XV. *On the Difference in the Magnetic Properties of Hot-Rolled and Cold-Rolled Malleable Iron, as regards the power of receiving and retaining Induced Magnetism of Subpermanent Character.* By George Biddell Airy, *Astronomer Royal.*

Received April 22,—Read May 15, 1862.

In reflecting on the differences exhibited by different iron-built ships in the change of their subpermanent magnetism, it has often occurred to me as a subject worthy of experimental investigation, whether a portion of this difference might not depend on the temperature at which the plates of iron are passed through the rollers in the last stage of their manufacture. No favourable opportunity of making these experiments presented itself until, in the course of the last winter, I became aware that Mr. Fairbairn had been engaged in experiments on the difference of the strength of plates of malleable iron, according as they had been rolled at a high or at a low temperature. I immediately requested Mr. Fairbairn's kind offices for procuring for me bars adapted to magnetic experiment, divided into the four classes of—1. Hot-Rolled, with the length of the bars parallel to the direction in which the rolling had lengthened the iron, or parallel to the direction of fibre; 2. Hot-Rolled, with the length of the bars transverse to the direction of fibre; 3. Cold-Rolled, with the length of the bars parallel to the direction of fibre; 4. Cold-Rolled, with the length of the bars transverse to the direction of fibre (which classes will hereafter be described by the words, 1. Hot-Rolled Longitudinal; 2. Hot-Rolled Transversal; 3. Cold-Rolled Longitudinal; 4. Cold-Rolled Transversal). Upon Mr. Fairbairn's application, the bars which I requested were promptly and gratuitously furnished by Richard Smith, Esq., Superintendent of Lord Dudley's Iron Works at the Round Oak Works near Dudley.

The number of bars was 24, namely, 6 in each of the four classes above described. Each bar was 16 inches long, 4 inches broad, and about $\frac{1}{4}$ inch thick: the aggregate weight of the bars in each class was,—1st, 28 lbs. 8 oz.; 2nd, 28 lbs. 10 oz.; 3rd, 27 lbs. 10 oz.; 4th, 27 lbs. 8 oz. The manufacture of the bars is described to me in substance as follows:—The hot-rolled and cold-rolled bars were all manufactured in the same way up to the stage of producing sheets of iron of the desired thickness; the last rollings having commenced with large bars at a welding heat, and having terminated with the bars (now converted into sheets) at a dull red heat. Then the sheets to be cold-rolled were allowed to cool to a perfectly cold state, and in that state were rolled afresh between other rollers. After this, the experimental bars were cut out of the sheets. Each set of six bars was packed in one box, with the maker's inscription on every bar reading forward in the same direction in all.

The bars when received by me, after resting some days in a room, were all placed

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upright in the same direction relatively to the direction of the maker's inscription, and the distinctive number of the bar was painted on the upper end of each; the end on which it was painted being that which is called "the Lettered End." The bars rested thus for several days, with the lettered end upwards.

The following apparatus was prepared for the experiments:—A wooden frame was constructed about 11½ feet in length; and this length, in the use of the frame, was placed very approximately in the direction of magnetic E. and W. Its ridge was 21 feet N. of the old front, or 13 feet N. of the new front, of the anteroom of the Magnetic Observatory. The upper and essential part of the frame consisted of two planes, each about 2 feet broad; of which one was very approximately in the position transverse to the direction of dip at Greenwich; and the other, at right angles to the former, included in its plane the direction of dip. These are called "Equatorial Plane" and "Dip Plane" respectively. Ledges of wood were attached to the planes, for the support of flagstones resting on the planes and lying parallel to them. And whether the wooden surface or the stone surface was employed, a frame of laths was placed upon it, which retained the length of each bar in the position nearest to the vertical, and prevented one bar from touching another. In this position the bars were struck with a hammer. If they were upon the equatorial plane, any induced magnetism was instantly struck out of them; if upon the dip plane, they became powerfully magnetized, the lower end having the same properties as the marked end of a compass-needle, or being charged with austral magnetism.

For testing the magnetism, a vertical wooden rod was provided, carrying two horizontal planes or stages, also of wood. The upper stage supported a prismatic Kater's compass, with which a well-defined mark (the ball-mast) was viewed, and its apparent azimuth was read. The lower stage supported the bar under experiment, which was placed in a horizontal position below the compass, at the distance of 5 inches, as nearly as could be conveniently measured, between the centre of the compass-needle and the centre of the bar. The reading of the compass-card under view increases as the card turns in the direction opposite to that of the sun's diurnal motion. From this it will appear that when the end of a bar, which has been downwards on the dip surface, is placed eastward on the lower plane, the austral magnetism of that end will attract the needle's south end towards the east, and will cause the card-reading to increase.

The bars were numerated as follows:—

(Hot-Rolled Longitudinal) Nos. 1, 2, 3, 4, 5, 6 (painted in white);
(Hot-Rolled Transversal) Nos. 7, 8, 9, 10, 11, 12 (painted in black);
(Cold-Rolled Longitudinal) Nos. 13, 14, 15, 16, 17, 18 (painted in red);
(Cold-Rolled Transversal) Nos. 19, 20, 21, 22, 23, 24 (painted in blue).

In the conduct of the experiments, the following rules were uniformly followed:—

The bars of the different classes were systematically intermixed, the same order being preserved in the whole series of experiments. Thus the order in which they were placed upon either plane (equatorial or dip), and the order in which their effects in disturbing the compass were observed, was always the following:—

Order of position, or experiment.	No. of bar.	Order of position, or experiment.	No. of bar.	Order of position, or experiment.	No. of bar.
1	1	9	3	17	5
2	7	10	9	18	11
3	13	11	15	19	17
4	19	12	21	20	23
5	2	13	4	21	6
6	8	14	10	22	12
7	14	15	16	23	18
8	20	16	22	24	24

The bars, when on the equatorial plane, were struck in the order 1 to 24 of the "Order of Position, or Experiment;" when on the dip plane, they were struck in the opposite order. They were always placed on the experimental stage under the compass in the order 1 to 24 of the "Order of Position, or Experiment." A printed skeleton form had been prepared, and the entries in it of the compass-readings were made without the slightest risk of confusion. The lettered end of the bar was always in the first instance placed towards the east; and, as soon as the compass-card was read, the bar was reversed in length, and its lettered end placed towards the west, and the compass-card was again read. The difference between these two readings (which has been carefully verified by examination, and by collateral formation and difference of sums of readings) is the number recorded in this paper. The zero, or card-reading when no bar was near, was usually taken at the beginning and at the end of each experiment, merely to enable me to detect erroneous readings, but no further use was made of it.

In two instances in Experiment 13, the presumption of error of 5° (undetected at the proper moment) was so strong, and the uncertainty as to the side on which the error was made was so great, that I judged it best to omit them, and to multiply the result for four bars by $\frac{3}{2}$, in order to produce the result for six bars.

The "Diff. readings" in the following Tables denotes the excess, with its proper algebraical sign, of the compass-reading when the lettered end of the bar is East above the compass-reading when the lettered end is West, and is taken as measure of the intensity of magnetism of the bar. When the bars have been struck with the lettered end downwards, the "Diff. readings" is positive.

Experiment 1, 1862, February 6, 0^h.

The bars were brought from the painting-room, and were immediately tried.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+18° 5′	7	+ 5° 15′	13	+ 1° 0′	19	+25° 20′
2	+13 30	8	+ 7 40	14	+ 8 0	20	+14 5
3	+14 30	9	+ 7 45	15	+ 7 20	21	+18 20
4	+ 7 0	10	+ 7 30	16	+ 1 10	22	+12 50
5	+11 20	11	+ 6 50	17	+20 30	23	+ 6 20
6	+12 10	12	+ 3 40	18	+ 7 0	24	+17 30
Sum...	+76 35	Sum...	+38 40	Sum...	+45 0	Sum...	+94 25

Total sum . . . +254° 40′.

The sign of the magnetism in this experiment is opposite to that which would have been given by terrestrial induction upon the bars in the position in which they had been standing for many days. It appears therefore that the magnetism had been produced by some circumstance in the manufacture, and that the terrestrial action upon the bars in a quiescent state had not reversed or destroyed it.

The bars were deposited on the flagstones of the equatorial plane, lettered end upwards.

Experiment 2, February 7, 0^h.

The bars, without being struck or subjected to any other violence, were tried.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+18° 0′	7	+ 3° 0′	13	− 2° 10′	19	+25° 0′
2	+13 45	8	+ 6 45	14	+ 6 30	20	+13 20
3	+12 20	9	+ 6 0	15	+ 5 25	21	+18 10
4	+ 5 0	10	+ 4 10	16	+ 0 20	22	+11 50
5	+11 35	11	+ 4 25	17	+19 40	23	+ 5 30
6	+10 30	12	+ 3 10	18	+ 7 15	24	+17 40
Sum...	+71 10	Sum...	+27 30	Sum...	+37 0	Sum...	+91 30

Total sum . . . +227° 10′.

The magnetism, it appears, had very slightly diminished. The bars were returned to the equatorial plane.

Experiment 3, February 7, 1^h.

Each bar as it lay on the flagstones of the equatorial plane, lettered end upwards, was struck with three rather heavy blows, from the unlettered to the lettered end. The hammer used was a geological hammer, weighing (with handle) about $2\frac{3}{4}$ lbs., and it fell in the blows about 2 feet. The bars were immediately examined.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	−2° 10′	7	− 2° 20′	13	−4° 35′	19	+2° 40′
2	+0 55	8	− 2 40	14	+0 40	20	−1 30
3	+0 50	9	− 2 0	15	−7 45	21	+3 50
4	−4 40	10	− 1 20	16	−2 15	22	+0 50
5	−1 20	11	− 7 20	17	+0 10	23	−3 50
6	−2 10	12	− 6 0	18	+6 25	24	+7 0
Sum...	−8 35	Sum...	−21 40	Sum...	−7 20	Sum...	+9 0

Total sum . . . −28° 35′.

Upon the whole, the antecedent magnetism is destroyed, and a small amount of mag-

netism of the opposite kind is left, but it is distributed very capriciously among the bars. It seems to have no relation to the former magnetism.

The bars were immediately placed on the flagstones of the dip plane, with lettered end upwards, and were immediately struck with the same hammer and in the same manner as above, but were not examined on this day.

Experiment 4, February 7, 22^h.

The bars had been resting on the flagstones of the dip plane since Feb. 7, 1^h, with lettered end upwards, and without further disturbance were taken from it for examination.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	− 22° 10′	7	− 21° 0′	13	− 27° 0′	19	− 18° 40′
2	− 19 50	8	− 19 10	14	− 23 40	20	− 25 40
3	− 18 0	9	− 17 30	15	− 30 30	21	− 14 30
4	− 21 20	10	− 23 20	16	− 29 40	22	− 20 50
5	− 21 20	11	− 20 40	17	− 25 15	23	− 26 10
6	− 19 40	12	− 20 30	18	− 25 20	24	− 30 0
Sum...	−122 20	Sum...	−122 10	Sum...	−161 25	Sum...	−135 50

Total sum . . . −541° 45′.

The bars were immediately returned to the flagstones of the dip plane, in the same position as before, with lettered end upwards, and were immediately struck for the next experiment.

Experiment 5, February 7, 23^h.

The bars on the flagstones of the dip plane, with lettered end upwards, were struck each with three blows, with the same hammer and with the same force as in Experiment 5.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	− 21° 20′	7	− 19° 10′	13	− 25° 5′	19	− 20° 0′
2	− 20 30	8	− 18 40	14	− 23 40	20	− 25 10
3	− 16 40	9	− 18 10	15	− 28 40	21	− 17 25
4	− 19 50	10	− 17 10	16	− 29 0	22	− 20 27
5	− 16 40	11	− 15 10	17	− 23 10	23	− 27 40
6	− 20 20	12	− 20 40	18	− 25 20	24	− 31 0
Sum...	−115 20	Sum...	−109 0	Sum...	−154 55	Sum...	−141 42

Total sum . . . −520° 57′.

The magnetism of the bars is, upon the whole, slightly diminished. The bars were

placed on the flagstones of the dip plane, with lettered end downwards, and were left undisturbed in that state.

Experiment 6, February 10, 23^h.

The bars, which had been resting undisturbed on the dip plane with lettered end downwards for three days, were taken out for examination without striking or disturbance.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	−16° 10′	7	−12° 35′	13	− 17° 50′	19	− 17° 40′
2	−14 20	8	−14 10	14	− 21 10	20	− 23 10
3	−15 0	9	−14 40	15	− 24 20	21	− 14 30
4	− 8 40	10	−13 40	16	− 23 10	22	− 17 30
5	−15 30	11	−12 30	17	− 19 20	23	− 23 35
6	−14 20	12	−16 0	18	− 20 30	24	− 23 0
Sum...	−84 0	Sum...	−83 35	Sum...	−126 20	Sum...	−119 25

Total sum . . . −413° 20′.

About $\frac{1}{5}$th part of the magnetism has been destroyed by three days' exposure to antagonistic terrestrial magnetism.

The bars were returned to the dip-plane flagstones in the same position, with lettered end downwards.

Experiment 7, February 11, 0^h.

The bars, immediately after the last examination, were returned to the flagstone dip plane with lettered end downwards, and each bar was struck once lightly at its centre with a joiner's hammer, weighing with its handle about $\frac{1}{2}$ lb., and were immediately examined.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+12° 10′	7	+16° 10′	13	+ 9° 0′	19	+17° 0′
2	+11 40	8	+15 30	14	+15 0	20	+11 20
3	+15 20	9	+12 0	15	+13 10	21	+16 30
4	+ 8 0	10	+11 0	16	+ 8 20	22	+ 9 40
5	+12 10	11	+10 15	17	+16 10	23	+ 8 40
6	+12 40	12	+10 40	18	+15 30	24	+ 5 40
Sum...	+72 0	Sum...	+75 35	Sum...	+77 10	Sum...	+68 50

Total sum . . . +293° 35′.

The light blow has destroyed the former magnetism, and has given an opposite magnetism of nearly three-fourths its amount.

The bars were returned to the flagstones of the dip plane in the same position, with lettered end downwards.

Experiment 8, February 12, 0^h.

The bars had not been disturbed in any way since the last examination. They had been resting on the flagstones of the dip plane, with lettered end downwards.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+14° 30′	7	+17° 10′	13	+ 7° 55′	19	+16° 30′
2	+11 25	8	+10 20	14	+16 0	20	+ 9 45
3	+11 55	9	+ 8 50	15	+12 10	21	+16 15
4	+ 8 20	10	+ 8 50	16	+ 9 40	22	+10 10
5	+11 0	11	+10 30	17	+13 30	23	+ 8 30
6	+11 10	12	+ 9 5	18	+13 15	24	+ 5 30
Sum...	+68 20	Sum...	+64 45	Sum...	+72 30	Sum...	+66 40

Total sum . . . +272° 15′.

It is remarkable that the magnetism, though favoured by the inductive force of terrestrial magnetism, has in this day's rest somewhat diminished.

The bars were returned to the flagstones of the dip plane, with lettered end downwards.

Experiment 9, February 12, 1^h.

The bars on the flagstones of the dip plane, with lettered end downwards, were struck each three times (from top to bottom) with the light hammer and with light blows, and were immediately examined.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+15° 55′	7	+16° 0′	13	+14° 10′	19	+18° 15′
2	+11 5	8	+14 10	14	+17 0	20	+14 30
3	+12 55	9	+12 20	15	+14 10	21	+18 50
4	+11 15	10	+13 15	16	+14 15	22	+18 5
5	+13 5	11	+12 55	17	+15 50	23	+10 25
6	+12 30	12	+12 40	18	+16 10	24	+11 0
Sum...	+76 45	Sum...	+81 20	Sum...	+91 35	Sum...	+91 5

Total sum . . . +340° 45′.

The magnetism is not much increased.

The bars were placed on the equatorial plane flagstones.

Experiment 10, February 15, 1h.

The bars had been lying undisturbed on the equatorial plane, lettered end downwards.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+11° 20′	7	+12° 0′	13	+11° 30′	19	+15° 45′
2	+11 25	8	+ 9 55	14	+13 5	20	+12 50
3	+10 20	9	+ 9 45	15	+ 7 55	21	+17 5
4	+ 6 40	10	+10 30	16	+ 7 5	22	+16 55
5	+ 9 40	11	+10 35	17	+10 25	23	+ 6 55
6	+ 7 30	12	+ 9 50	18	+ 9 20	24	+ 9 5
Sum...	+56 55	Sum...	+62 35	Sum...	+59 20	Sum...	+78 35

Total sum . . . +257° 25′.

No specific cause is known for this decided decrease of magnetism.

The bars were returned to the flagstone equatorial plane.

Experiment 11, February 15, 2h.

The bars, lying on the flagstones of equatorial plane, with lettered end downwards, were struck each in the middle of its length, with a single blow of the light hammer. The hammer was raised about 18 inches.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+1° 20′	7	+0° 35′	13	− 4° 20′	19	+3° 25′
2	−0 20	8	−0 25	14	− 1 10	20	−1 40
3	−0 35	9	−0 55	15	− 5 55	21	+3 50
4	−3 0	10	−0 55	16	− 5 5	22	+0 15
5	+0 30	11	−0 20	17	− 2 35	23	−5 30
6	−1 20	12	−1 35	18	− 2 25	24	−5 30
Sum...	−3 25	Sum...	−3 35	Sum...	−21 30	Sum...	−5 10

Total sum . . . −33° 40′.

The bars were returned to the flagstones of equatorial plane, lettered end downwards.

Experiment 12, February 20, 23^h.

The flagstones had been removed, and the bars were lying on the wooden boards of the equatorial plane, with the lettered end upwards. Each bar was slightly rapped three times with a wooden mallet, weighing about $1\frac{7}{8}$ lb.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+ 1° 0′	7	− 1° 20′	13	− 4° 50′	19	+0° 10′
2	− 1 50	8	− 2 30	14	− 1 30	20	−1 55
3	− 1 5	9	− 2 20	15	− 7 10	21	+3 5
4	− 4 5	10	− 2 40	16	− 6 20	22	−0 35
5	− 1 30	11	− 1 50	17	− 3 30	23	−6 10
6	− 3 20	12	− 2 40	18	− 4 25	24	−3 25
Sum...	−10 50	Sum...	−13 20	Sum...	−27 45	Sum...	−8 50

Total sum . . . −60° 45′.

It would appear that, after a certain diminution, the shocks on the equatorial plane have no tendency to reduce the magnetism further.

The bars were placed on the wood of the dip plane, with lettered end upwards.

Experiment 13, February 21, 0^h.

The bars upon the boards of the dip plane, with lettered end upwards, were fairly struck each three times with the mallet.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	−18° 20′	7	° ′	13	− 19° 25′	19	− 15° 5′
2	−15 30	8	−14 20	14	− 19 10	20	− 20 5
3	−17 50	9	−15 40	15	− 23 40	21	− 10 25
4	−17 55	10	.....	16	− 24 20	22	− 14 0
5	−15 50	11	−14 0	17	− 19 55	23	− 20 5
6	−14 25	12	−14 10	18	− 20 0	24	− 21 20
Sum...	−99 50	Sum...	−87 15	Sum...	−126 30	Sum...	−101 0

Total sum . . . −414° 35′.

The readings for bars 7 and 10 appeared suspicious, and have been omitted, the "sum" for the second series being formed by multiplying the sum for bars 8, 9, 11, 12 by $\frac{3}{2}$. It scarcely differs from that which would have been given by the use of the recorded numbers.

The bars were returned to the wood of the dip plane, with lettered end downwards.

Experiment 14, February 21, 1h.

The bars upon the wood surface of the dip plane, with lettered end downwards, were struck each with one light blow of the wooden mallet.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+ 8° 5′	7	+ 7° 15′	13	+ 1° 20′	19	+ 4° 10′
2	+ 6 50	8	+ 3 35	14	+ 6 55	20	− 0 10
3	+ 5 20	9	+ 5 10	15	+ 3 45	21	+ 6 55
4	+ 5 20	10	+ 5 20	16	− 0 50	22	− 1 50
5	+ 8 20	11	+ 7 55	17	+ 8 50	23	+ 0 40
6	+ 8 25	12	+ 6 35	18	+ 9 55	24	+ 3 15
Sum...	+42 20	Sum...	+35 50	Sum...	+29 55	Sum...	+13 0

Total sum . . . +121° 5′.

The bars were placed on the wood of the dip plane, with lettered end upwards, and were struck each three times with the wooden mallet, and so left. The mallet was raised about a foot for each blow.

Experiment 15, February 22, 0h.

The bars were not disturbed before examination.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	− 19° 10′	7	− 16° 40′	13	− 23° 15′	19	− 18° 30′
2	− 18 50	8	− 18 50	14	− 24 5	20	− 21 10
3	− 17 50	9	− 18 15	15	− 26 55	21	− 13 55
4	− 18 30	10	− 19 35	16	− 24 10	22	− 17 55
5	− 17 35	11	− 15 50	17	− 22 40	23	− 24 45
6	− 15 45	12	− 18 25	18	− 23 35	24	− 26 45
Sum...	−107 40	Sum...	−107 35	u m ...	−144 40	Sum...	−123 0

Total sum . . . −482° 55′.

The bars were placed on the wood of the equatorial plane, lettered end downwards.

Experiment 16, March 24, 0h.

The bars had been lying 30 days undisturbed on the equatorial plane.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	−16° 50′	7	−14° 50′	13	− 20° 15′	19	− 15° 5′
2	−14 10	8	−14 40	14	− 19 30	20	− 18 55
3	−14 20	9	−12 45	15	− 20 50	21	− 10 45
4	−14 15	10	−13 30	16	− 18 20	22	− 13 55
5	−13 40	11	−11 50	17	− 18 55	23	− 21 10
6	−12 15	12	−13 45	18	− 19 20	24	− 22 35
Sum...	−85 30	Sum...	−81 20	Sum...	−117 10	Sum...	−102 25

Total sum . . . −386° 25′.

Experiment 17, March 24, 1h.

Immediately after the last examination, the bars were placed on the wood of the equatorial plane, lettered end downwards, and were struck with the wooden mallet very lightly, the mallet being lifted about 2 inches, each bar three times. As soon as the series of blows was finished, the bars were struck again in the same manner. They were then immediately examined.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	−11° 5′	7	−11° 45′	13	−17° 40′	19	−11° 20′
2	−10 15	8	−11 10	14	−15 5	20	−14 15
3	− 7 5	9	−10 15	15	−13 30	21	− 7 55
4	−10 30	10	− 9 45	16	−11 55	22	−11 45
5	−11 5	11	− 9 50	17	−12 50	23	−19 0
6	− 9 10	12	−11 30	18	−15 50	24	−20 50
Sum...	−59 10	Sum...	−64 15	Sum...	−86 50	Sum...	−85 5

Total sum . . . −295° 20′.

The bars were placed on the wood of the equatorial plane, lettered end upwards.

Experiment 18, March 24, 2h.

The bars on the wood of the equatorial plane, lettered end upwards, were struck with the mallet, each bar three times, the mallet being raised more than 1 foot; and the series of blows was then repeated. The bars were examined immediately.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	− 1° 45′	7	− 3° 30′	13	− 1° 5′	19	+ 1° 30′
2	− 2 0	8	− 1 5	14	+ 0 50	20	− 1 5
3	− 2 5	9	− 0 35	15	− 3 10	21	+ 3 45
4	− 1 25	10	− 0 5	16	− 2 15	22	+ 1 20
5	− 1 10	11	− 0 5	17	− 0 55	23	− 3 35
6	− 0 15	12	− 0 40	18	+ 0 10	24	− 0 15
Sum...	− 8 40	Sum...	− 6 0	Sum...	− 6 25	Sum...	+ 1 40

Total sum . . . −19° 25′.

The bars were returned to the wood of equatorial plane, lettered end upwards.

Experiment 19, March 25, 22h.

The bars were shifted to the wood of dip plane, with lettered end downwards, and were struck heavily with the geological hammer swung out horizontally to arm's length, each bar three times. They were examined immediately.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+ 21° 45′	7	+ 19° 40′	13	+ 24° 55′	19	+ 28° 10′
2	+ 18 25	8	+ 19 0	14	+ 26 15	20	+ 24 55
3	+ 17 25	9	+ 20 25	15	+ 21 30	21	+ 27 5
4	+ 15 20	10	+ 15 30	16	+ 23 25	22	+ 26 25
5	+ 18 15	11	+ 16 35	17	+ 22 10	23	+ 20 15
6	+ 15 55	12	+ 15 50	18	+ 24 45	24	+ 29 10
Sum...	+107 5	Sum...	+107 0	Sum...	+143 0	Sum...	+156 0

Total sum . . . +513° 5′.

The bars were returned to the wood of dip plane, lettered end upwards.

Experiment 20, March 25, 23h.

The bars, on wood of dip plane, lettered end upwards, were struck heavily with the geological hammer at arm's length, each three times. They were then immediately placed with lettered end downwards, and struck with blows of similar force, each three times. They were then examined immediately.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+ 21° 20′	7	+ 18° 50′	13	+ 25° 55′	19	+ 27° 25′
2	+ 17 30	8	+ 18 30	14	+ 24 35	20	+ 19 35
3	+ 16 15	9	+ 18 10	15	+ 24 10	21	+ 27 0
4	+ 17 0	10	+ 19 25	16	+ 24 55	22	+ 26 55
5	+ 20 0	11	+ 16 40	17	+ 25 0	23	+ 23 0
6	+ 17 35	12	+ 16 30	18	+ 26 30	24	+ 35 10
Sum...	+109 40	Sum...	+108 5	Sum...	+151 5	Sum...	+159 5

Total sum . . . +527° 55′.

It is worthy of remark that the diff. reading for the bar No. 20 (8th in the order of examination) at first appeared to be 24° 25′. After examining bar No. 5, bar No. 20 was again examined, and the diff. readings was found to be 19° 35′ as is given above. If the first reading was correct (which there is no special reason for doubting), it would appear that the bar lost one-fifth part of its magnetism in a few minutes.

The bars were returned to the dip plane, lettered end upwards. On March 27, 1^h, they were moved to the equatorial plane, lettered end upwards.

Experiment 21, March 31, 1^h.

The bars had been resting undisturbed on the equatorial plane since March 27.

Hot-rolled longitudinal.		Hot-rolled transversal.		Cold-rolled longitudinal.		Cold-rolled transversal.	
No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.	No.	Diff. readings.
1	+12° 40′	7	+12° 25′	13	+ 16° 5′	19	+ 23° 35′
2	+13 40	8	+15 10	14	+ 21 30	20	+ 19 30
3	+12 55	9	+16 15	15	+ 17 40	21	+ 21 40
4	+15 5	10	+14 15	16	+ 19 0	22	+ 22 50
5	+15 55	11	+15 35	17	+ 22 30	23	+ 22 10
6	+15 50	12	+15 5	18	+ 24 35	24	+ 32 5
Sum...	+86 5	Sum...	+88 45	Sum...	+121 20	Sum...	+141 50

Total sum . . . +438° 0′.

The bar No. 20 does not appear to have undergone any further change in its magnetism.

After this, the apparatus was dismounted, and the bars were packed up in the same order as at first.

I shall now proceed to exhibit the principal results deducible from the details above.

For abbreviation, I shall sometimes use the expression "tendency 0" to denote that the operation on the bars has been performed while they were lying on the equatorial plane; "tendency +" to denote that the bars were lying on the dip plane, with lettered end downwards; "tendency —" to denote that they were on the dip plane with lettered end upwards.

I. Aggregate of magnetism in the twenty-four bars.

Exp. 1.	After standing several days, tendency —	+254° 40′
2.	After resting one day, tendency 0	+227 10
3.	Struck heavily, on flagstones, large iron hammer, tendency 0 . .	— 28 35
4.	Struck heavily, tendency —; examined after a day's rest, with tendency —	—541 45
5.	(Immediately after Exp. 4), struck heavily, tendency — . . .	—520 57
6.	Not struck, but under + tendency for three days	—413 20
7.	(Immediately), struck lightly with light iron hammer, tendency +	+293 35
8.	After resting quietly one day, under + tendency.	+272 15
9.	(Immediately), struck fairly with light iron hammer, tendency +	+340 45
10.	After three days' rest, tendency 0	+257 25
11.	(Immediately), struck fairly with light iron hammer, tendency 0	— 33 40

From this time the bearing is on wood, and the blows are given with a wooden mallet, unless otherwise mentioned.

		° ′
Exp. 12.	Lightly struck, tendency 0	− 60 45
13.	Fairly struck, tendency −	−414 35
14.	Very lightly struck, tendency + ...	+121 5
15.	Fairly struck, tendency −, rested one day	−482 55
16.	After thirty days' rest, tendency 0	−386 25
17.	Struck very lightly, tendency 0	−295 20
18.	Struck fairly, tendency 0	− 19 25
19.	Struck heavily with geological hammer, tendency + ...	+513 5
20.	(Immediately), first struck heavily, tendency −; then struck heavily (immediately), tendency + ...	+527 55
21.	After one day's rest, tendency −, and four days' rest, tendency 0	+438 0*

It appears that the greatest amount of magnetism is about $\pm 530°$, and this requires a heavy blow; but it is nearly or quite indifferent whether the bars are supported on stone or on wood, and whether the blow is given by an iron hammer or a wooden mallet. This amount of magnetism, the bars lying with tendency 0, is diminished in one or two days by about one-fifth part, and is scarcely diminished further in thirty days. The loss of magnetism is not greater when the bars, instead of lying with tendency 0, are placed in a tendency opposite to the magnetism with which they are charged. When the charge of magnetism is smaller than the maximum, the diminution in a day or two is nearly in the same proportion.

It appears also that the effect of violence on the bars while lying with tendency 0 is not completely to destroy the magnetism; and that sometimes the magnetism is actually increased by the violence.

II. Proportions of the Aggregate of Magnetism carried by the different classes of Bars; excluding those experiments in which the Bars had been struck while lying with tendency 0.

	Hot-rolled longitudinal.	Hot-rolled transversal.	Cold-rolled longitudinal.	Cold-rolled transversal.
Experiment 4, tendency −	·226	·225	·297	·250
5, −	·222	·209	·298	·272
6, −	·204	·203	·306	·289
7, +	·245	·258	·263	·235
8, +	·251	·238	·266	·245
9, +	·225	·239	·269	·267
10, +	·221	·244	·231	·306
13, −	·241	·211	·306	·244
14, +	·349	·295	·247	·107
15, −	·223	·222	·299	·255
16, −	·221	·211	·303	·266
17, −	·201	·218	·293	·288
19, +	·209	·208	·279	·305
20, +	·207	·205	·287	·302
21, +	·196	·202	·277	·323
Mean	·229	·226	·281	·264

These results appear to leave no doubt that, as a general rule, the cold-rolled iron will, under similar circumstances, take up a heavier charge of magnetism than the hot-rolled iron, in the proportion of 545 : 455, or 1·2 : 1·0, very nearly. It also appears that the cold-rolled longitudinal takes a heavier charge than the cold-rolled transversal.

The departures from this result, in Experiments 8, 9, 10, 14, are confined to small charges of magnetism, in which accident might have greater play. They are also confined to magnetism of + character; of this, perhaps, the following is the explanation.

The bars when received from the manufacturer had + magnetism (see Experiments 1 and 2). It would seem therefore that the hot-rolled bars differ from the cold-rolled bars in this particular, that the hot-rolled bars retain rather more of their primitive magnetism, under all changes, than the cold-rolled bars retain.

III. Proportions of the Aggregate of Magnetism, without regard of sign, carried by the different classes of Bars, when they have been struck while lying with tendency 0.

	Hot-rolled longitudinal.	Hot-rolled transversal.	Cold-rolled longitudinal.	Cold-rolled transversal.
Experiment 3.	·184	·464	·157	·193
11.	·102	·106	·638	·154
12.	·178	·220	·457	·145
18.	·380	·264	·282	·073
Mean	·211	·264	·384	·141

I do not attach great importance to the apparent tendency of the cold-rolled longitudinal bars to retain much magnetism and of the cold-rolled transversal bars to retain little. The observed deviations are small, and a trifling accidental error may materially disturb the results.

IV. Spontaneous Losses of Magnetism in the Bars of different Classes, when they have rested undisturbed.

	Hot-rolled longitudinal.	Hot-rolled transversal.	Cold-rolled longitudinal.	Cold-rolled transversal.	Sum.
Exp. 1 to 2, 1 day, tendency 0	5° 25′	11° 10′	8° 0′	2° 55′	27° 30′
5 to 6, 3 days, tendency +, opposing	31 20	25 25	28 35	22 17	107 37
7 to 8, 1 day, +, favouring	3 40	10 50	4 40	2 10	21 20
9 to 10, 3 days, 0	19 50	18 45	32 15	12 30	83 20
15 to 16, 30 days, 0	22 10	26 15	27 30	20 35	96 30
20 to 21, 1 day, —, opposing; 4 days, 0 ...	23 35	19 20	29 45	17 15	89 55
Sum.....	106 0	111 45	130 45	77 42	426 12

V. Proportions of the Losses of Magnetism in the Bars of different Classes to the Aggregate of Losses.

	Hot-rolled longitudinal.	Hot-rolled transversal.	Cold-rolled longitudinal.	Cold-rolled transversal.
Experiment 1 to 2.	·197	·407	·291	·106
5 to 6.	·293	·236	·266	·207
7 to 8.	·172	·509	·218	·101
9 to 10.	·238	·225	·387	·150
15 to 16.	·230	·272	·285	·214
20 to 21.	·263	·215	·331	·192
Means	·232	·311	·296	·162

It appears, as I think (though the last line of Table IV. would lead to a different conclusion), that there is a real difference in the retentive powers for magnetism among the different classes of bars; and that the cold-rolled bars, under the circumstances of the experiments, lose less magnetism, spontaneously, than the hot-rolled bars lose. If, instead of comparing the absolute losses of magnetism, we had compared the proportions for loss of magnetism in each class to entire magnetism in that class, the difference would have been still more remarkable.