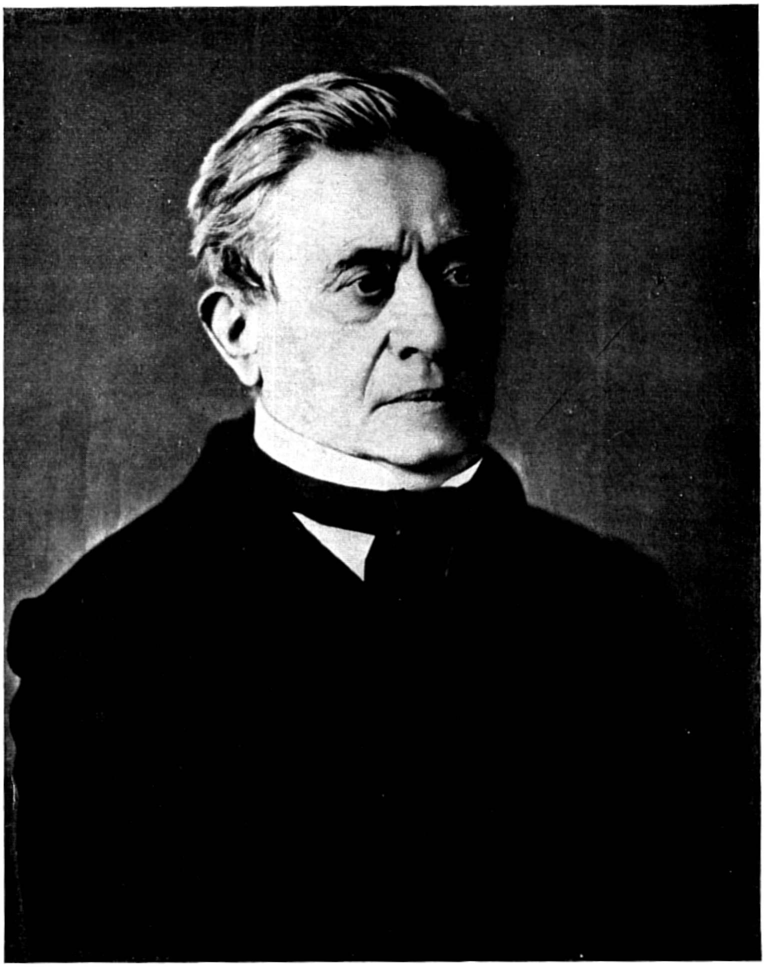

JOSEPH HENRY
1799–1878

The Bell System Technical Journal

January, 1926

Joseph Henry

The American Pioneer in Electrical Communication

By BANCROFT GHERARDI and ROBERT W. KING

IN the brilliant galaxy of investigators to whom we owe our knowledge of electrical science, Joseph Henry stands out as of the first magnitude; and for those who are associated with the Bell System, the present is a most appropriate time to review his researches which had an important guiding influence on the development of electrical communication. The present year marks the fiftieth since the invention of the telephone by Alexander Graham Bell, and among the scientists with whom Bell conferred at that time, he gave a place of honor to Henry. In a letter to his parents written in March, 1875, while he was busy in an effort to perfect the harmonic telegraph, and before he had turned his attention to the telephone, Bell wrote:

"Now to resume telegraphy. When I was in Washington, I had a letter of introduction to Professor Henry, who is the Tyndall of America. I had found on inquiry at the Institute of Technology, that some of the points I had discovered in relation to the application of acoustics to telegraphy had been previously discovered by him. I thought I would, therefore, explain all the experiments, and ascertain what was new and what was old. He listened with an unmoved countenance, but with evident interest to all, but when I related an experiment that at first sight seems unimportant, I was startled at the sudden interest manifested.

"I told him that on passing an intermittent current of electricity through an empty helix of insulated copper wire, a noise could be heard proceeding from the coil, similar to that heard from the telephone. He started up, said, 'Is that so? Will you allow me, Mr. Bell, to repeat your experiments, and publish them to the world through the Smithsonian Institute, of course, giving you the credit of the discoveries?'

"I said it would give me extreme pleasure, and added that I had apparatus in Washington, and could show him the experiments myself at any time. . . .

"We appointed noon next day for the experiments, I set the instrument working and he sat at a table for a long time with the empty coil of wire against his ear listening to the sound. I felt so much encouraged by his interest that I determined to ask his advice about the apparatus I have designed for the transmission of the human voice by telegraph. I explained the idea and said, 'What would you advise me to do, publish it and let others work it out, or attempt to solve the problem myself?' He said he thought it was 'the germ of a great invention,' and advised me to work at it myself instead of publishing. I said that I recognized the fact that there were mechanical difficulties in the way that rendered the plan impracticable at the present time. I added that I felt that I had not the electrical knowledge necessary to overcome the difficulties. His laconic answer was, 'GET IT.'

"I cannot tell you how much these two words have encouraged me. Such a chimerical idea as telegraphing vocal sounds would indeed to most minds seem scarcely feasible enough to spend time in working over. I believe, however, that it is feasible, and that I have got the cue to the solution of the problem.

"Professor Henry seemed to be much interested in what I told him, and cross-questioned me about my past life, and specially wanted to know where I had studied physics . . . . "

Joseph Henry was born in Albany, New York, in 1799, and coming to full maturity of mind at the beginning of a century which will probably never be surpassed for fruitful research in the field of electricity, he demonstrated, at the very outset of his career, his right to stand for all time with the foremost investigators in this department of natural science. Henry was, moreover, a many-sided man. His distinguished career leads into many fields and before reviewing his researches on electro-magnetism we may note briefly the very diversified and yet important character of his other work.

During the latter half of his life, official duties as the director of the Smithsonian Institution consumed an ever increasing portion of his time, but he still found opportunity to prosecute many original inquiries,—for example, into the application of acoustics to building, into the best construction and arrangement of lecture rooms, and into the strength of various building materials. As one of his first administrative acts, he organized a widespread corps of observers for simultaneous weather and meteorological reports by means of the telegraph which was yet in its infancy. He was the first to have the daily atmospheric conditions indicated upon a map of the country and to utilize this information in making weather forecasts.

He was an active and long-standing member of the Lighthouse Board of this country and his diligent investigations into the efficiency of various illuminants and the best conditions for their use greatly improved the beacons which dotted our coasts. During the dark days of the Civil War, Henry clearly saw the tremendous advantage to be derived from a mobilization of the nation's scientific men for cooperative service. His vision, backed by his tremendous energy and ability, resulted in the formation of the National Academy of Sciences, under a Congressional charter signed by Abraham Lincoln.

More than fifty years later this same National Academy of Sciences was again called upon in time of national need, and, using the mechanism inspired by Henry, there re-occurred, in 1916, under presidential proclamation, a mobilization of the nation's scientific and technical men.

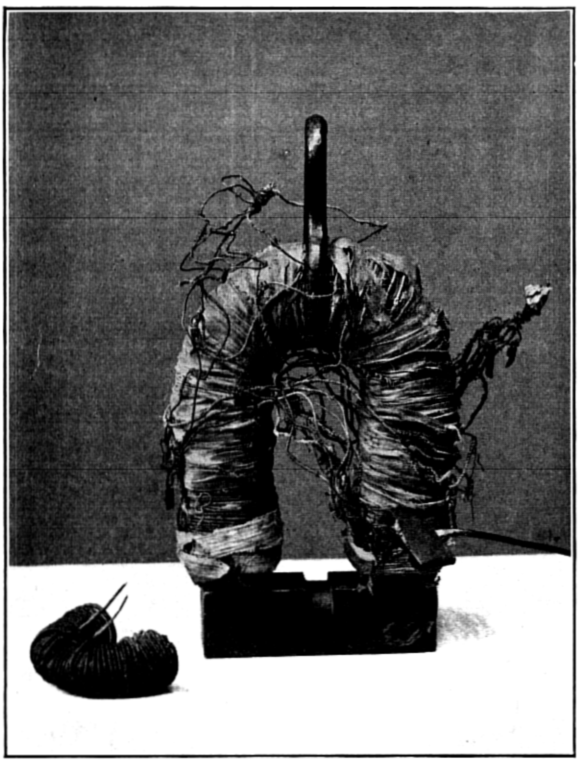

Fig. 1

While the details of Henry's life and work are perhaps not widely known, his researches are of the most enduring character, and for all time must enter intimately into the lives of all civilized mankind. He was without peer among the American physicists of his time, and it is well attested by every record that he was a man of varied culture, of large breadth and liberality of views, of generous impulses, of great gentleness and courtesy of manner, combined with equal firmness of purpose and energy of action.

Let us now turn to Henry's investigations of electro-magnetism, which were among his earliest scientific undertakings. He began his career in 1826 in New York State at the Albany Academy, where he had only the apparatus he could construct with his own hands and, out of each year, but a single month uninterrupted by other duties to devote to his researches. It was there—independently of Faraday and on some fundamental points prior to him—that Henry discovered the laws of current induction. At the same time he undertook a study of the electromagnet which prepared the way for not only the telephone and telegraph, but also for all types of dynamos and motors.

The electromagnet was discovered by Sturgeon in England, but Henry's contributions to our knowledge of it were so great that after his work, a powerful instrument suitable for many uses replaced what had been a feeble toy. When he started his work on the electromagnet its design was not understood; when he had completed his work he had developed a magnet, the design of which was understood and which could be adapted, according to the rules which he laid down, to a multitude of purposes.

With reference to the making of electromagnets, Henry pointed out the improvements which resulted from insulating the conducting wire itself, instead of the rod to be magnetized, and by covering the whole surface of the iron with a series of coils in close contact. This was effected by insulating a long wire with silk thread, and winding this around the rod of iron in close coils from one end to the other. The same principle was extended by employing a still longer insulated wire, and winding several strata of this over the first, care being taken to insure the insulation between each stratum by a covering of silk ribbon. By this arrangement the rod was surrounded by a compound helix formed of a long wire of many turns instead of a single helix of a few turns.

Thus Henry laid down the rules, which, in general, are followed today in the construction of commercial electromagnets; namely, that the wire should be insulated, that it should be wound in layers, and that there should be several layers, one above the other. He also did another thing in his actual construction: he adopted what may be called the spool construction, the placing of the windings on spools, and then the sliding of the spools on the core. That is a standard method of building electromagnets today.

Soon after doing this work Henry built a magnet to be used at Yale University, which was in its time a wonder and would even today be considered very powerful. He also built a series of magnets in which the emphasis was placed upon the lifting power in relation to the weight of the magnet and succeeded in designing one which, when energized by a single small cell, could support 420 times its own weight.

The improvements which Henry made in magnets suggested to him applications of magnetic attraction to the production of mechanical motion. He realized that electromagnets such as he built were easy to control, and believed that he could design a machine by which he could get power from an electric current and this at a time when the only source of current were primary batteries as the dynamo did not yet exist.

His electric motor was the first ever built to use electromagnets;[1] it was extremely simple consisting of an electromagnet supported at its center by a pivot so that it could rock back and forth under the alternating pulls of two permanent magnets. To effect the reversal of magnetization of the electromagnet and hence the alternation of pulls, mercury cups were arranged so that wires would dip in them as the suspended magnet rocked to and fro. These contacts were the prototype of the commutator which is found in every direct current motor and dynamo today. It is interesting to note the words in which Henry described this invention. In Silliman's *American Journal of Science* for 1831 he wrote, "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 a philosophical toy; although in the progress of discovery and invention it is not impossible that the principle or some modification of it on a more extended scale may hereafter be applied to some useful purpose."

The modesty of this statement and Henry's vision of the future possible applications of the principle there shown cannot fail to com-

[1] Faraday has some years before shown that a wire carrying a current could be caused to revolve continuously around the pole of a permanent magnet. Henry's advance over this was considerable in that he materially increased the force causing motion by employing the attraction between two magnets, one permanent and one generated by current. The motor using electromagnets throughout did not come until later.

mand our admiration. Of course, until the dynamo was invented at a later date, and a substantial electric current became available, the motor could not be much more than he characterized it, "a philosophical toy."

Henry also became interested in a determining whether an electromagnet could be operated from a distance so that the doing of some work—for example the ringing of a bell—could be controlled from a distant station. From his investigations directed to this end, Henry was the first to appreciate that the effect of the resistance of long lengths of wire to the passage of electric current could be minimized by properly proportioning the battery and the magnet windings to the length and resistance of the line wires.

Efforts had been made by others prior to Henry's time to devise successful electric telegraphs. They had failed, however, because they did not know how to proportion their magnets and their batteries so as to operate over any substantial length of line. The literature of that time contains a number of demonstrations of the impossibility of operating an electric telegraph, because scientists could arrange instruments which would operate successfully when separated by a few feet, or even one hundred feet, but they would not work at a distance of thousands of feet because of the resistance of the long line wire.

What Henry did was to determine the proportioning of the various parts of the system so as to secure operation. He found, when his magnet was connected by a short wire to the battery, that the greatest magnetizing effect was obtained by joining the cells of the battery in parallel, but that a series arrangement of the battery would give the greatest pull if a long wire (a length of a mile or more was used in some of his experiments) carried the current. He also obtained the best operation over a short line when the magnet winding consisted of several distinct coils, all connected in multiple; and for operation over a long line he found it best either to connect these coils in series or to apply to the magnet a single long winding. Henry was therefore the first to produce an electric telegraph, and more than that, the transmission of electrical energy to a distance. That first telegraph paved the way for all the telegraph systems, all the ocean cable systems, and contained the principle of all telephone call bells.

One of Henry's greatest discoveries from the standpoint of electrical science, but a discovery in which he must yield the first place to Faraday, is that of mutual induction—the fact that a wire when moving with respect to a magnetic field has an electromotive force generated in it. Although Henry made his discovery independently of Faraday, the latter was the first to make known his observations to the world, and it is no trifling index of Henry's character that he never in any way intimated that he was entitled to share with Faraday credit for the discovery.

Because Henry was anticipated in the publication of his observation of mutual induction, he does not appear to have left a verbal record of the steps of reasoning by which he was led to the discovery. However, he does tell us what the arrangement of apparatus was and if we bear in mind that he was seeking a method of generating an electric current from a magnet—this magnet, in turn, being itself the product

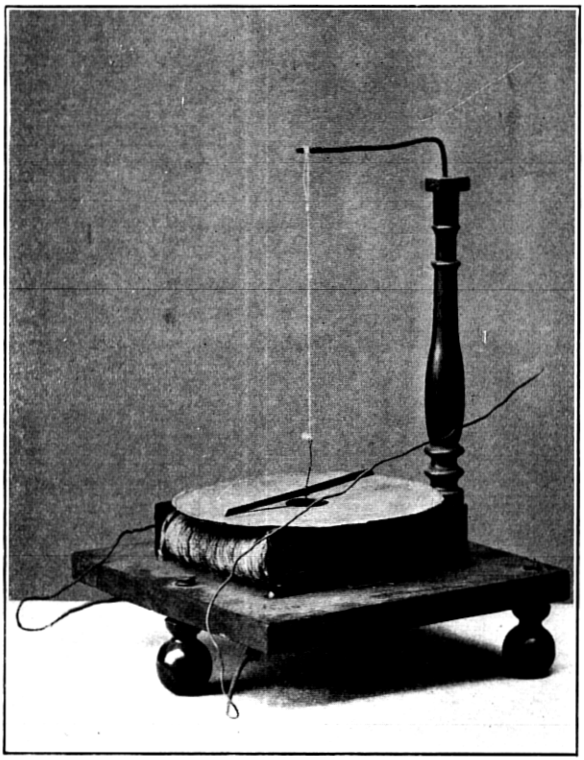

Fig. 2

of a current—we cannot but be impressed by the directness of his method.

Writing of his original observations, Henry says he "succeeded in producing electrical effects in the following manner, which differs from that employed by Mr. Faraday and which appears to me to develop some new and interesting facts. A piece of copper wire, about thirty feet long and covered with elastic varnish, was closely coiled around the middle of the soft iron armature of a galvanic magnet . . . which, when excited will readily sustain between six and seven hundred pounds. The armature thus furnished with wire was placed in its proper position across the ends of the magnet and fastened so that no motion could take place. The two projecting ends of the helix were connected with a distant galvanometer by means of two copper wires each about forty feet long. This arrangement being completed, I stationed myself near the galvanometer and directed an assistant at a given word to suddenly immerse the galvanic battery attached to the magnet. At the instant of immersion the north end of the needle was deflected 30° to the west, indicating a current of electricity from the helix surrounding the armature. The effect, however, appeared only as a single impulse, for the needle after a few oscillations, resumed its former undisturbed position, although the action of the battery was still continued. I was, however, much surprised to see the needle suddenly deflected from a state of rest to about 20° to the east, when the battery was suddenly withdrawn from the acid, and again deflected to the west when it was re-immersed. This operation was repeated many times in succession, and uniformly with the same result."

It was in this same paper that Henry announced his observation of the phenomenon of self-induction, a most important discovery and one for which he holds full credit for having first made it known to the world. He writes, "I may, however, mention one fact which I have not seen noticed in any work, and which appears to me to belong to the same class of phenomena as those before described; it is this: when a small battery is moderately excited by diluted acid, and its poles, which should be terminated by cups of mercury, are connected by a copper wire not more than a foot in length, no spark is perceived when the connection is either formed or broken; but if a wire of thirty or forty feet long be used instead of the short wire, though no spark will be perceptible when the connection is made, yet when it is broken by drawing one end of the wire from its cup of mercury, a vivid spark is produced . . . . . . The effect appears somewhat increased by coiling the wire into a helix." In a somewhat later paper we find the following statement. "A ribbon of sheet copper nearly an inch wide, and twenty-eight and a half feet long, was covered with silk, and rolled into a flat spiral similar to the form in which woolen binding is found in commerce. With this a vivid spark was produced, accompanied by a loud snap. The same ribbon uncoiled gave a feeble spark."

Henry tried many modifications of this experiment and in the end drew the conclusion that the after-current he was observing was due to the inductive effect of the current in the wire upon itself, and that this became particularly apparent when the wire was so coiled that its various turns lay close together. The discovery of mutual induction by Faraday and the discovery of self-induction by Henry constitute two halves of a whole, and it is appropriate that to these men should go equal recognition in the matter of having electrical units names after them. Of the three units by which the properties of every electric circuit are measured, the unit of capacity was named after Faraday, and unit of inductance after Henry; the third unit, that of resistance, recognizes the fundamental researches of Ohm.

A few years later, after having accepted the chair of physics at Princeton University, Henry returned to the subject of induced currents. In his earlier work he, like Faraday, had used the continuous currents which a voltaic battery generates. He now chose the currents which flow when a Leyden jar is discharged. To register the inductive effects of the fleeting currents of discharge Henry adopted a device consisting of an unmagnetized needle placed in a small coil of wire. Through this coil the induced current had to flow. The use of the needle as an indicator led Henry to an important observation. He noticed that following a discharge, the direction of magnetization of the needle depended upon the distance across which the inductive effect had occurred. To account for this curious result, he advanced the hypothesis—later shown to be correct—that the discharge is oscillatory.

Here was the germ of a great discovery. The oscillatory character of the discharge is one of the fundamental and important properties of certain types of electric circuit. Henry did not have the facilities, however, for carrying his investigations in this field far enough to attract the attention of the scientific world. It was not until 1855, some thirteen years later, when Lord Kelvin was led independently by mathematical considerations to believe that the discharge is oscillatory, that the significance of the phenomenon began to be understood.

Henry's work contained the germ of yet another important discovery. Some of his experiments on induction by Leyden jar discharges involved the transmission of electric force without wires through distances as great as two hundred feet, and through the floors and walls of buildings. And in similar experiments in which he observed the effects of lightning flashes in place of sparks from a Leyden jar, he found that he could get the lightning to magnetize needles up to a distance as great as eight miles. This was about 1842. Here we have the earliest evidence of ether waves of the type that the radio engineer employs. But again the significance of Henry's work was not recognized. This could only have come after much fuller investigation. However, it is instructive to reflect for a moment on what might have been had Henry possessed the time and facilities for carrying his work further. Needless to say, there is a wide gulf between the wireless telegraph of today and its earliest precursor with which Henry received an electromagnetic signal from a lightning flash eight miles away, but it is wholly possible that, had Henry not been called to other work, the world might have possessed a wireless telegraph capable of sending messages over substantial distances many years before it did.

Writing of Henry, Simon Newcomb, the celebrated astronomer said,[2] "His scientific work is marked by acuteness in cross-examining nature, a clear appreciation of the logic of science, and an enthusiasm for truth without respect to its utilitarian results." A man of the highest scientific ability, Henry spent the better part of his life as the head of an institution dedicated to "the increase and diffusion of knowledge among men."

"The mantle of Franklin has fallen upon the shoulders of Henry," wrote Sir David Brewster,[3] the eminent English scientist, and it is reported that Abraham Lincoln declared, when he became acquainted with Henry after assuming the Presidency, "The Smithsonian Institution must be a grand school if it produces such thinkers as Henry." He was, in every way and in the best that the word implies, a scientist, and the interest in scientific questions which dominated his life, remained with him to the very end,—almost the last words to pass his lips were whether the transit of the planet mercury had been successfully observed. If we use the word "Dean"—so rich in academic association—to stand at once for the greatest usefulness to one's fellowmen as well as for the highest achievements in the field of scholarship and research, for lifelong devotion to public service, for breadth of view and tolerance regarding all questions, whether arising in science or directly out of human relations, and as epitomizing all that is best and highest in man's intellectual life, we may well call Joseph Henry the Dean of American scientists.

[2] Biographical Memoir; National Academy of Sciences, Apr. 21, 1880.
[3] Biographical Memoir; prepared by Prof. Asa Gray in behalf of the Board of Regents of the Smithsonian Institution.