PHILOSOPHICAL

TRANSACTIONS.

XIX. *Experiments and observations on the developement of magnetical properties in steel and iron by percussion.* *By* WILLIAM SCORESBY, *Jun. Esq. Communicated by Sir* HUMPHRY DAVY, *Bart. P. R. S.*

Read March 7th, 1822.

DR. GILBERT, so early as the year 1600, discovered that iron became sensibly magnetic on being hammered and drawn out while lying in a north and south direction; but I am not aware that either Dr. GILBERT, or any other person, ever gave to iron or steel, by this process, any considerable lifting power. I cannot indeed discover that any magnetical effect, by hammering, has been produced, beyond that of occasioning a deviation in the compass needle, or of giving to floating bars, or needles, the power of conforming their position to that of the magnetic meridian.

In the course of some experiments made in the autumn of 1820, I succeeded in determining, in a great measure, the principal laws by which the developement and destruction of magnetism in iron, by percussion, scowering, filing, bending, &c. are governed. As the result of this investigation is already before the public,* the communication that I have now the honour of laying before the Royal Society, will be confined to the application of these laws to practical magnetism; and particularly to the construction of magnets, without the use of any magnetised substance.

In examining the magnetical effect of percussion on different kinds of iron and steel, two tests were employed; the weight of iron that the body would lift, and the quantity of deviation that it would produce on a magnetic needle when presented to it in a certain position, and at a certain distance. For the first test, common iron nails of different sizes were made use of: they were of the weights of 2, 4, 6½, 14, 24, 37, 45, 88, 130, and 188 grains. For the purpose of securing a good and uniform contact with the magnetised bar, the oxide on the ends of the nails was removed by means of a fine file, and the extremities were then polished by rubbing them on a turkey stone. The second test I employed, consisted of a board two feet in length, with a longitudinal line down the middle divided into inches, and a sensible pocket compass. To guard against the effects of the magnetism of position, the central line of the board was placed exactly in an east and west direction by the compass, and as the board was laid horizontally on a table, this line was known to be in the plane of the magnetic equator, and consequently in a situation in which small bars of iron are not affected by the magnetism of position. In applying this simple apparatus as a measure of magnetism, the bar, whose magnetism was to be examined or compared, was laid along the central line of the board, with its north pole always nearest the compass.

* Edin. Phil. Trans. 1821.

The compass was placed with its centre at the commencement of the scale, so that its needle was exactly at right angles to the direction of the bar; and before the deviation took place, both its poles were equidistant from the bar. The distance was estimated by the scale on the board, and always represented the space between the north end, or nearest end of the bar, and the centre of the compass.

Three hammers were also employed: No. I. of 22 ounces; No. II. of 12 ounces; and No. III. of $2\frac{1}{2}$ ounces weight.

It may be remarked, that no exact value can be given to the number of blows, because, having struck them by the hand, they must have been liable to considerable variation in intensity; and also, that the lifting power cannot be considered as an exact measure of the magnetism developed by the process. The deviation, however, produced on the compass by the bodies presented to it at equal distances and in the same direction, was decisive as a comparative measure of their magnetisms; for, though the actual magnetic force is not given by this means, yet it is clear that a greater or less deviation, must be the effect of a greater or less magnetic force; while in bars of a similar kind and dimensions, an equal deviation must be the effect of equal magnetic forces.

I. *Experiments with a cylindrical bar of soft steel, for determining the effect of percussion, when the bar was held in a vertical position and resting upon a piece of metal not ferruginous. Length of the bar 6½ inches; diameter a quarter of an inch; weight 592 grains.*

Number of Blows.		Weight lifted.	Distance of Compass and Bar.	Deviation.	Hammer.
at each trial.	Total.				
1	1	2	3	8	II.
1	2	—	....	10	....
5	7	4	....	12	....
10	17	6½	....	12½	....
5	22	6½	....	12½	I.

This bar was next hammered upon a large mass of freestone: after twenty blows with the large hammer had been struck upon it, the deviation it was found had not increased, but still remained at 12½°.

Dr. GILBERT tried this experiment on iron; but instead of hammering it in the direction of the dipping needle, or in a vertical direction, which produces almost an equal effect, he placed it horizontally in the magnetic meridian, which, in London, is a plane elevated only 19½ degrees above the magnetic equator. Now, as my former experiments proved that hammering iron in the plane of the magnetic equator destroys its polarity, it is evident, that a very small part only of the full influence of percussion must have been obtained by Dr. GILBERT.

As magnetism in steel is more readily developed by the contact of magnetisable substances, and particularly if these substances be already magnetic, it occurred to me, that the magnetising effects of percussion might be greatly increased by hammering the steel bar, with its lower end resting on the upper end of a large rod of iron or soft steel, both the masses being held in a vertical position: and that if the rod were first rendered magnetic by hammering, the effect on the bar would probably be augmented. The following experiments prove that these opinions were not incorrect.

II. *Experiments for determining the effect of percussion on a soft steel bar, when the bar was held in a vertical position and resting upon a parlour poker.*

[*a. Both the bar and the poker were first deprived of magnetism.*]

Number of Blows.		Weight lifted.	Distance of Compass and Bar.	Deviation.	No. of the Hammer.
at each trial.	Total.				
		Grains.	Inches.	°	
1	1	$6\frac{1}{2}$	3	13	II.
1	2	14	. . .	16	. . .
1	3	. . .	. . .	18	. . .
4	7	37	. . .	21	. . .
5	12	45	. . .	25	. . .
10	22	88	. . .	27	. . .
20	42	88	. . .	30	. . .
30	72	. . .	. . .	31	. . .
10	82	. . .	. . .	$31\frac{1}{2}$	. . .

The effect seemed now to be at a maximum, for more blows with the same hammer produced no alteration; but on substituting a larger hammer, the deviation was augmented.

[*b. Change of Hammer.*]

3	85	. . .	. . .	33	I.
5	90	130	. . .	34	
3	93	. . .	. . .	30 !	

The bar was now inverted, so that the north pole was upward.

[*c. Change of the ends of the Bar.*]

1	. . .	0	3	5	II.
1	2	0	. . .	2	Poles changed.

In this stage of the experiments the poker had become *strongly* magnetic, and its magnetism was farther increased by hammering it upon another bar of iron.

[*d. The bar deprived of magnetism; but the poker rendered magnetic by hammering.*]

Number of Blows.		Weight lifted.	Distance of Compass and Bar.	Deviation.	Hammer.
at each trial.	Total.				
			Inches.	°	
1	1	. . .	3	16	I.
[The experiment repeated.]					
1	1	. . .	3	18	I.
1	1	. . .	3	17	II.
1	1	. . .	. . .	$12\frac{1}{2}$	III.
100	101	. . .	. . .	27	. . .
100	201	. . .	. . .	$28\frac{1}{2}$	. . .
2	203	. . .	. . .	$28\frac{1}{2}$	I.

The bruised end of the bar was now hammered horizontally until it formed a kind of cup; this being easily compressed by the hammer, the effect was increased.

[*e. Bar deprived of magnetism; poker hammered.*]

1	1	. . .	3	23	I.
1	1	. . .	3	22	II.
5	6	. . .	. . .	30	. . .
4	10	188	. . .	36 ?	I.
5	15	188	. . .	33	. . .

III. *For determining the effect of percussion on magnets properly tempered, a flat bar magnet of a blue temper was employed; it was* $7\frac{7}{10}$ *inches long,* $\frac{1}{2}$ *an inch broad, and* $\frac{1}{7}$*th thick, and weighed* 1170 *grains.*

[*a. The magnet held vertically on a rod of iron; South end upward.*

No. of Blows.		End of the Magnet upward.	Distance of the Compass.	Deviation.
at each trial.	Total.			
			Inches.	°
0	0	. . .	8	45
5	5	S.	. . .	37
5	10	. . .	. . .	32
10	20	. . .	. . .	30
10	30	. . .	. . .	28
10	40	. . .	. . .	27
20	60	. . .	. . .	26
20	80	. . .	. . .	25
20	100	. . .	. . .	25
	[*b.* North end up.]			
0	0	. . .	8	25
1	1	N.	. . .	20
10	11	. . .	. . .	16
20	30	. . .	. . .	14
[*c. Bar again magnetised and hammered upon a piece of pewter.*]				
0	0	. . .	8	50
10	10	S.	. . .	37
10	20	. . .	. . .	33
10	30	N.	. . .	27
10	40	. . .	. . .	26
20	60	. . .	. . .	24
20	80	. . .	. . .	24
20	100	S.	. . .	24
20	120	N.	. . .	23
20	140	. . .	. . .	23
20	160	S.	. . .	$23\frac{1}{2}$

The general results of these experiments are as follow:

1. A cylindrical bar of *soft steel*, $6\frac{1}{2}$ inches long, and weighing 592 grains, lifted, after repeated hammering on pewter and stone, $6\frac{1}{2}$ grains; but could not be made to lift a nail of 11 grains.

2. The same bar hammered vertically upon a parlour poker, the poker also held erect, after 22 blows, lifted, with the lower end, which was a North pole, 88 grains (2 *a*); and on using a larger hammer, received a considerable increase of power, producing a deviation of the compass, three inches distant, of 34 degrees (2 *b*): farther hammering, it was found, rather diminished than increased the effect (2 *b*). On the bar being inverted, so that the north pole was upward, the magnetism was very nearly destroyed by a single blow; while two blows changed the poles (2 *c*). Hammering the end of the bar in the plane of the magnetic equator also destroyed the polarity; but the effect was not fully produced until many blows had been struck.

When the poker had been previously hammered in a vertical position, an increase of magnetic effect on the bar was obtained; a single blow being now sufficient to enable the bar to lift about 20 grains: and when the end was hammered into a kind of cup, so as to be easily bruised, the bar was, by one blow, rendered capable of lifting between 30 and 40 grains (2 *e*). After 10 blows, the highest effect obtained in all the experiments was produced, the same bar readily lifting a nail of 188 grains, being nearly one-third of its own weight! (2 *e*).

The magnetism by percussion was found, by subsequent experiments, to be augmented when the length of the bars was increased; thus a quarter-inch cylindrical bar of steel five inches long, after receiving 20 smart blows, produced a deflection of the needle, at the distance of three inches, of 13°, and lifted 6½ grains. Another piece of the same bar 7¾ inches long, after similar treatment, produced a deviation of 24°, and lifted 45 grains; and a third bar of the same kind 12 inches long, after twenty similar blows, occasioned a deviation of the compass of 33°, and easily lifted 88 grains. The shortest bar, it was observed, received the full effect by the two first blows; but the others continued to increase in energy as the percussion was continued. These bars did not receive a power equal to that first used; the cause was probably their greater hardness.

3. A *strong magnet* properly tempered, was injured in whatever position it was hammered; but most rapidly when the north pole was upward. After no farther diminution of its magnetism could be produced with the south end upward, a quick loss of power was effected by hammering it with the north pole upward (3 *b*). But after the magnetism had been reduced to a certain extent, by hammering in both positions, the power became nearly stationary; so that on striking it in any position with the same hammer, very little change of intensity occurred (3 *c.*).

Besides these results, I may mention the effect of percussion on soft steel magnets; on soft iron not magnetised; and on cast iron.

4. A *soft steel magnet* capable of lifting upwards of 1000 grains, when placed vertically upon the poker with its north pole upward, had its magnetism destroyed by five blows.

5. A bar of *soft iron,* of the same size and form as the

steel bar used in the first and second series of experiments, and weighing about 600 grains, was hammered for a considerable time while held vertically upon the poker. The greatest effect which I could produce with the large hammer, was a deflection of the compass needle, at the distance of three inches, of thirteen degrees; in this state it lifted a nail of $6\frac{1}{2}$ grains, but refused one of 11 grains weight.

6. A *cast iron* bar of the same size and form as the last, became capable of lifting a nail of 37 grains weight. After it had acquired this power, its magnetism was nearly destroyed by five blows with the north pole upward.

The strong magnetising effect of percussion on soft steel, induced me to apply the property to the formation of magnets. For this purpose I procured two bars of soft steel, 30 inches long and an inch broad; also six other flat bars of soft steel 8 inches long and half an inch broad, and a large bar of soft iron. The large steel and iron bars were not however absolutely necessary, as common pokers answer the purpose very well; but I was desirous to accelerate the process by the use of substances capable of aiding the developement of the magnetical properties in steel. The large iron bar was first hammered in a vertical position. It was then laid on the ground with its acquired south pole towards the south, and upon this end of it the large steel bars were rested while they were hammered; they were also hammered upon each other. On the summit of one of the large steel bars, each of the small bars, held also vertically, was hammered in succession, and in a few minutes they had all acquired considerable lifting powers. Two of the smaller bars, connected by two short pieces of soft iron in the form of a parallelogram, were now rubbed with the other four bars in the manner of CANTON. These were then changed for two others: and these again for the last two. After treating each pair of bars in this way for a number of times, and changing them whenever the manipulations had been continued for about a minute, the whole of the bars were at length found to be magnetised to saturation; each pair readily lifting above eight ounces!

In accomplishing this object, I took particular care that no magnetic substance was used in the process. All the bars were freed of magnetism before the experiment, so that none of them, not even the largest, produced a deviation of five degrees on the compass at three inches distance. The hammers were also carefully examined. Any bars which had been strongly magnetised, and had had their magnetisms destroyed or neutralised (either by hammering, heating, or by the simultaneous contact of the two poles of another magnet placed transversely,) I always found had a much greater facility for receiving polarity in the same direction as before, than the contrary. Hence it generally happened, that one blow with the original north end downward, produced as much effect as two or three blows did with the original south end downward. I also observed that the polarity of *pokers*, generally supposed to be permanent and considerable in intensity, was rather transient and weak: for in no instance did I meet with a poker, the magnetism of which I could not destroy by a blow or two with a hammer, on the point; and, in general, two blows, even when the poker was held in the hand, and not rested upon any thing, were sufficient to invert the poles.

Liverpool,
18*th February,* 1822.