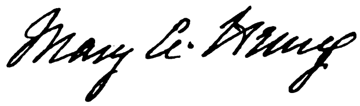
AMERICA'S PART IN THE DISCOVERY OF MAGNETO-ELECTRICITY—A STUDY OF THE WORK OF FARADAY AND HENRY.—IV.

BY



IV.

And now let us go over the ocean to Faraday, and see how he asks the great question. Bence Jones tells us that as far back as 1824, Faraday began the study of the subject. "He believed"—as did Henry—"with all his energy, that as voltaic electricity powerfully affects a magnet, so the magnet ought to exert a reaction upon the electric current,"[1] and he makes an experiment which nearly makes the discovery.[2] He again makes experiments in November, 1825, December, 1825, and April, 1828, but without result. "*The momentary existence of the phenomena escaped him.*" "The good time was now come."[3]

In the beginning of the year 1831 comes over the sea Henry's paper in *Silliman's Journal*. It describes the magnets that have sprung up under Henry's hands, and the rules of their construction. Faraday, with quick philosophic instinct, sees in these powerful instruments for producing magnetism; means for a new trial of the old experiments, and again he goes to work. "He began his experiments on August 29, 1831."[4] Let us look at his apparatus. We see at a glance it is Henry's magnet, with its poles elongated, and the whole bent into the form of a ring. On the side B are wound the wires to convey the electric current for magnetizing the ring; there are "three lengths of wire, each about 20 feet long," insulated and wound as Henry taught Faraday to do in his paper in *Silliman's Journal*. These "three lengths" may be "connected as one," when the ring will be an "intensity" magnet, a long single wire; or, each of the three strands may be independently connected with the battery, when it will be a "quantity" magnet. Connected as one, the three strands are used by Faraday, and for the intensity magnet thus formed, if Henry's instructions are followed properly, there must be an "intensity" battery—a battery of many pairs of plates, and we find there is "*a battery of 10 pairs of plates, four inches square*." On the A side of the ring is a wire, corresponding exactly to the wire surrounding the armature in Henry's experiment, and it is carried to a distance, and brought so near to a magnetic needle that upon the passage of the current it will oscillate, as did the needle in Henry's galvanometer. The essential apparatus; the means of the discovery used by the two men, like the discovery itself, is identical. Faraday saw his needle "oscillate," as Henry saw his "swerve" at the making and the breaking of the galvanic current. There is, however, a marked difference in the immediate mental attitude of the two men in regard to the observed phenomenon. Henry sees instantly that the question is answered. He says:

> "This experiment illustrates most strikingly the reciprocal action of electricity and magnetism, if it does not indeed prove their absolute identity. In the first place magnetism is developed in the soft iron of the galvanic magnet by the action of the currents of electricity from the battery, and secondly the armature, rendered magnetic by contact with the poles of the magnet induces in its turn currents of electricity in the helix which surrounds it. We have thus as it were *electricity converted into magnetism and this magnetism into electricity*."

He immediately recognizes the condition essential to the production of electricity by magnetism—that is, *motion* or *change*. He tries other ways of producing the effect: "*slipping off the armature by degrees until the contact was entirely broken*," dipping the battery plates but a little way into the acid at first, and afterwards immersing them by degrees, etc., all detailed in his paper, and then again he emphatically repeats his clear statement of the phenomenon:

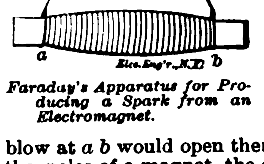
> "A current of electricity is produced for an instant in a helix of copper wire surrounding a piece of iron, whenever magnetism is produced in the iron. An instantaneous current, in one or the other direction, accompanies every change in the magnetic intensity of the iron."

Faraday, on the other hand, does not seem to have understood the reply of Nature, or at least he seems far from confident of it. He writes to a friend the 23d of September, "*I think that I have hold of a good thing; I cannot say. It may be a weed instead of a fish that after all my labor I may pull up.*" On the next day, September 24th, the third day of his experiments, he is again trying the effect of a helix of wire conveying the voltaic current of 10 pairs of plates, upon another wire connected with a galvanometer, and other like experiments, but "*no induction sensible.*" Had Faraday at this time discovered the essential nature of the phenomenon, experiments like these could not have failed, in his hands, to give conclusive results. "He gave up experiments for that day with the electromagnet and tried instead the effect of bar (permanent) magnets." An iron cylinder had a helix wound around it. The ends of the helix were placed between the poles of the magnet, arranged as in the accompanying figure. Every time the magnetic contact was made or broken there was motion in the galvanometer." Now, but not until now, he reaches a positive conclusion: "Hence here distinct *conversion of magnetism into electricity*."

This constitutes his first distinct annunciation of the phenomenon, so that his discovery can scarcely, in justice, be said to have been made until this day, September, 24, 1831.

Not until the ninth day of experiment, October 17, does he produce the deflection of the needle by thrusting a bar magnet into a helix of wire; the experiment which came over to Henry in that brief paragraph of April, 1832, and which incited him to repeat his own experiments in the last two weeks of June of the same year. With no other knowledge of Faraday's work than this particular mode of producing the effect, it is curious to see Henry in these June days bending the armature of his magnet into a ring (see page 104 of this article), while on the other hand, Faraday, equally unconscious of Henry's efforts, in his paper of November, 1831, makes the important observation that "a soft iron bar, in the form of a lifter to a horseshoe magnet, when supplied with a coil of this wire, becomes, by juxtaposition with a magnet, a ready source of a brief but determinate current of electricity," thus adopting the precise method which had been employed by Henry.

Faraday, as Henry, desired that the electricity he could produce through magnetism might be manifested by a spark. An entry in his note-book of February 8, says:



Faraday's Apparatus for Producing a Spark from an Electromagnet.

> "This evening at Woolwich, experimented with magnet, and for the first time got the magnetic spark myself. Connected ends of a helix into two general ends, and then crossed the wires in such a way that a blow at *a b* would open them a little. Then bringing *a b* against the poles of a magnet, the ends were disjoined and bright sparks resulted."

It may be well to give in full Bence Jones's account of Faraday's work up to the 24th of September, so that the reader may be enabled to judge for himself whether we have interpreted it correctly. We break its thread, here and there, for comment, as we have already done with Henry's paper.

> "On August 29th, 1831, Faraday began his Electrical Researches."

1. *Life of Faraday*, ii., 1.
2. Quarterly Jour. Science, July, 1825, p. 338.
3. *Life of Faraday*, ii., 2.
4. *Ibid*, ii., 2.

"In December, 1824, he believed with all his energy that as voltaic electricity powerfully affects a magnet, so the magnet ought to exert a reaction upon the electric current. Guided by this idea he made an experiment, of which one part (the passage of a magnet through a metallic helix connected with a galvanometer), if separated from the rest of the experiment, would then have made the great discovery of magneto-electricity. This experiment he published in the *Quarterly Journal of Science*, July, 1825, p. 338."

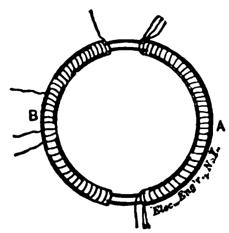
The phenomenon, it will be noticed, was here actually produced under Faraday's hands, although unperceived by him. To use our former simile, he had failed to catch the moment when the gnome was at work.

"In November, 1825, also, he had failed to discover voltaic induction. He passed a current through a wire, which was lying close to another wire, which communicated with a galvanometer, and found 'no result.' *The momentary existence of the phenomena of induction then escaped him.*

"Again, Dec. 2, 1825, and April 22, 1828, he made experiments which gave 'no result.' These experiments were not published.

"The good time was now come. The first paragraph in the laboratory note-book is 'Experiments on the production of electricity from magnetism.' His first experiment detailed in the second paragraph records the discovery by which he will be forever known.

"'I have had an iron ring made (soft iron), iron round and ⅞ of an inch thick, and ring six inches in external diameter. Wound many coils of copper round, one half of the coils being separated by twine and calico: there were three lengths of wire, each about twenty-four feet long, and they could be connected as one length, or used as separate lengths. By trials with a trough each was insulated from the other. Will call this side of the ring *A*. On the other side, but separated by an interval, was wound wire in two pieces, together amounting to about sixty feet in length, the direction being as with the former coils. This side call *B*.'"



Faraday's Inductive Ring.

We here find Faraday working with an electromagnet made exactly in accordance with Henry's plan as given in his paper in *Silliman's Journal* of January of the same year. It is immaterial that Faraday's iron core is in the form of an endless ring instead of a horseshoe. That Faraday had carefully studied Henry's paper is shown not only by this use of Henry's system of construction, but in the publication of his results in the *Experimental Researches*, Nov. 31, 1831, he says:

"'There is no doubt that the arrangements like the magnets of Moll, Henry and Ten-Eyck and others, in which as many as *two thousand pounds* have been lifted, may be used for these experiments.'"

Henry had introduced Moll's results, very much inferior to his own, with his paper in *Silliman's Journal;* and Ten-Eyck had been mentioned in Henry's paper as his assistant who had been engaged in constructing magnets under his personal direction. There were no others at work upon the subject. It was Henry's little giants Faraday saw in Henry's paper lifting the enormous weight of 2,000 lbs., and the notice, although couched in undiscriminating language, nevertheless makes it certain that the paper had come under Faraday's notice, and that he had learned the lesson it had to teach. Before the paper of Henry had reached his hands, the only electromagnet available for Faraday's use was Sturgeon's horseshoe bar, with its single loosely wound uninsulated helix of wire.

"'Charged a battery of ten pairs of plates four inches square. Made the coil on *B* side one coil, and connected its extremities by a copper wire passing to a distance, and just over a magnetic needle (three feet from wire ring), then connected the ends of one of the pieces on *A* side with the battery: immediately a sensible effect on needle. It oscillated and settled at last in original position. On breaking connection *A* side with battery, again a disturbance of needle.'"

"In the 17th paragraph, written on the 30th, he says: 'May not these transient effects be connected by causes of difference between power of the metals at rest and in motion in Arago's experiments?'"

The requisition of change or motion obviously occurs here, in a certain sense, to Faraday's mind, but only as a question. As the children say, Faraday is at this point "very warm" in this curious game of hide-and-seek, but the gnome is not yet caught, as we plainly see from the experiment next described. Faraday is even not absolutely sure that his ring produced the phenomenon, as the next paragraph unmistakably indicates:

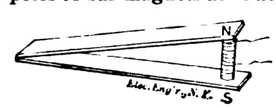
'After this he prepared apparatus. Writing to his friend R. Phillips, September 23, he says: 'I am busy just now again on electromagnetism, and I think that I have hold of a good thing, but I can't say. It may be a weed instead of a fish that, after all my labor, I may at last pull up.'

"September 24 was the third day of his experiments. He began paragraph 21 by trying to find the effect of one helix of wire, carrying the voltaic current of ten pairs of plates, upon another wire connected with a galvanometer. 'No induction sensible.'"

Faraday is here repeating the ring experiment; this time, to him, without apparent result.

"Longer and different metallic helices show also no effect." These experiments are essentially the same. In them, although unperceived by Faraday, magnetism must necessarily have produced electricity. With a conception of the necessary condition of change or motion (which, considering the failure of these experiments, could apparently have been but a passing thought) he has laid, as it were, his very fingers upon the result, yet it continues to elude him. Not sure of the glimpse he has had of it with his ring—that experiment repeated is apparently denying its former assertion while those other experiments fail. He is here evidently still baffled by the transitory nature of the effect and so is still failing to catch the moment when it is produced. Not yet can the discovery be said to have been made; since the very existence of the phenomenon was to this date still unproven. He gives up experiments for that day, and tries the effects of a bar magnet instead of the ring magnet that he had used on the first day. In paragraph 33 he says:

"'An iron cylinder had a helix wound on it. The ends of the wires of the helix were connected with the indicating helix at a distance by copper wire. Then the iron placed between the poles of bar magnets as in accompanying figure. Every time the magnet contact at *N* or *S* was made or broken, there was magnetic motion at the indicating helix—the effect being, as in former cases, not permanent, but a mere momentary push or pull. But if the electric communication (*i. e.*, by the copper wire,) was broken, then the disjunction and contacts produced no effect whatever. *Hence here distinct conversion of magnetism into electricity.*'"



Faraday's Conversion of Magnetism into Electricity.

In this sentence we find the first positive recognition of the phenomenon; of its necessary condition of change or motion. Faraday has at last caught the moment when the gnome is at work; the discovery is made—but not in justice can it be said until this day, September 24, 1831.

Two or three other experiments follow, with helices of wire around a core of wood instead of iron, and, as we may conjecture, are successful, since the essential condition of the phenomenon is no longer a mystery. Then follows the experiment usually given in the text-books, as the one by which Faraday made the discovery.

"'The fifth day of experiment was October 17. Paragraph 57 describes the discovery of the production of electricity by the approximation of a magnet to a wire.

"'A cylindrical bar magnet, three-quarters of an inch in diameter and eight inches and a half in length, had one end just inserted into the end of the helix cylinder (220 feet long); then it was quickly thrust in the whole length, and the *galvanometer* needle moved; then pulled out, and again the *needle moved*, but in the opposite direction. This effect was repeated every time the magnet was put in and out, and therefore a wave of electricity was so produced from *mere approximation of a magnet;* and not from its formation *in situ*.'

"The ninth day of his experiments was October 28, and this time he 'made a copper disc turn around between the poles of the great horseshoe magnet of the Royal Society. The axis and the edge of the disc were connected with a galvanometer. The needle moved as the disc turned.' The next day, November 4, he found 'that a copper wire, one eighth of an inch, drawn between the poles and the conductors produced the effect.' * * *

"In ten days of experiment these splendid results were obtained. He collected the facts into the first series of *Experimental Researches in Electricity*. It was read Nov. 24th, at the Royal Society. Then he went to Brighton."

THE PRACTICAL MANAGEMENT OF DYNAMOS AND MOTORS.—IV.

BY

Francis B. Crocker and Schuyler S. Wheeler.

CHAP. III.—*Continued.*

Series Dynamo on Constant-Current Circuit.—The connections in this case (Fig. 8) are

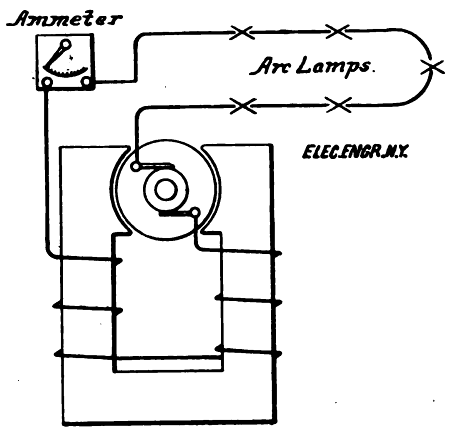


FIG. 8.—SERIES DYNAMO ON CONSTANT CURRENT CIRCUIT WITH LAMPS IN SERIES.

extremely simple, the armature, field-coils, amperemeter, main circuit and lamps, all being connected in one series.

Alternating-Current Plant.—The proper connections in this case are shown in Fig. 9, in which the names of the different parts of the plant are given and which therefore requires no explanation.

The diagrams of connections of all cases of *dynamos coupled together* and of *electric motors* are given in the chapter on Starting where they are required to explain the proper steps.

CHAPTER IV.

DIRECTIONS FOR STARTING DYNAMOS AND MOTORS.

General.—Make sure that the machine is clean throughout, especially the commutator, brushes, electrical connections, etc. Remove any metal dust, as it is very likely to make a ground or short circuit.

Examine the entire machine carefully and see that there are no screws or other parts that are loose or out of place. See that the oil cups have a sufficient supply of oil, and that the passages for the oil are clean and the feed is at the proper rate. In the case of self-oiling bearings see that the rings or other means for carrying the oil work freely. See that the belt is in place and has the proper tension. If it is the first time the machine is started it should be turned a few times by hand, or very slowly, in order to see if the shaft revolves easily and belt runs in centres of pulleys.

The brushes should now be carefully examined and adjusted to make good contact with the commutator and at the proper point, the switches connecting the machine to the circuit being left open. The machine should then be started with care and brought up to full speed gradually if possible, and in any case the person who starts either a dynamo or motor should closely watch the machine and everything connected with it and be ready to instantly shut down and stop it (and throw it out of circuit if it is connected) if the least thing seems to be wrong, and should then be sure to find out and correct the trouble before starting again. (See "Locating and Remedying Troubles.")

Starting a Dynamo.—In the case of a dynamo it is usually brought up to speed either by starting up a steam engine or by connecting the dynamo to a source of power already in motion. The former should of course only be attempted by a person competent to manage steam engines and familiar with the particular type in question. This requires special knowledge acquired by experience, as there are many points to appreciate and attend to, the neglect of any of which might cause serious trouble. For example, the presence of water in the cylinder might knock out the cylinder head; the failure to properly set the feed of the oil cups might cause the piston rod, shaft or other part to cut, or other great or small damage might be done by ignorance or carelessness. The mere mechanical connecting of a dynamo to a source of power is usually not very difficult; nevertheless, it should be done carefully and intelligently, even if it only requires throwing in a friction clutch or shifting a belt from a loose pulley. To put a belt on a pulley in motion is difficult and dangerous, particularly if the belt is large or the speed is high, and should not be tried except by a person who knows just how to do it. Even if a stick is used for this purpose it is apt to be caught and thrown around by the machinery unless it is used in exactly the right way.

It has been customary to bring dynamos to full speed before the brushes are lowered into contact with the commutator, but there is no particular reason for this practice, provided the dynamo is not allowed to turn backwards, which sometimes occurs from carelessness in starting, and might injure copper brushes by causing them to catch in the commutator. If the brushes are put in contact before starting they can be more easily and perfectly adjusted, and the E. M. F. comes up slowly so that any fault or difficulty will develop gradually and can be corrected, or the machine stopped, before any injury is done to it or to the system. In fact, if the machine is working alone on a system and is absolutely free from any danger of short-circuiting any other machine or storage battery on the same circuit, it may be started up connected to the circuit, in which case the E. M. F. and current feel their way, so to speak, through the whole system, and any trouble manifests itself so slowly that it can be taken care of before serious injury results.

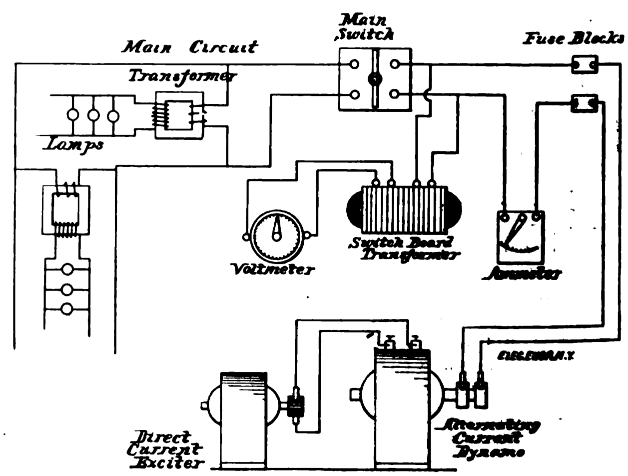


FIG. 9.—ALTERNATING CURRENT PLANT.

If, however, a dynamo is to be connected to another or