.98	6.46	29.91
1.40	1.24	1.24	5.48	25.38
1.65	1.45	1.45	4.24	19.63
1.25	1.30	1.30	2.79	12.92
0.85	1.05	1.05	1.49	6.90
0.25	0.29	0.29	0.44	2.04
0.50	0.75	0.75	0.15	0.69
0.20	0.05	0.05	-0.60	-2.78
-1.50	-1.15	-1.15	-0.65	-3.01
			+0.50	+2.32
1.45	0.50	0.50	0	0
0.10	0.06	0.06	-0.06	-0.28
0.05	0.09	0.09	-0.15	-0.69
0.30	0.28	0.28	-0.43	-1.99
0.90	0.98	0.98	-1.41	-6.53
1.15	1.34	1.34	-2.75	-12.73
1.25	1.36	1.36	-4.11	-19.03
1.10	1.26	1.26	-5.37	-24.87
0.90	1.04	1.04	-6.41	-29.68
0.50	0.84	0.84	-7.25	-33.57
		14.51		

ERMELO (WET MILLED) -325

WEIGHT OF SAMPLE = 7.523

MEASUREMENTS FOR THE NORMAL MAGNETISAT

(THE BALLISTIC GALVANOMETER

1	2	3	4	5	6	7
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER THROW ON REVERSAL CURRENT IN cm				
		LEFT	RIGHT	LEFT	RIGHT	MEAN
0.0109	2	6.80	6.75	6.75	6.80	6.7
0.038	11	5.10	5.05	5.10	5.05	5.0
0.063	11	9.70	9.70	9.70	9.70	9.7
0.142	33	8.80	8.80	8.85	8.80	8.8
0.39	49	12.85	12.70	12.85	12.75	12.7
0.81	49	16.80	16.80	16.90	16.95	16.8
1.54	65	14.25	14.20	14.25	14.15	14.2
2.25	97	9.85	9.80	9.85	9.75	9.8
3.30	97	9.90	9.80	9.85	9.80	9.8
4.40	97	9.85	9.80	9.85	9.85	9.8
		103.90	103.40	103.95	103.60	
Asymmetry of throws*		0.50 = 0.48%		0.35 = 0.34%		

---

*Difference between columns 3 and 4 or 5 and 6 respecti

E B8a.

PRESSED INTO A PILL AT 25 TONS.
IXED WITH 1.0015g DENTAL CEMENT.
CURVE STARTING WITH THE LOWEST CURRENT FLOW.
STANT K = 2394.04 MAXWELL/cm.).

8	9
x MEAN = $\overline{\beta}$	CALCULATED MAGNETISATION IN GAUSS $I = F'\overline{\beta}$
13.55	31.9
55.83	131.4
106.70	251.1
290.73	684.2
626.71	1474.9
826.14	1944.3
923.65	2173.8
951.57	2239.5
954.48	2246.3
954.48	2246.3

10
PERCENTAGE DIFFERENCE BETWEEN MEAN AND THE TWO SINGLE MEASUREMENTS OF TABLE B8a AND B8b (COLUMN 9)
1.5%
0.8%
0.2%
0.1%
0.5%
0.03%
0.6%
0.5%
0.5%
0.6%

y.

TABI

ERMELO (WET MILLED) -325 MESH
WEIGHT OF SAMPLE = 7.5237g MI
MEASUREMENTS FOR THE NORMAL
WITH THE HIGHEST CURRENT FLO
DECREASE OF TH
(THE BALLISTIC GALVANOMETER CON

1	2	3	4	5
EXCITING CURRENT IN A	MULTIPLIER n	GALVANOMETER VERSAL OF CU		
		LEFT	RIGHT	LEF
4.52	97	9.90	10.15	10.
3.37	97	9.75	9.70	9.
2.28	97	9.85	9.70	9.
1.57	65	14.05	14.05	14.
0.825	49	16.85	16.85	16.
0.398	49	12.95	12.90	12.
0.144	33	8.85	8.80	8.
0.064	11	9.75	9.75	9.
0.039	11	5.20	5.15	5.
0.0112	2	6.90	6.95	6.
		104.05	104.00	104.

Asymmetry of throws* 0.05
= 0.05% =

*Difference between columns 3 and 4 or 5

B8b.

RESSED INTO A PILL AT 25 TONS.
D WITH 1.0015g DENTAL CEMENT.
GNETISATION CURVE STARTING
AND DEMAGNETISING AFTER EACH
CURRENT FLOW.
ANT IS K = 2392.16 MAXWELL/cm).

6	7	8	9
ROW ON RE- ENT IN cm		n x MEAN = $\bar{\beta}$	CALCULATED MAGNETISATION IN GAUSS I = F'$\bar{\beta}$
RIGHT	MEAN		
9.85	9.85	967.58	2275.4
9.75	9.75	944.78	2221.8
9.65	9.71	941.87	2214.9
14.05	14.06	913.90	2149.1
16.85	16.86	826.14	1942.8
12.85	12.93	633.33	1489.4
8.85	8.84	291.72	686.0
9.75	9.75	107.25	252.2
5.10	5.14	56.54	132.9
6.95	6.93	13.85	32.6

103.65

.35
.34%

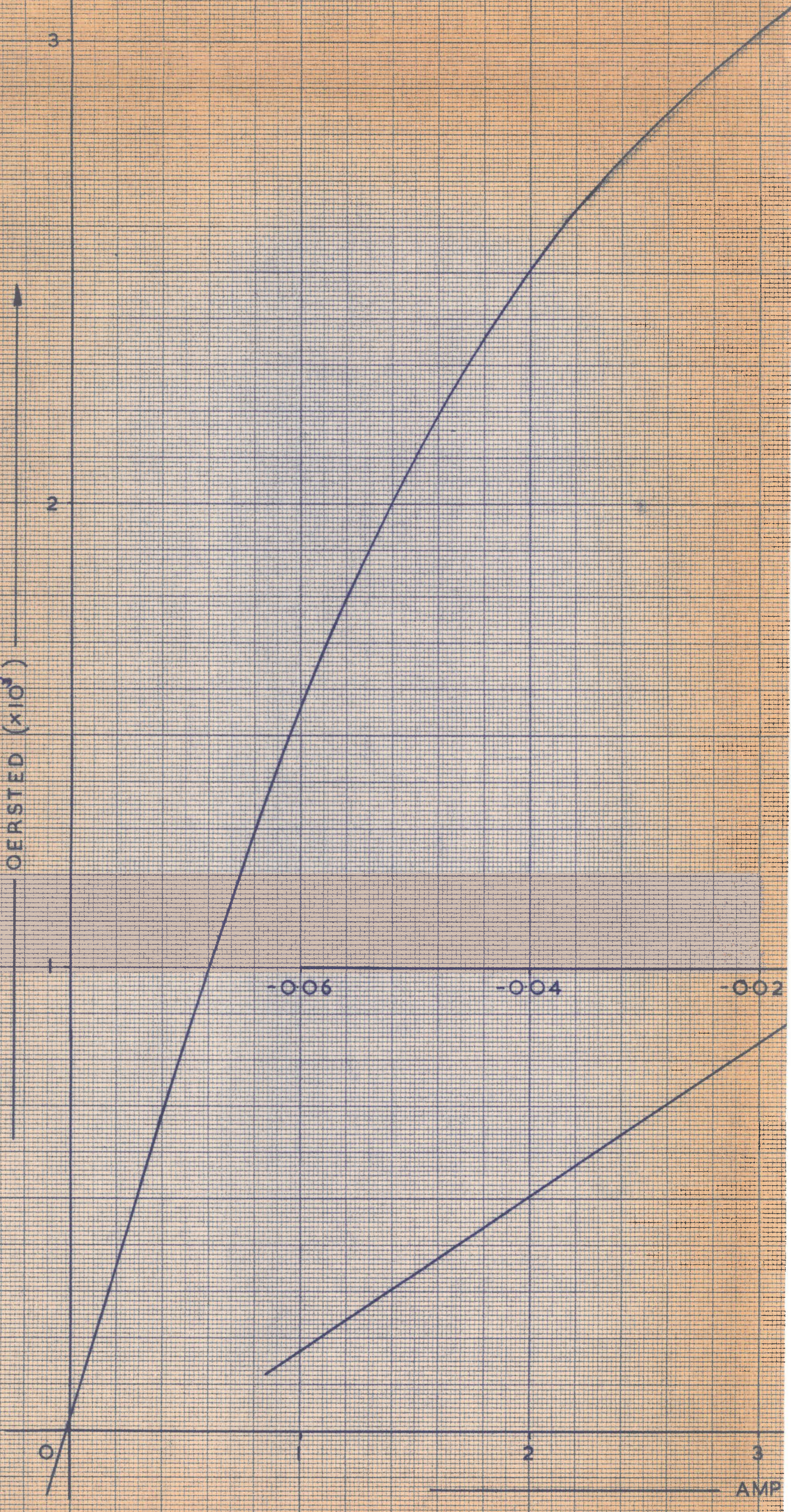
nd 6 respectively.

CALIBRATION OF TWIN ISTHMUS APPARA

HYSTERESIS LOOP

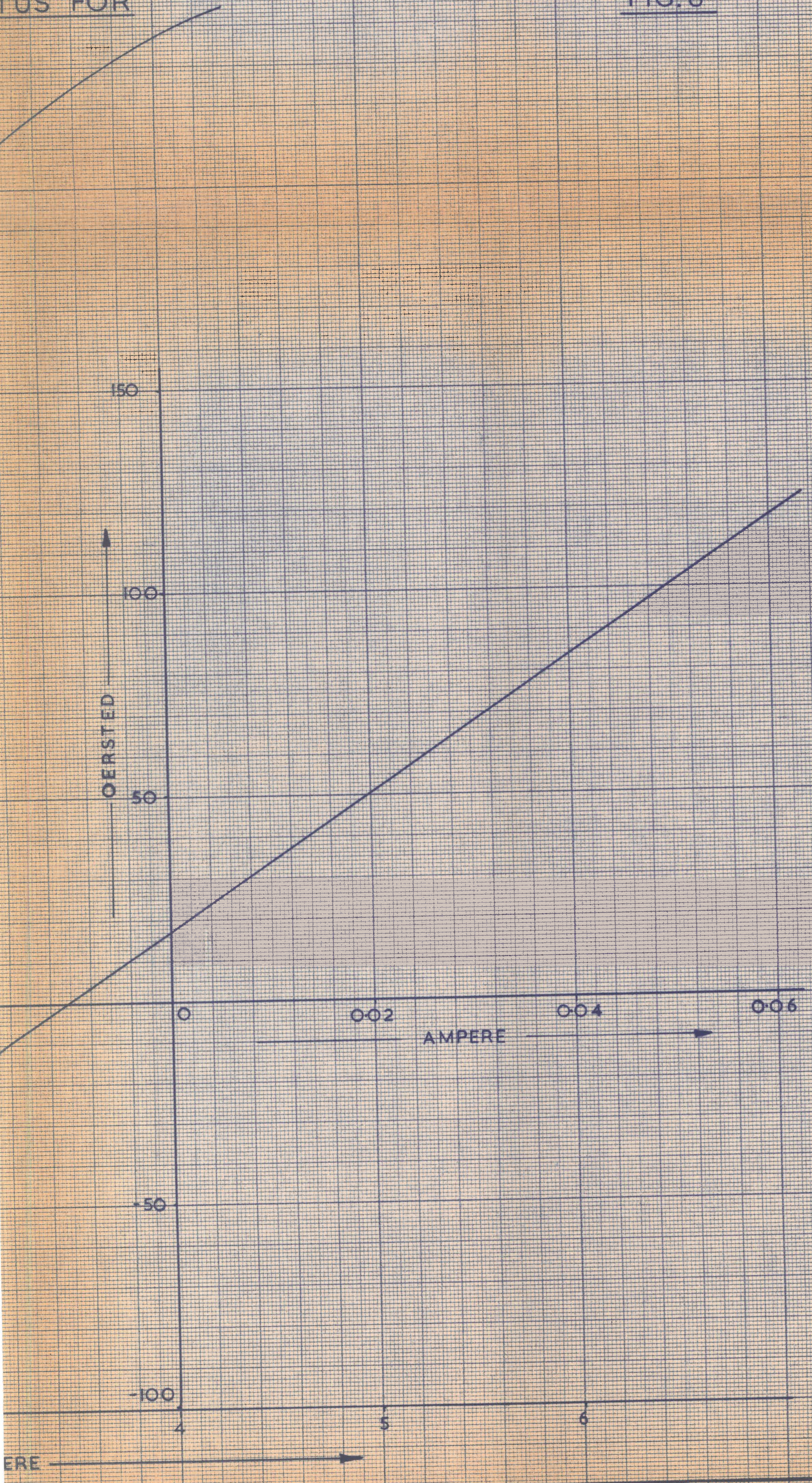
(after renewal of the two wedges)

see Table B 2 a



TUS FOR

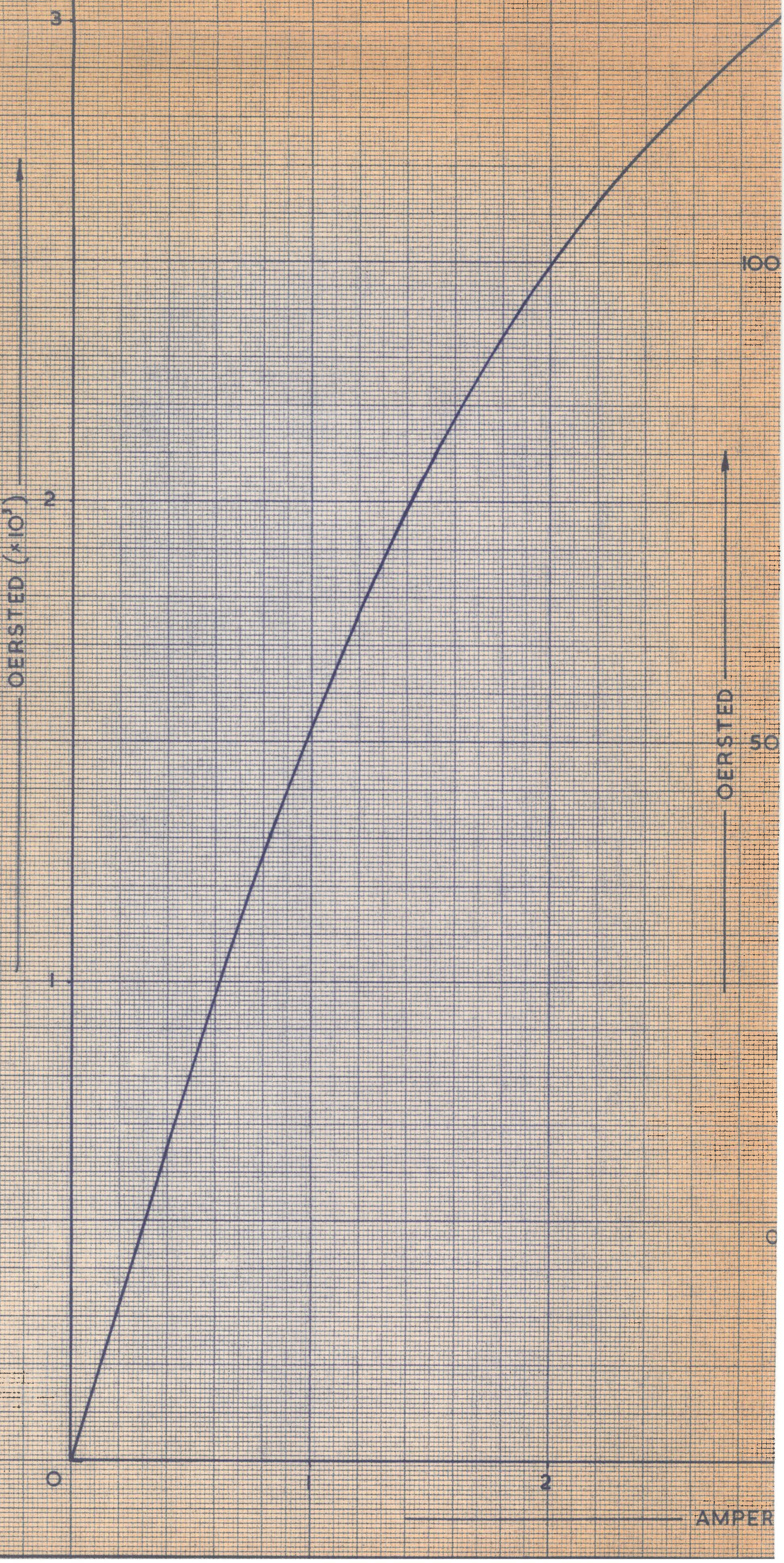
FIG. 8



CALIBRATION OF TWIN ISTHMUS APPAR
NORMAL MAGNETISATION CURV

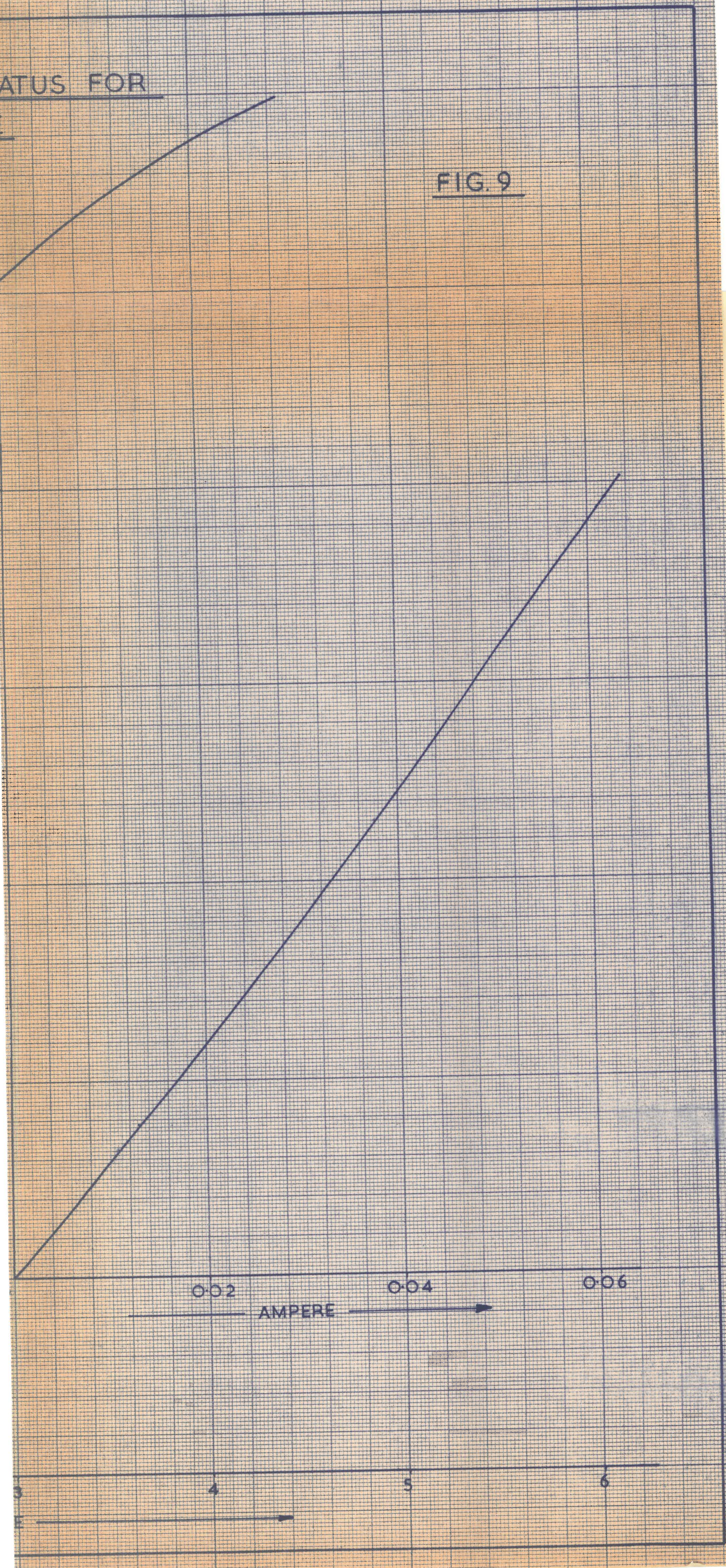
(after renewal of the two wedges)

see Table B 3 a



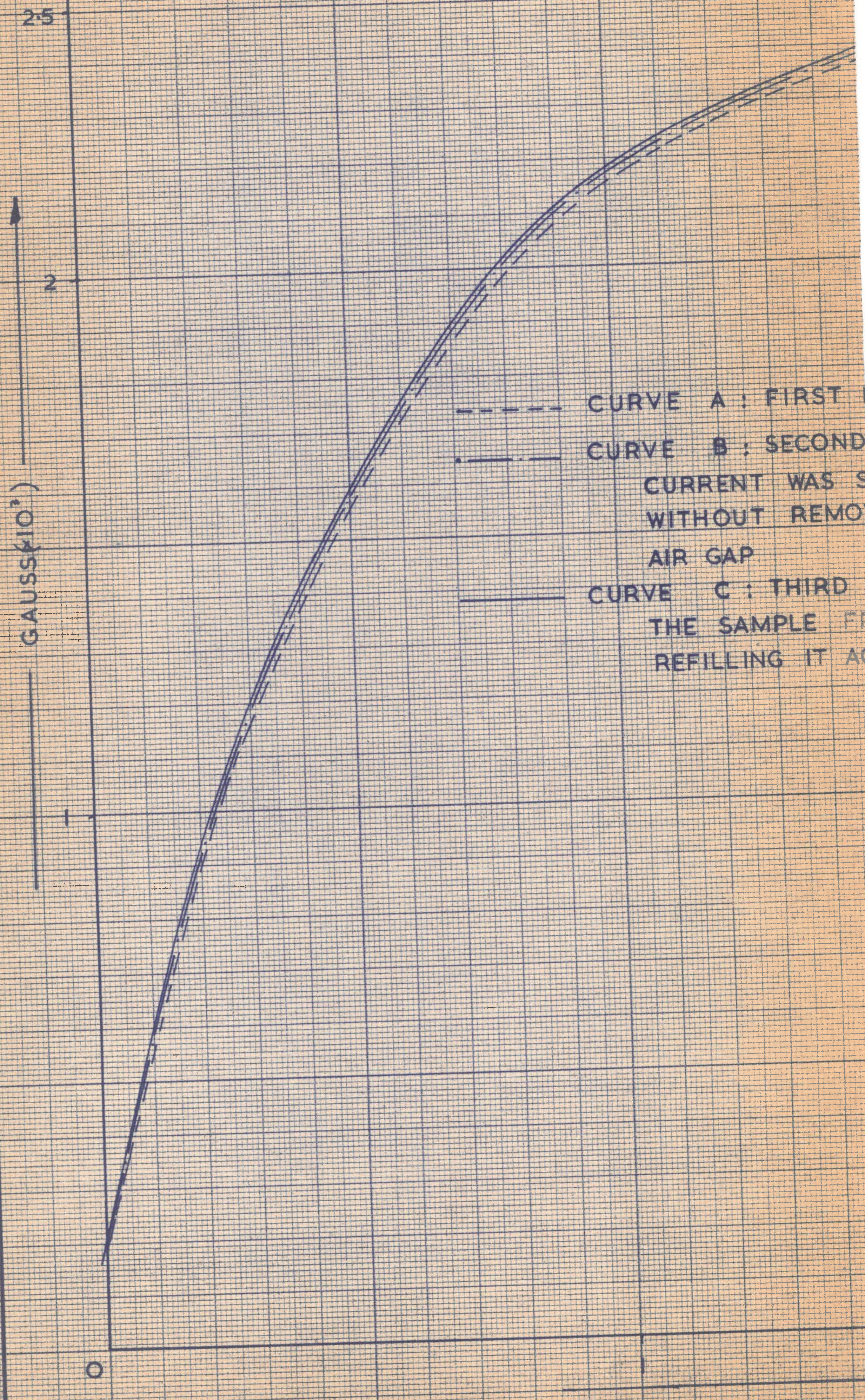
ATUS FOR

FIG. 9



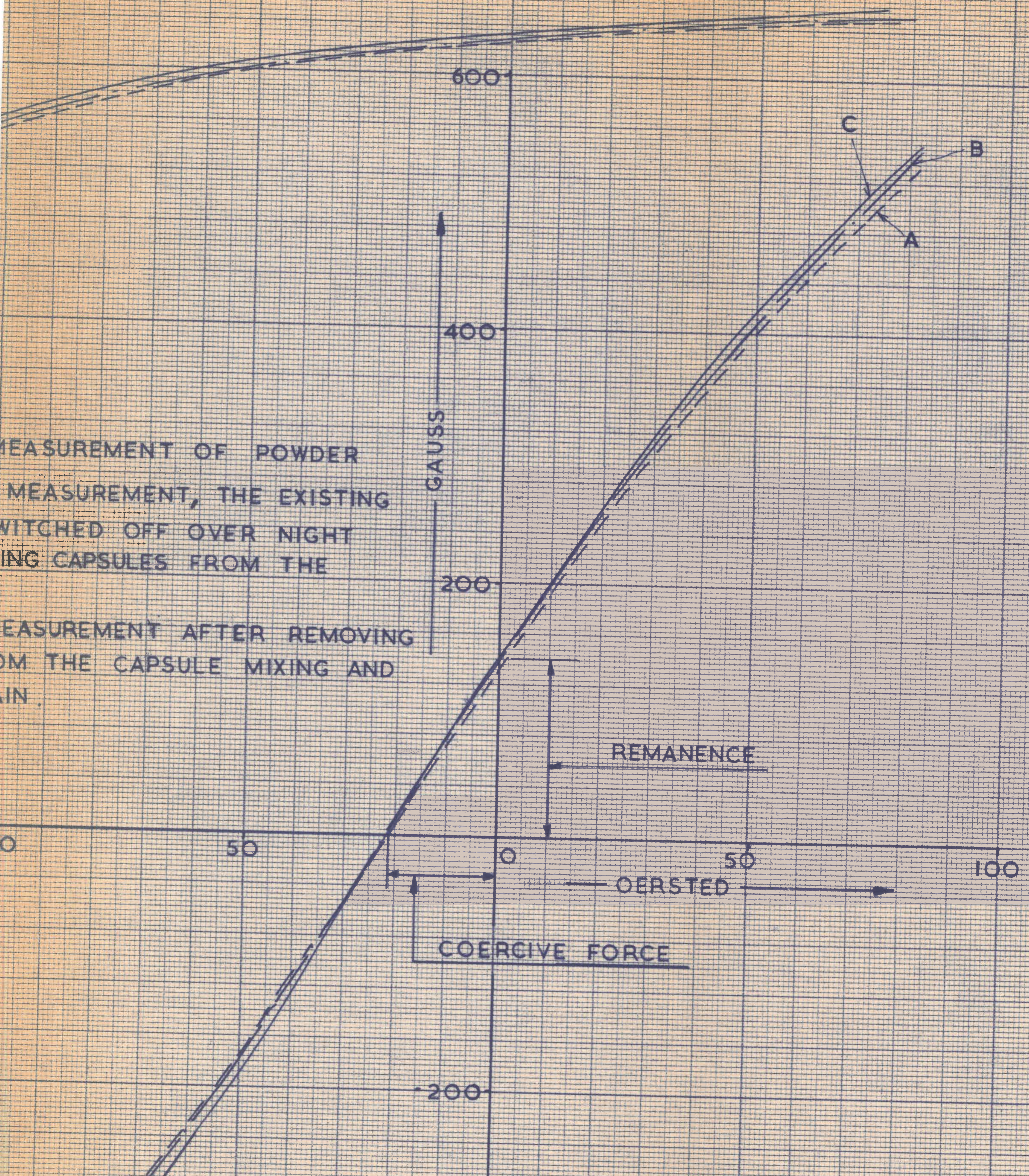
HYSTERESIS LOOPS OF ALAN WOOD M

real packing density = 2·60 g/cc



MAGNETITE -270 +325 mesh (-53+44μ)

FIG.10



MEASUREMENT OF POWDER
MEASUREMENT, THE EXISTING
WITCHED OFF OVER NIGHT
ING CAPSULES FROM THE

EASUREMENT AFTER REMOVING
OM THE CAPSULE MIXING AND
AIN.