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AMERICA'S PART IN THE DISCOVERY OF MAGNETO-ELECTRICITY—A STUDY OF THE WORK OF FARADAY AND HENRY.—II.

BY

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LET us now return to the great discovery which is the subject of our story. The permanent artificial steel magnet, up to this time the sole instrumentality available for interrogating Nature in regard to the point in question, is, as we know, always a magnet. Steel once endowed with magnetism, retains it, at least in some degree, forever, but soft iron has no such capacity. The electromagnet of soft iron remains a magnet only so long as the electric current traverses the wire encircling its core. The electric current is its vital principle; when this ceases its magnetism dies. Springing to intense life in an instant; as quickly losing almost every vestige of energy, these magnets of Henry, not only by their enormous power, by their ready capacity for instant change, were well calculated to betray the great secret which Nature had hitherto so jealously hidden from philosophic eyes.

If electricity can produce magnetism, may not magnetism produce electricity? Surely this was but a natural question for Henry to ask. He had compelled electricity to endow his magnets with their great force; could he do the reverse—compel these, his wonderful children, to produce the electricity to which they owed their existence? Early in the making of the magnets the question, he says, occurred to him. Let us stand beside him, as he actually asks the question and is answered. He is in that same room in the Albany Academy; the room which is at his disposal only during vacation. His quantity magnet stands there in its frame. A dead mass of iron, and copper and wood, it is as it stands, but Henry has only to dip the plates of copper and zinc, attached to the ends of its wires, into a tumbler of acidulated water, and the electric current will endow with magnetism not only the iron horseshoe but the armature clinging to its poles. Around the middle of this armature, Henry winds a thin copper wire, the ends of which he connects with the coil of a galvanometer, forty feet away. Now if this magnet can produce electricity it will, when awakened to life, produce electricity in this

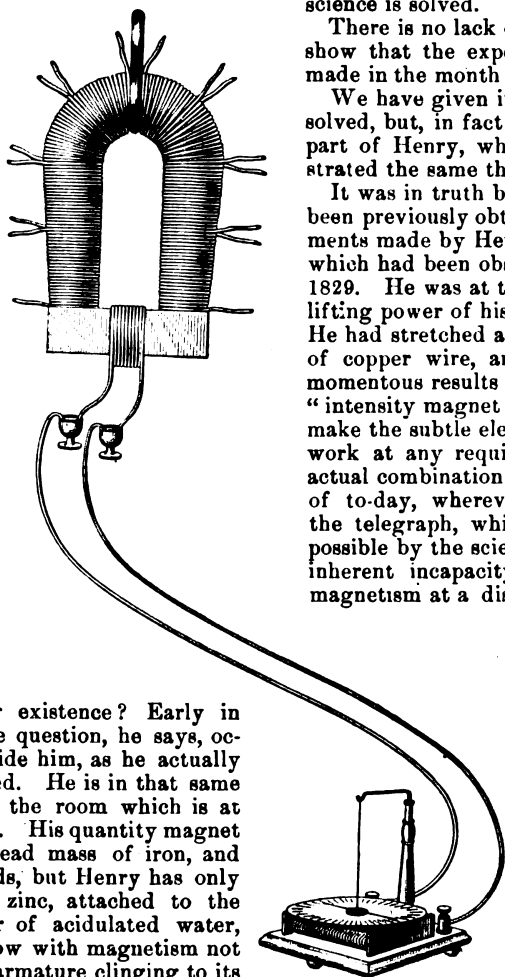
wire, and the sensitive galvanometer will betray its presence; *its needle will swerve*. He holds the metal plates suspended over the tumbler; his assistant intently watches the distant needle. What a moment of interest, as he stands there ready to ask the momentous question! He was of an especially reverent nature; he was accustomed at such times to pause a moment and say to himself: "I am about to ask a question of God." The plates are dropped into the tumbler; the electric current begins—the magnet is instinct with living power, and it *does* produce electricity in the wire around its armature, for see—the *needle of the galvanometer swerves*. The question is answered *Magnetism can produce electricity*, but—most important but—only at the instant of the making and breaking of its galvanic circuit. The gnome has at last been caught at work; the great problem of electrical science is solved.

There is no lack of evidence, as we shall hereafter see, to show that the experiment we have described was actually made in the month of August, 1830.

We have given it as the one by which the problem was solved, but, in fact this was not the first experiment on the part of Henry, which, when properly interpreted, demonstrated the same thing.

It was in truth but a logical sequence of results which had been previously obtained. It occurred in a series of experiments made by Henry to investigate a curious phenomenon which had been observed by him a year earlier, in August, 1829. He was at that time, in this very room, testing the lifting power of his magnets with different lengths of wire. He had stretched around its bare walls, one-fifth of a mile of copper wire, and had made a discovery fraught with momentous results; the discovery that by connecting his "intensity magnet" with an "intensity battery," he could make the subtle electric force effective to do mechanical work at any required distance. He had in fact made the actual combination which constitutes the electric telegraph of to-day, wherever found and under whatever name; the telegraph, which had been hitherto pronounced impossible by the scientific world, by reason of the seemingly inherent incapacity of the electric current to generate magnetism at a distance. He made his magnet, excited

by the intensity battery through that long wire around the room, ring a little bell to announce that the electric telegraph was an accomplished fact; and then the time came, when as usual, he was compelled to give up the room. Many times, during the busy years that followed, Henry rang his little bell, by means of the electric current, for the edification of the Academy students. He was deeply interested in the experiments which led to this important result, but in the course of them a brilliant and unexpected *spark* had flashed under his eyes from a break in the circuit of a long coiled wire, with which he had united the opposite poles of his battery. Nature, like a coy maiden, had lifted her veil for a moment to lure him in a different



ARRANGEMENT OF APPARATUS IN HENRY'S CRUCIAL EXPERIMENT OF AUGUST, 1830, IN WHICH ELECTRICITY WAS FIRST PRODUCED FROM MAGNETISM.

direction, and so it happened that when vacation came round again in August, 1830, he had taken up the investigation of this new phenomenon, which he called "electrical self-induction in a long helical wire connecting the poles of a galvanic battery."¹³

It was in the prosecution of this new series of researches that Henry obtained, as we have related, the phenomenon of magnetic electricity. From the self-induced currents in his long coiled wire to the production of electricity by his magnet, was only a natural and logical step. Henry, from the first, had considered the two phenomena as manifestations of one and the same principle, and later referred to them as such, in his paper on the subject in Silli-

periments must cease, not to be resumed until the last two weeks of June, 1832. A glimpse we have of the unfinished magnet standing in Henry's room, in a letter, yellow with age, written by him to Prof. Cleveland, under date Albany, November 6, 1831 :

I have lately had forged a large horseshoe weighing 101 lbs. which I intend fitting up for some contemplated experiments in the identity of electricity and magnetism. It will be more powerful than any heretofore made, being almost double the weight of the Yale College magnet (59½ lbs).

Prof. Silliman hears of the new magnet and writes March 5, 1832, from New Haven to Henry :

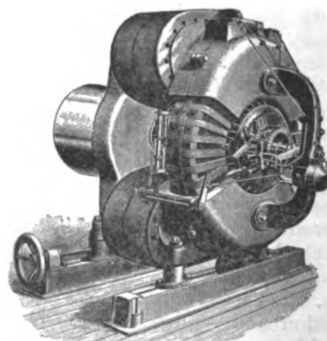
"I have been told that you have constructed a larger galvanic magnet than those of which notices have been published. I write to inquire if there is anything that you would like to have published in the *American Journal* for April, as to any extension or new application of your discovery. I am informed that you have applied it to the separation of fragments of magnetic iron from the mixtures of other things."¹⁴

And Henry in his reply of March 28th, 1832, says :

"In answer to your inquiries as to my further experiments in magnetism, I have little definite to communicate at the present time. I have not entirely abandoned the subject, but have been prevented by circumstances from prosecuting a series of experiments, which were commenced on a very extensive plan. I had partially finished a magnet much larger than any before made, and have constructed a kind of reel on which more than a mile of copper wire was wound. I was obliged to abandon the experiments on account of the room in which my apparatus was erected being wanted for the use of the Academy, and it has not been convenient to me to resume them during the winter."

Other yellow letters tell of the varied occupations of Henry's busy life, which allowed no place for the intensely interesting researches, commenced on so grand a scale and interrupted so opportunely. They were, as we have said, resumed in the latter part of the following June. What was it that set Henry at work at that time? A paragraph in a periodical, announcing that Faraday too had made the great discovery that magnetism could produce electricity. The notice was brief; it showed that electricity in one wire might be made to generate electricity by induction in another wire, and it gave this experiment :

"In a coil of wire a permanent magnet was inserted, and Faraday found that electricity was produced in the wire when the magnet was inserted in the coil, and when it was withdrawn."

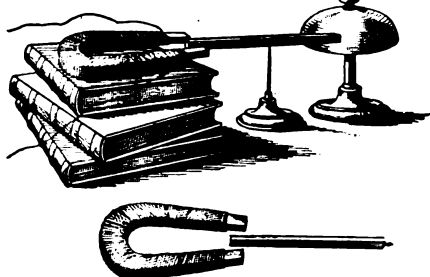


A MODERN DYNAMO ELECTRIC MACHINE.

Was this the experiment; the one by means of which Faraday made the discovery? We shall see. It should

14. It is a matter of more than casual interest, that this, the earliest industrial application of Henry's electromagnet, should have been the means of directly bringing about the rotary electric motor, as we have it to-day. It was at the Penfield Iron Works, near Crown Point, Lake Champlain, N. Y., and the village at that place still bears the name Port Henry, given to it at that time in honor of the philosopher. In *THE ELECTRICAL ENGINEER* of Jan. 7, 1891, the story of the visit of the Vermont blacksmith, Thomas Davenport, to the Penfield Works, and how he was led to purchase the Henry magnet and to employ it in the construction of an electric motor, has been graphically told by Franklin L. Pope. It is worthy of note, also, that the separation of the constituents of pulverized iron ore by means of magnetism, has within the last year or two attracted great attention, and seems likely to become of vast industrial importance. [EDITOR.]

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HENRY'S DEMONSTRATION OF THE PRINCIPLE OF THE ELECTRO-MAGNETIC TELEGRAPH, 1829.

man's *Journal*. The world of science has of late years come to the same conclusion. In view of this fact, we may say that the discovery of magneto-electricity was really made by Henry in 1829, when he first obtained sparks from the inductive action of the extra current.

Many other important results were obtained, which cannot be enumerated here, but the inexorable first of September came all too quickly; the academic year of treadmill work; of drilling noisy boys from the rising until the setting of the sun—almost literally, since one of his classes assembled at six in the morning. And so we come down to August, 1831—the August we have dwelt upon so persistently, and very interesting it is now to see what Henry was doing, when Faraday, far away across the sea, is about to enter upon his great work. Spurred to enthusiasm by the brilliant results of the labors of the past year, Henry, to use his own words, is "making preparation for an exhaustive series of experiments upon the identity of electricity and magnetism," and is constructing for the purpose a still larger magnet. But he is not only making this larger magnet, he has constructed a great "reel" wound with a mile of wire. With the magnet we saw him using, and the wire around its armature, he had been able to move a needle forty feet away. What is he doing with this larger magnet and this great reel of a mile of wire? He is making an instrument capable of powerful work. Now look at the picture of a modern "dynamo." What is its essential feature? A reel, wound closely with wire, made to revolve within the influence of a great magnet.

We do not know in what way Henry intended to revolve his reel within the influence of his magnet, but this does not matter. What he is doing in these August days of 1831, is literally *making a dynamo*, in the modern acceptance of the term. Surely, it was not too much to say that Henry was already almost lost to sight in this particular path in which Faraday is only just about to enter. But the first of September came too soon for the completion of his preparations. His room must be given up, as usual, for the ordinary requirements of the Academy.

The great magnet must remain unfinished, and all ex-

13. This constitutes the discovery of the extra current made by Henry in 1829, by Faraday in the summer of 1831. M. A. H.

be remembered that this notice conveyed to Henry all the knowledge he had of Faraday's efforts. It impressed upon him the immediate importance of publishing his own results. Although the notice of Faraday's experiment had been published in April, it did not come under Henry's eyes until the following June. He thereupon immediately set to work; repeated the experiments mentioned in the notice, added some others of his own, and hastily prepared a paper for the July number of *Silliman's Journal*, giving—a fact much to be regretted—only a few of the many interesting and important results he had obtained.

THE PRACTICAL MANAGEMENT OF DYNAMOS AND MOTORS.—II.

BY

Francois B. Crocker and Allyn Keeler.

CHAP. II.—Continued.

The Various Kinds of Circuits on which dynamos and motors are commonly used, and the best type of machine in each case, is as follows :

CONSTANT POTENTIAL.

(Circuits on which potential or voltage is kept constant, machines, lamps, etc., run in parallel.)

Circuits intended for—	Potential.	Dynamo should be—	Motor should be—
Incandescent lighting.....	110 volts (2-wire sys.) 220 volts (3-wire sys.)	Plain shunt or compound wound.	Plain shunt wound.
Electric railway. Power circuits...	500 volts.	Plain shunt or compound wound.	Series wound for railway. Shunt wound for stationary.

CONSTANT CURRENT.

(Circuits on which current or amperes are kept constant, machines, lamps, etc., run in series.)

Circuits intended for—	Current in Amperes.	Dynamo should be—	Motor should be—
Arc lighting....	6.8 9.5 or 18	Series wound with current regulator.	Series wound with speed regulator.
Power circuits..			

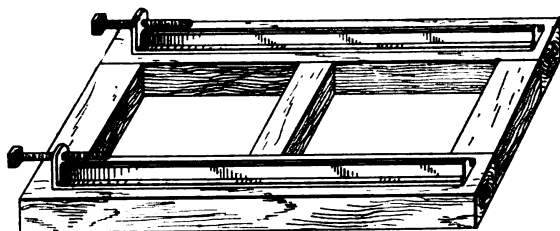


FIG. 1.—BASE FRAME.

The above suggestions as to selecting a dynamo or motor may be followed when it is possible to make only a general examination of the machine, or even in cases where it is only possible to obtain a drawing or description of it. If it is desired to make a complete investigation of the ma-

chine, it is, of course, necessary to make a thorough test and measure exactly its various constants. This can be done as completely as may be required by following the Directions for Testing, which are given in another chapter.

A satisfactory test cannot usually be made, however, until after the machine is set up in place; and, moreover, it is not generally necessary if the machine is obtained from a reputable source.

CHAP. III.

DIRECTIONS FOR INSTALLING DYNAMOS AND MOTORS.

Setting up.—The place selected for a dynamo or motor should be dry, clean, cool, away from all pipes if possible, where the machine is in plain sight and is easily

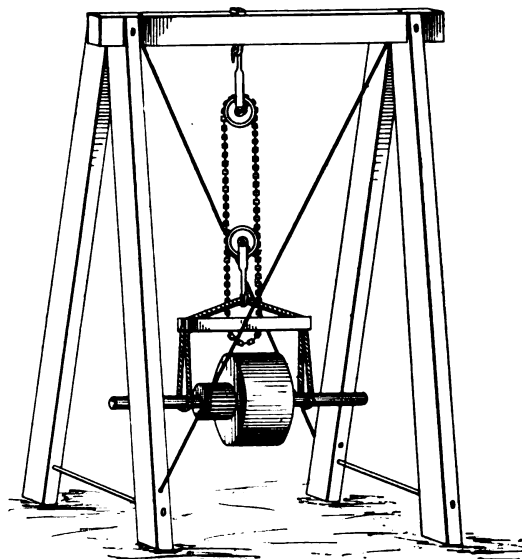


FIG. 2.—SLING FOR HANDLING ARMATURE.

accessible and taken care of. Avoid particularly any dusty, wet or hot location. Any place near which grinding, filing, turning or similar work is likely to be done, is very undesirable for a dynamo or motor, as the dust and chips produced are liable to injure the bearings, commutator and insulation of the machine. A firm and level foundation should be provided in any case, and larger machines of 20 h. p. or more should be set on solid stone, brick or timber foundations. It is well, particularly in the case of high-voltage machines, to have them placed upon an insulating base-frame of wood, the pores of which should be filled with paraffine or well varnished to keep out moisture. If a wooden belt-tightening base is used this will answer the purpose, but if iron tracks are used they should be placed on a wooden base-frame. Fig. 1.

In unpacking and putting the machines together the greatest possible care should be used in avoiding the least injury to any part, in scrupulously cleaning each part and in putting the parts together in exactly the right way. This care is particularly important with regard to the shaft, bearings, magnetic joints and electrical connections from which every particle of grit, dust, chips of metal, &c., should be removed. It is very desirable to have machinery put together by a person thoroughly familiar with its construction, and in the absence of such a person no one should attempt it without at least a drawing or photograph of the complete machine as a guide. An exception may be made to this rule if the machine is very simple and the way to put it together is perfectly obvious, but in no event should the installation or management of machinery be left to guess-work. The armature should be handled with the greatest possible care in order to avoid injury to the