A Modified Permeameter.

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In his work on the Magnetic Induction in Iron and Other Metals, Ewing briefly describes a permeameter. (See page 247, Art. 148.) The instrument is for the purpose of determining the magnetisation of a metal by means of the tractive force. In Ewing's work the permeameter method constitutes the fourth method of measuring the magnetic properties of a metal, that of the ballistic, the direct magnetometric, and the optical methods having been

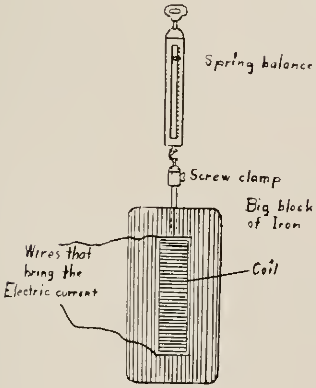

Fig. 130.

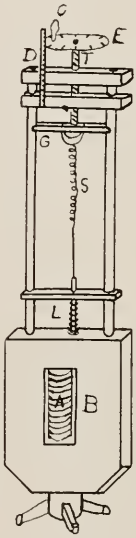

Fig 1.

previously described. After describing the apparatus and developing the equations the author closes his discussion thus: "The tractive method is at best inexact, but it affords a ready means of making rough measurements, especially for purposes of comparison."

Two primary objects were sought in modifying the Thompson Permeameter as shown in Ewing's work, Fig. 130, page 249: First, to render the instrument more accurate, and Second, to avoid complexity such as is necessary in the ballistic method so that the magnetic properties of iron may be introduced earlier in a students' course.

The modified apparatus is shown in Fig. 1. The solenoid (A) is surrounded by a cast iron field (B) which furnishes a metal path for the return lines of force. The lug (L) is separated from the core of the solenoid by a very thin piece of paper. The core of the coil can be easily replaced by a core of a different metal, thus giving a different test. The force required to separate the lug from the core is measured by means of the spring (S). Since the pull exerted by a spring is directly proportional to the distance it is stretched it becomes necessary simply to measure accurately the distance the spring is stretched in separating the lug (L) from the core. The upper end of the spring is attached to a sliding guide bar (G), to which is fastened a micrometer screw (T). By turning this micrometer screw the spring may be stretched sufficiently to pull the lug away from the core which is being tested. The number of whole turns of the screw may be read from the index bar (D), and the fractional part of a turn to one-tenth of a turn may be read from the disk (E.) By standardizing the spring and reading micrometer by means of known weights the force in screw turns may be reduced to grams or pounds.

The permeameter with the auxiliary apparatus is set up as shown in Fig. 2.

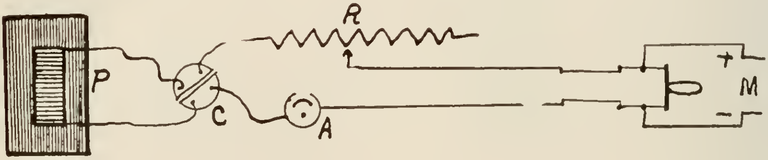

Fig. 2.

P, is the permeameter.

C, is rotary commutator by means of which an alternating current may be thrown through the solenoid, thus demagnetizing the core.

R, is a variable resistance by means of which the current may be varied from zero to twenty-five amperes.

A, is an ammeter.

M, represents the source of current, which is the ordinary 110 volt direct lighting current.

The method of obtaining data is as follows: First demagnetize the core specimen to be tested by rotating the rotary commutator, thereby causing an alternating current to flow through the solenoid. When the specimen is demagnetized it will exert no pull on the lug (L). Next pass a very slight current through the solenoid, place the lug in contact with the core and turn the crank until the lug and core are separated. The number of turns can be read directly from the slide index (D) and the disk (E). The current strength is read from the ammeter. The current is then increased and the force measured which is required to separate the lug and core. This process is continued, noting in each instance the current strength and the pulling force of the spring, until the pulling force ceases to increase with an increase of current, indicating that the core is saturated. The current is now decreased step by step and the pulling force and the current strength noted in each case. When the current reaches zero it is reversed and the process indicated above is repeated. When the current is again brought back to zero it is reversed the second time and increased to the point of saturation. Thus data for the complete hysteresis loop may be taken.

The equations for transforming the results from a permeameter into the B and H values for plotting the hysteresis loop are as follows. (See Ewing's work page 248.)

$$\text{Pull in lbs.} = \frac{(B - H)^2 \times S(\text{sq. cm.})}{11183000}$$

$$\text{or } B = 3344 \sqrt{\frac{\text{Pull in lbs.}}{S(\text{sq. cm.})}} + H$$

$$\text{or } B = 1317 \sqrt{\frac{\text{Pull in lbs.}}{S(\text{sq. cm.})}} + H$$

The value of H may be determined by the following equation, in which N is the number of turns, I the current strength in amperes and l is the length of the solenoid in cm.

$$H = \frac{1.26\ N\ I}{l}$$

Fig. 3.

DATA.

Length of solenoid, 9.5 cm. Number of turns, first coil 176, second coil 273. The force of the spring represented by one turn of the micrometer screw is 13 grams or 0.028 lb.

Record for a Cold Rolled Steel Rod 0.5 in. Diam. Coil 176 Turns.

Amp. I.	Pull in Turns.	Pull in Pounds.	Amp. I.	Pull in Turns.	Pull in Pounds.	Amp. I.	Pull in Turns.	Pull in Pounds.
0.0	0.0	0.0000	0.0	1.0	0.028	0.0	1.0	0.028
0.4	0.4	0.0112	0.4	0.3	0.008	0.4	0.2	0.006
0.8	3.0	0.0840	0.8	2.5	0.060	0.8	2.0	0.056
1.2	10.5	0.294	1.2	9.0	0.262	1.2	8.5	0.238
1.6	17.0	0.4761	1.6	18.0	0.484	1.6	19.0	0.541
2.0	22.0	0.6160	2.0	26.0	0.628	2.0	25.0	0.700
2.5	28.0	0.7840	2.5	28.5	0.798	2.5	30.0	0.840
3.5	35.0	0.9800	3.5	36.0	1.008	3.5	35.0	0.980
4.5	36.0	1.0080	4.5	40.0	1.120	4.5	39.0	1.094
5.0	38.0	1.0640	5.0	40.0	1.120	5.0	40.0	1.120
5.5	38.0	1.0640	5.5	40.0	1.120	5.5	41.0	1.1 8
6.0	39.0	1.0940	6.0	40.0	1.120	6.0	41.0	1.148
5.5	39.0	1.0940	5.5	40.0	1.120			
5.0	38.0	1.0640	5.0	40.0	1.120			
4.5	39.0	1.0940	4.5	40.0	1.120			
3.5	37.0	1.0360	3.5	8.0	1.064			
2.5	32.0	0.8960	2.5	36.0	1.008			
2.0	28.0	0.7840	2.0	31.0	0.868			
1.6	27.5	0.7700	1.6	28.0	0.784			
1.2	23.0	0.6440	1.2	24.0	0.672			
0.8	17.0	0.4761	0.8	18.0	0.484			
0.4	6.0	0.1642	0.4	8.0	0.204			
0.0	1.0	0.0280	0.0	1.0	0.028			

Above Results Converted into H and B Values.

Amp. I.	H.	B.	Amp. I.	H.	B.	Amp. I.	H.	B.
0.0	0.00	0.00	0.0	0.00	497.79	0.0	0.00	497.79
0.4	9.32	324.14	0.4	9.32	307.82	0.4	9.32	239.75
0.8	18.64	878.84	0.8	18.64	742.27	0.8	18.64	747.30
1.2	27.96	1642.76	1.2	27.96	1550.66	1.2	27.96	1480.26
1.6	37.28	2137.28	1.6	37.28	2106.88	1.6	37.28	2225.33
2.0	46.60	2381.40	2.0	46.60	2404.10	2.0	46.60	2525.60
2.5	58.25	2692.25	2.5	58.25	3039.95	2.5	58.25	2617.25
3.5	81.55	3025.75	3.5	81.55	3173.05	3.5	81.55	3025.75
4.5	104.85	3090.95	4.5	104.85	3253.05	4.5	104.85	3216.35
5.0	116.50	3185.10	5.0	116.50	3264.70	5.0	116.50	3264.70
5.5	128.15	3196.75	5.5	128.15	3276.35	5.5	128.15	3315.50
6.0	139.80	3255.30	6.0	139.80	3288.00	6.0	139.8	3327.15
5.5	128.15	3243.65	5.5	128.15	3276.35			
5.0	116.50	3185.10	5.0	116.50	3264.70			
4.5	104.85	3220.35	4	104.85	3253.05			
3.5	81.55	3162.25	3.5	81.55	3150.05			
2.5	58.25	2874.15	2.5	58.25	3149.75			
2.0	46.60	2680.60	2.0	46.6	2818.10			
1.6	37.28	2617.60	1.6	37.28	2671.28			
1.2	27.96	2451.96	1.2	27.96	2466.56			
0.8	18.64	2071.04	0.8	18.64	2088.24			
0.4	9.32	1215.02	0.4	9.32	1352.92			
0.0	0.00	497.79	0.0	0.00	479.79			

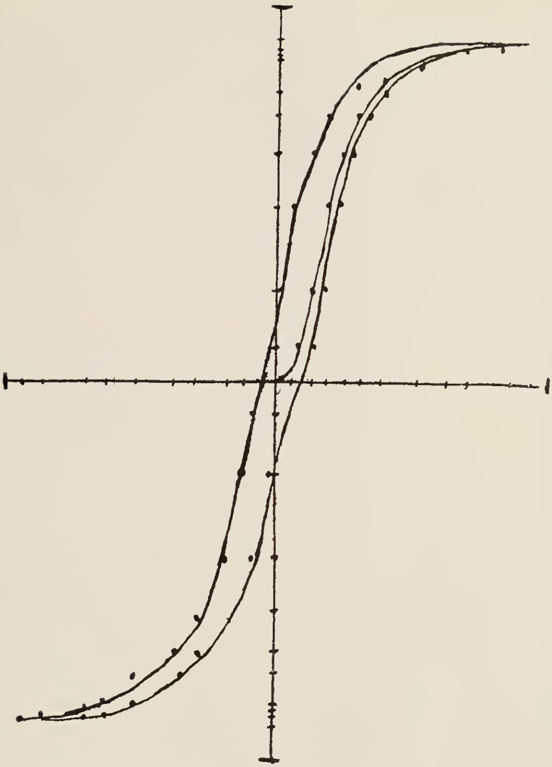

Fig. 4. Hysteresis Plot.

CONCLUSIONS.

The plot here given establishes the fact that the magnetic properties of iron and steel can be obtained by the permeameter method to a reasonable degree of accuracy, sufficient for student purposes.

From a number of tests which have been made the permeameter establishes in an interesting way the fact that a much stronger current is required to bring a hard metal to magnetic saturation than a soft metal.

The permeameter test also demonstrates that the magnetic pull exerted by a soft metal is much stronger than that of a hard metal under the influence of the same current.

These peculiarities are more easily shown by this instrument than any toher, owing to the fact that different metals can be examined under the same conditions.

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