

Mr. Davies observed, that Mr. Slate's engine could give a steady blast for a furnace, with full pressure, which Mr. Murdock's engine could not do.

Mr. Slate remarked, that though Mr. Murdock's engine had been at work at Soho for the period stated, no further progress had been made in the construction of the blast engine; for at Soho they still continued to make only the old ponderous engines.

Mr. Middleton said, it had been applied at the smithy at Woolwich, and had been at work there for many years. He thought, though Mr. Slate's engine was different in some respects, it was similar in principle to Mr. Murdock's.

Mr. W. Smith was quite satisfied that Mr. Slate's engine would maintain a constant blast for a furnace. He had seen Mr. Murdock's engine at work; it was an open-top cylinder, and was quite another kind of engine. He thought that Mr. Slate's plan of blowing engines was an important advantage in the saving of expense in the erection of iron works, and he believed that a blowing engine could now be erected for £500 on that plan, as well as one on the old plan for £1500, to do the same work.

The Chairman thought that Mr. Slate's engine was certainly deserving of approbation, and he hoped that he would continue his investigation of the subject, as any improvement or economy in the manufacture of iron was of great importance.

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*On the Use of Electro-magnets made of Iron Wire for the Electro-magnetic Engine. By J. P. JOULE, Esq. Communicated in a Letter to the late Mr. Sturgeon.\**

DEAR SIR: In my last letter I gave you an account of some experiments which were intended to prove that electro-magnets made of iron wire are the most suitable for the electro-magnetic engine. In those experiments round wire was used; and it was my opinion that the wire magnets were put in a disadvantageous position, in consequence of the interstices between the wires. I have since confirmed my views on this subject by the following experiment:—

I constructed two magnets. The first consisted of sixteen pieces of square iron wire, each  $\frac{1}{11}$ th of an inch square and 7 inches long, bound very tightly together so as to form a solid mass, whose transverse section was  $\frac{4}{11}$ ths of an inch square; it was enveloped by a ribbon of cotton, and wound with sixteen feet of covered copper wire, of  $\frac{1}{8}$ th inch diameter. The second was made of solid iron, but was in every other respect precisely like the first. These magnets were fitted to the apparatus used in my former experiments, and care was taken to make the friction of the pivots equal in each. The mean of several experiments gave 162 revolutions per minute with the first, and 130 with the second magnet.

In the further prosecution of my inquiries, I took six pieces of round iron of different diameters and lengths, and also a piece of hollow round iron, half an inch in diameter, and  $\frac{1}{8}$ th of an inch thick in metal; these were bent into the U-form, so that the shortest distance between the poles of

\* Annals of Electricity, vol. iv. p. 58.

each was half an inch; each was then wound (with the usual precautions to ensure insulation) with ten feet of covered copper wire of  $\frac{1}{40}$ th inch diameter. The lengths and diameters are given in the following table. No. 1 is the hollow magnet. The attraction was ascertained by suspending a straight steel magnet,  $1\frac{1}{2}$  inch in length, horizontally to the beam of a balance, and bringing the several electro-magnets directly underneath at the distance of half an inch, which was preserved by the interposition of a piece of wood half an inch thick. Care was taken that the battery remained constant during the experiments.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Length in inches, . . .	6	$5\frac{1}{2}$	$2\frac{3}{4}$	$5\frac{1}{4}$	$2\frac{1}{8}$	$5\frac{1}{4}$	$2\frac{1}{2}$
Diameter in inches, . . .	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{4}$
Weight lifted in ounces, .	36	52	92	36	52	20	28
Attraction for steel magnet in grains,	7.5	6.3	5.1	5.0	4.1	4.8	3.6

A steel magnet of such dimensions as enabled me to compare it fairly with the electro-magnets, was found to exert an attraction of 23 grains for the small steel magnet, though its lifting power was only 60 oz.

These results will not appear surprising if we consider, first, the resistance which iron presents to the induction of magnetism; and secondly, how very much the power of iron to conduct magnetism is exalted merely by the completion of the ferruginous circuit. In order, however, to explain why the long electro-magnets have a *greater* attracting power at a distance, though they lift *less* weight, than the short magnets of the same diameter, it will be necessary to observe that it was impossible to wrap the whole ten feet of wire on the smaller magnets, without disposing it in two or three layers (according to the size of the magnets.) This was a great disadvantage; and one might have anticipated in consequence, that the power of the long magnets would be greater than that of the short ones for lifting, as well as distant attraction, which is contrary to the results of the table; this may however be explained, if we admit that the comparative resistance of the iron of the electro-magnet increases to a very great amount, when its magnetism is so greatly excited as by the contact of the armature.

Nothing can be more striking than the difference between the ratios of lifting to distant attractive power, in the different magnets; whilst the steel magnet attracts with a force of 23 grains and lifts 60 oz., No. 3 attracts 5.1-grains and lifts 92 oz.

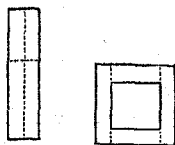
The following are some general directions for making electro-magnets for lifting:—1st, The magnet, if of considerable bulk, should be compound, and the iron used of good quality and well annealed. 2d, The bulk of the iron should bear a much greater ratio to its length than is generally the case. 3d, The poles should be ground quite true, and fit flatly and accurately to the armature. And 4th, The armature should be equal in thickness to the iron of the magnet.

I shall now proceed to consider with greater care what form of electro-magnet is best for distant attraction, as that is the only force of any use in the electro-magnetic engine. Here two things must be considered the length of the iron, and its sectional area.

Now with regard to the length of the iron, I have found that its in-

crease is always accompanied with disadvantage, unless the wire is (by using a shorter length) forced to too great a distance from the iron. In making magnets for an engine, it will be proper to use a length less than that which gives the maximum of attraction, on several accounts.

The next thing to be considered is the sectional area. You have shown\* that, on placing a hollow and solid cylinder of iron successively within the same electro-magnetic coil, the hollow piece exerted the greatest influence on the needle. I wished to ascertain whether a hollow magnet could be represented by a solid one, of which the sectional area and circumference are the same, and the thickness of which is twice that of the hollow magnet. The accompanying figures represent sections of hollow and solid rectangular magnets; and it will be seen, that if either of them is divided at the dotted lines, the separate pieces, when put properly together, will make up the other. Two electro-magnets were constructed, each 7 inches long, and wound with twenty-two feet of insulated copper wire; the sections were similar to, but twice the size of the figures. Their attractions at half an inch distance for the contrary pole of a straight steel magnet were as follows:—



	Hollow magnet.	Solid magnet.
Attraction in grains,	1·9	1·7
Do. with a more powerful battery,	4·5	4·0

The above results show that the hollow magnet has the greater attractive force; but I do not think that the difference between the two is so great as to counterbalance the practical advantages which solid bars would give if used in the engine. I shall now therefore attempt to determine the sectional area of solid iron most proper for various galvanic powers.

I made five straight electro-magnets of square iron wire  $\frac{1}{16}$ th of an inch thick; each was 7 inches long, and wound with twenty-two feet of insulated copper wire of  $\frac{1}{16}$ th of an inch diameter. No. 1 consisted of nine, No. 2 of sixteen, No. 3 of twenty-five, No. 4 of thirty-six, and No. 5 of forty-nine square iron wires, arranged in the form of square prisms. Five other electro-magnets were made of square iron rod, but in every other respect were exactly similar to the first. The following are the attractions (at half an inch distance) for a straight steel magnet, with three different voltaic forces:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
1st experiment. { Attraction of iron bar } { magnet in grains, } { Ditto of wire magnet, }	1·5	1·9	1·6	2·1	2·0
2d experiment. { Iron bar magnet, } { Wire magnet, }	2·0	2·5	2·35	2·45	2·2
3d experiment. { Iron bar magnet, } { Wire magnet, }	2·7	3·6	3·4	3·2	3·1
	3·3	3·8	3·0	2·9	2·65

The square iron wire of which the wire magnets were constructed, was taken at the same degree of temper that it possessed when it came

\* Annals of Electricity, vol. i, p. 470.

from the manufacturer. It was in consequence not so well annealed as the iron bars. On this account the numbers opposite the wire magnets are less than they would have been with better annealed wire: still the results of the table seem anomalous; for it will be remarked, that whilst the wire magnets are the most powerful of the smaller electro-magnets, the bar magnets are most powerful of the larger ones.

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*Action of the Sea-Worm on Timber, and the Best Means of Protection.* By  
SAMUEL CLEGG, JUN.\*

Timber exposed in marine works is subject to be destroyed by the *teredo navalis*, and *limnoria terebrans*. The *teredo*, by means of auger-like shells with which its head is furnished, bores into the timber, and forms long circular holes, lining them with a shelly substance. These worms are very numerous, and the timber attacked by them soon assumes the form of a honeycomb. They appear to penetrate all kinds of timber; that which it seems to destroy with the greatest ease is fir, in which it works more speedily and successfully than in any other, and perhaps grows to the greatest size. In a fir-pile taken from the old pier-head at Southend, a worm was found 2 feet long and  $\frac{3}{4}$ -inch in diameter, and they have been heard of 3 feet and 4 feet in length, and 1 inch in diameter. In hard wood they do not grow so large. Wood which has been perforated presents to casual observation no symptom of destruction on the surface, nor are the animals themselves visible until the outer part of the wood has been broken away, when their shelly habitations come in sight, and show the perfect honeycomb they have formed. On a close examination of the wood, however, a multitude of very minute perforations are discovered in the surface, generally covered with a slimy matter; and on opening the wood at one of these, and tracing it, the tail of the animal is immediately found, and after various windings and turnings the head is discovered, which in some cases is as much as 3 feet from the point of entrance. Sometimes it will happen, especially if the wood has been much eaten, that their shelly tubes are partly visible on the surface, but this is rare. They enter at the surface, and bore in every direction, both with and against the grain of the wood, growing in size as they proceed.

The *limnoria terebrans* is a minute crustacean, similar in appearance to a woodlouse, and confines its destructive operations to the surface of the wood, so that what is left undestroyed by the *teredo* is completed by the *limnoria*. On the surface of a piece of wood, only 12 inches square, Mr. Paton estimated no less than 54,000 different perforations, caused by this little creature penetrating to about an inch from the surface.†

The *teredo* enters the timber at various heights of the tide, sometimes confining their operations between low water mark of neap tides and the bottom of the river, occasionally piercing below the ground; and at others, attacking the wood 8 or 10 feet above low water, to 2 feet below the bed of the sea. They, however, appear gradually to relax in their destructive

\* From the London Architect for October, 1851.

† They are said not to attack teak, but this is doubtful.