THE ANNALS

OF

ELECTRICITY, MAGNETISM, AND CHEMISTRY;

AND

Guardian of Experimental Science.

MARCH, 1839.

LIV. *Historical Sketch of the rise and progress of Electro-magnetic Engines for propelling machinery.*

To trace the invention of electro-magnetic engines to the first ideas which were formed in the minds of philosophers, concerning the probability of their structure and usefulness, would be an undertaking which no one could possiby accomplish; but, as has been the case in many other inventions, it may probably have been at a much earlier period, in the history of electro-magnetism, than the date of any contrivance, for that purpose, which has hitherto been described. The electro-magnetic rotations, first suggested by Dr. Wollaston,* and actually performed by the ingenious contrivances of Mr. Faraday,† were depending upon forces too feeble to anticipate from them an accumulation of power to a sufficient extent to be applicable in propelling machinery; though, as we are well aware, that subsequent forms of the apparatus, especially the stellar wheel of Mr. Barlow,‡ and the rotating disc of Mr. Sturgeon § on an extensive scale, were subjected to trials for this purpose; but, although voltaic apparatus and horse-shoe magnets of great powers, were employed in these trials, the combined forces were found to be insufficient to keep even the wheels themselves in motion. Mr. Sturgeon's discovery of magnetizing bars of soft iron to a considerable power, and rapidly changing their polarity by miniature voltaic batteries,‖ and the subsequent improved plan, by professor

* Phil. Trans. for 1823. Quarterly Journal of Science, Vol. XII. p. 79. Vol. XV. p. 289.

† Quarterly Journal of Science, Vol. XII. p. 74.

‡ Barlow's Magnetic Attractions, 2d. Edit. Part III. p. 280.

§ Transactions of the Society of Arts. London. Vol. XLIII.

‖ Transactions of the Society of Arts. Vol. XLIII. 1825.

Henry, of raising the magnetic action of soft iron,* developed new and inexhaustible sources of force which appeared easily and extensively available as a mechanical agent: and it is to the ingenious American philosopher, above named, that we are indebted for the first form of a working model of an engine upon the principle of reciprocating polarity of soft iron by electro-dynamical agency. Dr. Henry's machine is described in the twentieth volume of Silliman's American Journal of Science, in a letter to the editor of that excellent periodical. The following is a copy of Dr. Henry's letter.—

"*On a reciprocating motion produced by magnetic attraction and repulsion: by Professor Joseph Henry.*

To the Editor.

"Sir,

"I have lately succeeded in producing motion in a little machine by a power, which, I believe, has never before been applied in mechanics—by magnetic attraction and repulsion.

"Not much importance, however, is attached to the invention, since the article, in its present state, can only be considered as a philosophical toy; although, in the progress of discovery and invention, it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose. But without reference to its practical utility, and only viewed as a new effect produced by one of the most mysterious agents of nature, you will not, perhaps, think the following account of it unworthy of a place in the Journal of Science.

"It is well known that an attractive or repulsive force is excited between two magnets, according as poles of different names, or poles of the same names, are presented to each other.

"In order to understand how this principle can be applied to produce a reciprocating motion, let us suppose a bar magnet to be supported horizontally on an axis passing through the centre of gravity, in precisely the same manner as a dipping needle is poised; and suppose two other magnets to be placed perpendicularly, one under each pole of the horizontal magnet, and a little below it, with their north poles uppermost; then it is evident that the south pole of the horizontal magnet will be attracted by the north pole of one of the perpendicular magnets, and its north pole repelled by the north pole of the other; in this state it will be at rest, but if, by any means,

* Silliman's American Journal of Science. Vol xix, P. 329.

we reverse the polarity of the horizontal magnet, its position will be changed, and the extremity which was before attracted will now be repelled; if the polarity be again reversed, the position will again be changed, and so on indefinitely: to produce, therefore, a continued vibration, it is only necessary to introduce, into this arrangement, some means by which the polarity of the horizontal magnet can be instantaneously changed, and that too by a cause which shall be put in operation by the motion of the magnet itself: how this can be effected, will not be difficult to conceive, when I mention, that, intead of a permanent steel magnet, in the moveable part of the apparatus, a soft iron galvanic apparatus is used.*

"The change of polarity is produced simply by soldering to the extremities of the wires which surround the galvanic magnet, two small galvanic batteries, in such a manner that the vibrations of the magnet itself may immerse these alternately into vessels of diluted acid; care being taken that the batteries are so attached that the current of galvanism from each shall pass round the magnet in an opposite direction.

"Instead of soldering the batteries to the ends of the wires, and thus causing them at each vibration to be lifted from the acid by the power of the machine; they may be permanently fixed to the vessels, and the galvanic communication formed by the amalgamated ends of the wires dipping into a jar of mercury.

"The whole will be more readily understood by a reference to fig. 4, Plate XI, where A B is the horizontal magnet, about seven inches long, and moveable on an axis at the centre; its two extremities when placed in a horizontal line, are about one inch from the north poles of the upright magnets C and D. G and F are two large tumblers containing dilute acid, in each of which is immersed a plate of zinc surrounded with copper. *l*, *m*, *s*, *t*, are four brass thimbles soldered to the zinc and copper of the batteries and filled with mercury.

"The galvanic magnet A, B, is wound with three strands of copper bell wire, each about 25 feet long; the similar ends of these are twisted together so as to form two stiff wires, which project beyond the extremity B, and dip into the thimbles *s*, *t*.

"To the wires *q*, *r*, two other wires are soldered so as to project in an opposite direction, and dip into the thimbles *l*, *m*. The wires of the galvanic magnet have thus, as it were, four

* For a method of constructing the galvanic method on an improved plan, see my paper in Vol, XIX. p. 329, of this (Silliman's) Journal.

A description of Prof. Henry's method of making soft iron magnets by voltaic electricity will soon appear in these Annals. Edit.

projecting ends; and by inspecting the figure it will be seen that the extremity *m*, which dips into the cup attached to the copper of the battery in G, corresponds to the extremity *r*, connecting with the zinc in F.

"When the batteries are in action, if the end B is depressed until *q*, *r*, dips into the cups *s*, *t*, A B instantly becomes a powerful magnet, having its north pole at B; this of course is repelled by the north pole D, while at the same time it is attracted by C, the position is consequently changed, and *o*, *p*, comes in contact with the mercury in *l*, *m*; as soon as the communication is formed, the poles are reversed, and the position again changed. If the tumblers be filled with strong dilute acid, the motion is at first very rapid and powerful, but it soon almost entirely ceases. By partially filling the tumblers with weak acid, and occasionally adding a small quantity of fresh acid, a uniform motion, at the rate of 75 vibrations in a minute, has been kept up for more than an hour, with a large battery and very weak acid, the motion might be continued for an indefinite length of time.

"The motion before described, is entirely distinct from that produced by the electro-magnetic combinations of wires and magnets; it results directly from the mechanical action of ordinary magnetism; galvanism being only introduced for the purpose of charging the poles.

"My friend Professor Green, of Philadelphia, to whom I first exhibited this machine in motion, recommended the substitution of galvanic magnets for the two perpendicular steel ones. If an article of this kind was to be constructed on a large scale, this would undoubtedly be the better plan, as magnets of that kind can be made of any required power, but for a small apparatus, intended merely to exhibit the motion, the plan here described is perhaps the most convenient."

This ingenious invention of Professor Henry does not appear to have been any further pursued, nor any improvement in the original instrument to have yet taken place, though it is obvious that for some purposes, where a reciprocating motion is wanted, as in the pistons of pumps &c., it might be brought into play with more facility than most other forms of electro-magnetic engines that have hitherto made their appearance.

In 1835 Dr. Schulthess published a small work in which he speaks at considerable length about Dal Negro's* apparatus, or rather about the unintelligible manner in which it is des-

* Dal Negro's was rather for experiments than for work.

cribed; and then gives a description of one which he himself had made and exhibited in a lecture which he delivered to the Philosophical Society at Zurich in February, 1833. Dr. Schulthess's miniature machine consisted of two horse-shoe soft iron electro magnets, placed horizontally with their ends opposite to each other, with a small space between for the play of another small magnet which performed a pendulous motion. The whole was supported upon a four-legged wooden frame resembling the frame which supports the plate of an air pump. See Taylor's Scientific Memoirs Part IV. p. 534.

The first rotatory electro-magnetic engine of which there is any account on record, is that invented by Mr. Sturgeon, as described in the first volume of this periodical.* This engine was constructed in 1832, and appears to be the first of this class which gave motion to working models of machinery or, indeed, to which any model of the kind was attached. This engine would draw light loads on a railway, pump water, saw thin pieces of wood by means of small models which it worked with considerable facility: and though the batteries were of small dimensions, yet when the zinc cylinders were amalgamated,† and enveloped in either a bladder, pasteboard, or paper case, to prevent the transmission of the mercury to the copper surface, and also to prevent the admixture of the exciting liquids‡ employed, the action would continue for some considerable time. But the force produced by these means, though it would last much longer, it was far from being so energetic as when dilute nitrous acid alone was employed for the exciting liquid of the battery. The moveable part of Mr. Sturgeon's engine works on a vertical shaft, which carries four steel magnets, whose attractions and repulsions operate in concert, and in unison with the attractions and repulsions of four vertical soft iron magnets, whose forces are brought into play by the electric currents from the two batteries: and the reversal of their poles is accomplished by four wires which, in succession, come into contact with four quadrantal copper plates.

* Annals of Electricity, &c. Vol. I. p. 75.

† The history of amalgamated zinc being employed in voltaic batteries, will be found in Vol. I. p. 81.

‡ Sir H. Davy appears to have been the first philosopher who employed two or more different exciting liquids at the same time in the voltaic battery. He was thus enabled to construct batteries which consisted of one metal only. Nicholson's Journal, quarto, Vol. V. p. 78, 341. Phil. Trans. for 1801, and 1826.

Professor H. Jacobi "constructed a magnetic machine for continued circular motion," in May 1834,* which was described in a note presented to the Academy of Sciences at Paris, in November of the same year.† Professor Jacobi published an excellent essay on electro-magnetism as a motive force, and on its application as a first mover in machinery. A translation of this essay, from the French original, by Mr. Lang, will be found in the first volume of these "Annals," commencing at page 408. Jacobi's engine consisted of sixteen soft iron magnets, eight of which were fixed to, and rotated with, a horizontal shaft or spindle; the other eight being fixed to a steady frame in such a manner that their poles might be approached as close as possible, without being touched by those of the moveable magnets in their rotation. The whole of these magnets were brought into play by four voltaic troughs, whose electric currents traverse spiral conducting wires which surround the iron bars. Besides a description, with an illustrative plate, of this engine, much curious and interesting information will be found in the author's essay.

At the meeting of the British Association at Dublin, in 1835, the Rev. J. W. Mc.Gauley produced an electro-magnetic engine which attracted considerable attention. The author proposed to augment its power by several improvements which he then had in contemplation. At the meeting at Bristol, the following year, Mr. Mc.Gauley again brought forward his engine, and detailed an extensive series of experiments, the results of which did not hold out to him much further prospects of making his apparatus applicable to general use.

Professor Callan, of Maynooth College, who has published some valuable papers on electro-magnetism, was constructing a large engine on this principle in June, 1836.‡ This engine was tried towards the latter end of the same month, but was found defective in its first form: but by a new arrangement it gave rapid rotation to a wheel which weighed about one hundred pounds.§ From the prospects afforded by this small engine, Professor Callan was induced to proceed to the structure of one of much larger dimensions; which was to be worked by forty electro-magnets, and expected to propel a

* Annals of Electricity, &c. Vol. I. p. 410.
† Ibid p. 409.
‡ Annals, Vol. I. p. 378.
§ Ibid, 494.

carriage and its load weighing thirteen hundred weight, at the rate of seven or eight miles an hour. The author has entered on some interesting calculations on the probable advantages of electro-magnetic engines, which the reader may consult at page 494, Vol I. of these Annals.

In November, 1836, Dr. C. Page, of Salem, United States, who is the author of several beautiful pieces of electro-magnetic apparatus, turned his attention to engines of this kind; and published an account of his progress, in the American Journal of Science, for October, 1837. The revolving iron electro-magnets in this philosopher's contrivance, are of the horse-shoe form: and arranged on arms, or radii, at right angles to the rotating shaft, like the spokes of a wheel; having the poles outwards and nearly in the circumference of a circle in which the stationary magnets are fixed. Dr. Page mentions a large engine which he was then constructing, whose revolving apparatus would weigh nearly a hundred pounds. See these Annals, Vol. II. p. 216.

In April, 1837, Mr. Sturgeon announced his having succeeded in propelling a boat, and also a locomotive carriage by electro-magnetism. Annals of Electricity, Vol. I. p. 250.

The electro-magnetic engines constructed by Mr. Davenport of Bandon, near Rutland, Vermont, United States, were first announced in the American Journal of Science, for April 1837 (See Annals of Electricity Vol. II. p. 257). Since that time various accounts of these engines have appeared through the same medium, and others by the medium of the Journal of the Franklin Institute; all of which have been transferred to the pages of these Annals. (See Vol. II. p. p. 257, 284, 347, &c.) Mr. Davenport's efforts, in bringing electro-magnetic engines into repute, have been strongly supported by the liberality and patronage of Mr. Ransom Cooke, and the apparent success with which they were attended, has been the means of forming an electro-magnetic association in America.* In February 1837, Mr. Davenport secured an American "patent for the application of electro-magnetism to the propelling of machinery" in his own name;† and in the Summer of 1838, a Mr. Coombes was sent to this country with a locomotive engine of Mr. Davenport's construction, for the purpose of securing a similar patent for these realms.‡ We are not aware why Mr. Coombes returned to America without accomplishing the object of his mission; but we imagine that

* Annals, Vol. II. p. 284.
† Ibid, p. 347.
‡ Annals, Vol. III. p. 156.

he could have little difficulty in discovering that Mr. Davenport had been anticipated, in almost every particular, in this country. It would occupy too much room, in this place, to pourtray an outline of the various accounts which have been published of the performances of Mr. Davenport's engines, nor indeed would it be necessary to do so, since they are to be found complete in the different parts of these Annals to which we have already alluded.

In the American Journal of Science, for October, 1837, Dr. B. R. Mc.Connell gives an account of an electro-magnetic engine, which works upon the principle of the electro-magnetic wheel between the poles of a horse-shoe magnet. We refer the reader to Vol. II. p, 123, of these Annals for the author's own account of this instrument.

An exceedingly ingenious arrangement of electro-magnets of soft iron was invented by J. P. Joule, Esq. of Salford, Manchester, in 1837, and described in these Annals in the January No. for 1838. (See Vol. II. p. 122.) The bars, in this beautiful instrument, are of a peculiar construction, and the transposition of their polarity effected by an exceedingly ingenious contrivance. Mr. Joule proposes to apply his engine both to locomotive carriages and to boats. The description is accompanied by two neat figures of illustration. Mr. Joule also mentions another small engine which he was then constructing; it was to consist of forty magnets. A description of another engine with a series of interesting experiments by the same gentleman, will be found at the latter part of this article.

The Rev. F. Lockey describes a very pretty arrangement of magnets for an engine, in a letter to the Editor of the Annals of Electricity, dated June 12th 1838. (See Annals Vol. III. p. 14.) Mr. Lockey's plan not only differs from every other yet published, but appears to be well adapted for efficiency of power. The moveable magnets, forty-eight in number, are of soft iron with the usual wire coils for the transmission of electric currents; and arranged in eight groups of six in each group, on the revolving central shaft. The fixed magnets are of the same kind and number, and also arranged in eight groups around the circle described by the outer poles of the moveable ones, in such a manner that both systems of magnets may operate mutually on each other and produce rotatory motion. See fig. 9, Plate I., Vol. III.

About the latter part of the year 1837 a variety of ingenious contrivances, in the form of rotating engines, were to be seen in the different philosophical instrument makers' shops in London. Some of them had miniature saw mills, pumps, and other pieces of machinery attached, and put in motion by them. Mr. Watkins gave a description of one in the Phil. Mag. for February, 1838, consisting of four vertical steel magnets, placed at equal distances from each other in the circumference of a circle; and four small iron electro-magnets which were fixed at right angles to, and rotated with, a vertical spindle, situated in the axis of the system. Mr. Palmer, of Newgate Street, has long had in his window a very great variety of rotating engines, with attached models of machinery which are kept in motion by them. It is highly probable that every individual instrument maker has some peculiarity in the mode of fitting up this class of apparatus.

We close this general historical sketch of all that has hitherto been accomplished in the application of electro-magnetism as a motive power, with the following description of another ingenious contrivance by Mr. Joule.

Description of an Electro-magnetic Engine, with experiments, in a letter to the Editor of the Annals of Electricity, &c.

New Bailey Street, Salford, December 1, 1838.

Dear Sir,

In Vol. II. p. 122 of your interesting work, is a communication of mine, describing a method of making electro-magnetic engines, which I thought might be adopted with advantage. I hoped that when the engine I was then constructing was finished, I should be able to send you a detailed account of its duty. The engine was completed in the summer: it weighs 7¼ lbs. The utmost power that I have succeeded in developing, on working it with a battery of forty-eight four-inch plates was equal to raise 15 lbs. a foot high, per minute.*

The very inferior power of the engine convinces me that the distances between its poles was much too little, and that the magnets should have been fewer in number, and of much greater bulk.

I was desirous, before I attempted to make another engine, to satisfy myself by experiments, conducted on a smaller scale, how far it was possible to increase the velocity of rotation. Now, of the many things which prevent an infinite velocity, the resistance which iron opposes to the instantaneous induc-

* In this estimate the enormous friction of the engine was accurately measured and reckoned as the load; the velocity of the moving magnets was about 3½ feet per second.

tion of magnetism is of considerable importance. I think I shall be able to show how this may be obviated in some measure.

The power of the electro-magnetic machine is much increased by the insertion of a bundle of wires instead of a solid nucleus of iron into its coil; this phenomenon is evidently occasioned by the peculiar texture of the wires, which allows Mr. Sturgeon's magnetic lines* to collapse with greater suddenness.

With a view to determine to what extent the velocity of rotation might be increased by the use of wire magnets, I constructed an apparatus as represented by fig. 1, Plate XIII., where *a b*, *c d*, are the steel magnets; *e f*, brass screws with very minute holes in their ends to receive the fine points of the steel axle on which the electro-magnet *m m* is fixed; *g*, *h*, are mercury cups to connect the wires of the electro-magnet with the pieces of watch spring *i*, *k*, which dip in the mercury cells; *w*, *w*, are wires which connect these cells with the battery; the distance between the poles *a*, *c*, was eight inches. I had four electro-magnets, which, with their spindles &c., could with great expedition be put off or on the machine, by means of the screws *e*, *f*.

No. 1 electro-magnet was made of a round bar of iron 1090 grains weight; No. 2 of nineteen iron wires of about $\frac{1}{10}$ inch diameter, weighing 642 grains: no particular pains were taken in annealing the iron and wires of these magnets. No. 3 and No. 4 magnets were made of iron and wire of the same quality and dimensions, but were annealed with very great care by a process in use among the manufacturers. Each of the magnets was first enveloped with a double covering of muslin, and then wound in the same manner with eleven yards of copper wire of $\frac{1}{40}$ inch diameter, well covered with silk: care was taken to make the friction of the pivots equal in each.

Here are the results of some experiments which I made with this apparatus. The numbers given in the table are revolutions per minute.

	No. 1. Hard iron.	No. 2. Hard wire.	No. 3. Soft iron.	No. 4. Soft wire.
With a single constant battery.	146	177	196	192
With two constant batteries arranged for intensity.	233	274	283	321

* See Mr. Sturgeon's Theory of Magnetic Electricity, Vol. I. p. 251, 277.

Ditto with weaker charge.	196	173	224	209
Mean..............	192	208	234	241

These experiments were frequently repeated with similar results, and every precaution was taken to guard against error. I obtained much greater velocities than those given above, which I rejected partly because I could not count them, and partly because the resistance of the air began seriously to affect the results.

Some allowance should be given to the wire magnets; for while the weight of iron in them was little more than half that in the others, their bulk and, consequently, the resistance of the air remained the same.

The sparks and shocks, on breaking the battery circuit, were hardly sensible in No. 1; twice as great, at least, in No. 2 and 3; in No. 2 they were a little greater than in No. 3; but by far the most brilliant and powerful in No. 4.

I intend to make another engine soon, and shall construct its magnets of wires drawn from rectangular holes; if I have more success with it than I had with my last, you shall hear from me again.

I am, Dear Sir,
Yours truly,
J. P. JOULE.

LV. *Upon Telegraphic communication, especially by means of Galvanism. By* Dr. Steinheil, *Professor of Mathematics and Natural Philosophy, at the University of Munich, &c. &c. &c.**

Telegraphic communication may in its most general sense be defined as the method employed by one individual to render himself intelligible to others, and being, when viewed in this light, synonymous with intercourse is no human discovery, but one of the most wonderful gifts of nature, not to man alone, but in common with him to all social creatures is granted the faculty of communicating his sensations to others, and of exciting in them conditions similar to his own. Communication is the most powerful tie of the living creation; it connects one individual existence with another, reproduces in one what is granted to all, thus forming out of individuals, species, which in their turn present themselves as organic beings.

* Translated from the German by Julian Guggsworth.