Table III.

Date.	Resistance at atmospheric temperature in ohms.
1st November, 1897	0·4625
3rd " "	0·4590
13th " "	0·4592
20th " "	0·4589
" " "	r_3 = 0·2269
" " "	r_4 = 0·2270
4th January, 1898	r_3 = 0·2275
" " "	r_4 = 0·2277

The strip was mounted on November 1, 1897, and submitted to currents varying from 100 amperes downwards. On November 20, 1897, it was adjusted for r_3, r_4. The results show that there is an initial diminution of resistance, and that then the resistance remains practically constant. This is worth noting, as this material is largely used at the present time, on account of its low temperature coefficient. The manganin strip is unvarnished and exposed to the atmosphere of the engine room. The conditions are therefore not the best to secure constancy of resistance, but in all probability the initial diminution is due to the brazing.

Messrs. C. J. Evans and H. H. Hodd have given me valuable assistance, not only in the experimental part of this paper, but also in the working out of the results. Messrs. Simpson, Greenbank, and Davey, the present Student Demonstrators in the Siemens Laboratory, have also helped me. I wish to acknowledge this, and to tender my thanks to these gentlemen.

"The Magnetic Properties of almost pure Iron." By ERNEST WILSON. Communicated by Dr. J. HOPKINSON, F.R.S.

Received January 11,—Read January 27, 1898.

One of the two rings of almost pure iron supplied by Colonel Dyer, of the Elswick Works, to Sir Frederick Abel, K.C.B., F.R.S., by whom they were sent to Dr. John Hopkinson, F.R.S., has already formed the subject of a communication,* and is herein referred to as Pure Iron I. As this pure iron has not been directly tested for dissipation of energy due to magnetic hysteresis, and the second ring was available, the author thought it would be interesting to examine

* 'Roy. Soc. Proc.,' vol. 52, p. 228.

its magnetic properties: it is referred to as Pure Iron II. The substances other than iron in this specimen are stated to be—

Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
Trace	Trace	None	0·013	0·1

This ring has an internal diameter of 3·2 cm., an external diameter of 4·5 cm., a depth of 2·6 cm., and is wound with sixty-one turns for the secondary coil next the iron, and forty-nine turns for the primary or magnetising coils. The method of test* employs a ballistic galvanometer, and is that in use in the Siemens Laboratory, King's College, London, where the present experiments were carried out. The currents in the primary circuit were supplied by storage cells and measured by balancing the potential difference due to such currents in a standard resistance against a Clark's cell. The current meter in the circuit was only used for convenience of adjustment.

Quoting from the communication above referred to, Pure Iron I gives the following induction curve at atmospheric temperature:—

B	34	118	467	2,700	7,060	10,980	14,160	15,590	16,570	17,120	17,440
H	0·15	0·38	0·60	1·06	2·11	3·77	7·48	13·36	23·25	33·65	44·66

Pure Iron II has been tested under two conditions: (*a*) as received and (*b*) after careful annealing. The results are given in Table I, which also contains the results obtained by Professor Ewing from a sample of transformer plate rolled from Swedish iron.† The figures of Professor Ewing relating to magnetic hysteresis are exceptionally low, and although annealing has considerably improved the Pure Iron II, it is still slightly inferior to the transformer plate. On the other hand, the permeability μ of this pure iron after annealing is exceptionally high, having a value 5490 for B = 9000. The coercive force for maximum B = 15,270 is 1·13 C.G.S. units.

The figures in Table I relating to Pure Iron II after annealing have been obtained by interpolation from the actual observed data given in Table II. An induction density of 15,270 for H = 9·24 is higher than the author remembers having seen. In fact, for values of H below about 10 or 12 this specimen is exceptionally good, as is shown by the very high permeability.

* 'Roy. Soc. Proc.,' vol. 53, p. 352.

† 'Proceedings Institution of Civil Engineers,' vol. 126, p. 185.

Table I.

Limits of B in C.G.S. units per square centimetre.	Dissipation of energy by magnetic hysteresis in ergs per cycle per cubic centimetre.					
	Transformer plate rolled from Swedish iron (Ewing).		Pure Iron II tested as received.		Pure Iron II tested after annealing.	
		μ.		μ.		μ.
2000	220	2560	350	2000	262	2500
3000	410	3340	500	2730	460	3190
4000	640	3880	800	3330	720	3810
5000	910	4230	1100	3700	1010	4350
6000	1200	4410	1450	4138	1350	4800
7000	1520	4450	1760	4375	1670	5380
8000	1900	4330	2160	4445	2020	5440
9000	2310	4090	2600	4615	2450	5490
10000		3790	3100	4545	2860	5460
12000			4400	4000		4900
14000			5900	2641		3260
15000				1415		2050

Table II.

Limits of H.	Limits of B.	$\frac{1}{4\pi}\int H\,dB$.	μ.	Coercive force in C.G.S. units.
0·783	1965	262	2510	0·50
1·14	4840	..	4245	..
1·17	5150	1080	4400	0·73
1·42	7500	..	5280	..
1·66	9100	2490	5480	0·90
2·23	11460	..	5140	..
2·68	12500	..	4660	..
4·74	14270	..	3010	..
9·24	15270	..	1650	1·13

Apparent Magnetic Instability.

Whilst making the foregoing experiments, the author noticed how great was the apparent magnetic instability in this specimen, and thought it worth while to investigate this more closely.

It has already been noticed, and is well known, that if the magnetising force be varied from one maximum value through zero to a value equal, say, to the then coercive force of the material, that tapping the specimen will produce a considerable change of induction; or, if the observed kick on a ballistic galvanometer (in circuit with a secondary coil wound on the specimen) due to such change be added to the observed kick when the magnetising force is raised to

the opposite maximum, the sum does not equal the whole kick which would be observed if the force were at once varied from the one maximum to the other. During the interval the magnetism appears to continue to settle down, so that the change which lastly takes place is not so great as it would be if such apparent settling down did not occur.

Experiments were made to investigate the effect when the limits of B were (*a*) large and (*b*) small. It is assumed that the instrument gives the true time integral of current.

(*a*) Maximum B = 15,270, coercive force 1·13 C.G.S. units. The maximum force H of 9·24 C.G.S. units was suddenly varied through zero to 1·13, and the secondary circuit kept closed until deflections to the left and right were observed, the periodic time of the galvanometer needle being 10·6 seconds. The scale is graduated from 0 on the left to 1000 on the right, and the readings taken were 351, 623, giving a difference of 272, corresponding to a change of induction per square centimetre of 12,630 C.G.S. units. When the magnetism had settled down, as was shown by closing the secondary key with no extra resistance in its circuit, and observing no deflection on the ballistic galvanometer, a suitable extra resistance was inserted, and the force suddenly raised to its maximum value, the observed deflections were 362, 627, the difference 265 corresponding to B = 12,350. These results were many times repeated.

The total change of induction produced a deflection 662, 330, the difference 332 corresponding to B = 15,270. We have therefore to account for a difference of 5560, or 18 per cent. of the total change from one maximum to the other. The zero, when the spot of light is perfectly steady, is 495, and we can see that when making the first change from one maximum through zero to force 1·13 the deflection to the left is 143 as against 128 to the right; whereas when making the second change the deflections are 133 to the left and 132 to right. There is evidence here of a change continuing in the same direction, since the first elongation is greater than the second, and the decrement would only account for about 1 per cent.

This effect was next observed in a slightly different manner. The change of force from one maximum through zero to the then coercive force was effected, and the secondary circuit closed at known intervals of time after such change. The results are given in Table III.

It will be seen from the figures that about 30 per cent. comes out after the first second has elapsed, and that the result is practically the same, whether the charging potential difference be that due to ten or fifty-six cells. With a total reversal from one maximum to the other no such effect was observed, the change taking place immediately. Having taken the force from one maximum through

Table III.

Time in seconds	0	1	2	3	4	5	6	10
Change of B, 10 cells exciting through extra resistance	13600	4030	1990	927	576	285	175	42
Change of B, 56 cells exciting through extra resistance	13800	3690	1680	944	529	256	..	40

zero to a value equal to the then coercive force, the specimen was tapped four times with a piece of wood, and at each stroke it delivered 105, 40, 56, 30 C.G.S. units per square centimetre in the direction of acquirement of magnetism.

(*b*) Maximum $B = 3770$, maximum $H = 1{\cdot}003$. The force was varied from one maximum through zero to 0·620 and a deflection corresponding to $B = 3620$ observed. The figures in Table IV give the results obtained by closing the secondary circuit at known intervals of time after reversal.

Table IV.

Time in seconds	0	1	2	3	5
Change of B, 5 cells exciting through extra resistance	3620	536	95	25	10

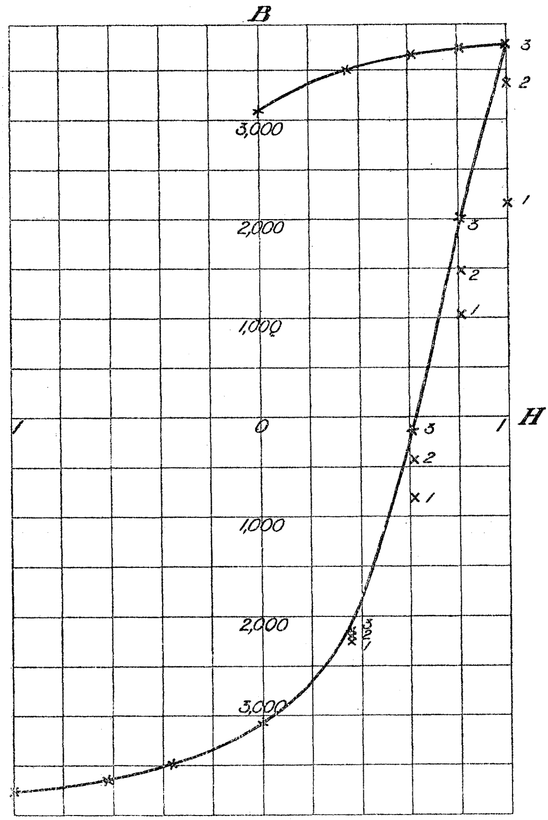
One would expect the maximum induction to be affected in this case, since it is on the steep part of the curve: the figures obtained are given in Table V.

Table V.

Time in seconds	0	1	2	3	5
Change of B, 5 cells exciting through extra resistance	3770	796	23	14	6·5

The curve in fig. 1 shows this effect clearly; the points 1, 2, 3, for any force show the observed change of induction density B when the secondary key is raised $\frac{1}{2}$ second, 1 second after reversal, and

Fig. 1.



kept down permanently as in the ordinary way. When observing the deflections for the curve in fig. 1, the five cells used for exciting had placed across their terminals a condenser of 4 microfarads capacity.

We are dealing with a very steep curve in these experiments, that is to say, the rising portion for the large forces is very nearly perpendicular. We observe that it is on the steep portions that these effects have been noticed, and such effects could very easily be produced by a slow change in the magnetising force. Such slow change might arise from the heating of resistances in the circuit if these be of carbon; this was looked into and only metal resistances used. The self-induction of the circuit might, if large enough, delay the magnetising current and produce the effect. We have seen that it is practically the same whether the applied potential be that due to ten or fifty-six cells. In any case the self-induction can be approxi-

mately calculated in our case. Take the curve in fig. 1—we see B increases 5750, whilst H increases 0·6. The total change is 9860, since the cross sectional area of the specimen is 1·715 sq. cm. H = 0·6 corresponds to a change of 0·117 ampere, and taking the volt as our unit and the primary turns at 50, we find $L = 4{\cdot}21 \times 10^{-2}$, where L is the coefficient of self-induction. If E be the applied potential and R the resistance of the circuit, the current at any time t after closing the circuit can be expressed by $\frac{E}{R}(1-\epsilon^{-\frac{R}{L}t})$. For $t = \frac{1}{2}$ second the current has its maximum value within an exceedingly small quantity. But the method of experiment enabled one to test the rapidity with which the current rises to its maximum value. Let a balance be made, say when the current is such that the force is equal to the coercive force of the material. Now suddenly reverse the force from its maximum through zero to this value. The immediate depression of a key tells at once if the current is still balanced. The current immediately after reversal, that is to say within $\frac{1}{4}$ second, had certainly attained its normal value to within 0·3 or 0·4 per cent.

The condenser had no material effect upon the rapidity with which the current attained its maximum value. We can only conclude that the effect is peculiar to the iron itself, and might be influenced by induced currents, since the ring is not subdivided. The subject of propagation of magnetism as affected by induced currents has been dealt with in the case of a magnet having a core 12 inches diameter,* and a magnet having a diameter of 4 inches.† Imagine that the cross-section of our pure iron specimen is circular instead of rectangular—it would have a diameter of 14·8 mm. If we assume equal conductivities and magnetic properties, we can infer roughly from the 12- and 4-inch magnets what the effect of induced currents in our specimen would be.

Take the 12-inch magnet. For reversal of maximum H = 2·4 the effects had died away in about 400 seconds. Similar events will happen in the pure iron core, but at times varying as $\left(\frac{14{\cdot}8}{305}\right)^2$: that is, we should expect the effects to have subsided in 0·85 second.

Take the 4-inch magnet. For reversal of magnetism H = 1·7 the effects had subsided in about 40 seconds: $\left(\frac{14{\cdot}8}{101{\cdot}6}\right)^2 \times 40$ gives 0·94 second.

It is, therefore, probable that the induced currents in the pure Iron II may have something to do with the effects observed in this paper, although it is difficult to account for such times as 5 and

* 'Journal of the Institution of Electrical Engineers,' vol. 24, No. 116 (1895).

† 'Phil. Trans.,' A, vol. 186, pp. 93—121.

10 seconds, unless the molecule itself is considered. This effect has been observed in laminated specimens.

The difficulty of working with alternate currents, if the core be subdivided, in order to investigate the effects observed, using the method in the 'Proceedings of the Royal Society,' vol. 53, p. 352, is the necessity for the very accurate control and measurement of the magnetising force. Small variations of this force would at once mask the effects observed. In the paper just mentioned a considerable difference was observed between cyclic curves obtained with the ballistic galvanometer and by means of alternate currents having frequencies of 72 and 125 per second in the case of a laminated hard steel ring for maximum B = 16,000. On the other hand, no such difference was observed in the case of a laminated soft iron ring when maximum B was 4000.* It would seem from the experiments in this paper that the amplitude of induction would not be so great for high frequency and small induction density B, and this is of importance in the case of iron cores for transformers. It is worth noting that when working on solid rings with the ballistic galvanometer induced currents may account for apparent magnetic instability.

Mr. H. H. Hodd has helped me in the experimental part of this paper, and I here wish to tender him my thanks.

"On a new Method of Determining the Vapour Pressures of Solutions." By E. B. H. WADE, B.A. Communicated by Professor J. J. THOMSON, F.R.S. Read May 13, 1897.

(Amplified Abstract, received December 22, 1897.)

On a previous occasion† I gave some boiling points of salt solutions under atmospheric pressure. As the dimensions of that abstract made a full account of the experimental method impossible, I have been given this opportunity, by the courtesy of the Council of the Royal Society, of describing the apparatus and procedure by which those results were obtained.

§ 1. *Difficulties to be overcome.*

The exact determination of boiling points of solutions has been attended hitherto with a good deal of difficulty. The boiling point of the pure solvent is first determined. Salt is then added, and the boiling point is redetermined. The experiment consists, in fact, of two parts, and the difficulty lies in making the circumstances in which the first part of the experiment was carried out identical with

* See 'Electrician,' September 9, 1892.

† 'Roy. Soc. Proc.,' vol. 61, pp. 285—287.