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Henry as an Electrical Pioneer

By BANCROFT GHERARDI

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The author expresses his appreciation of the researches of Dr. Harold S. Osborne and Mr. A. M. Dowling in establishing many of the facts upon which this address is based, and of other assistance in its preparation. This research developed many facts of interest and its results are separately published as a supplement to this issue of the *Bell System Technical Journal*.

THIS evening we are gathered together to celebrate the hundredth anniversary of the electrical discoveries of Joseph Henry. I have been assigned the honorable and pleasant duty of speaking of Henry's work as an electrical pioneer. According to the Century Dictionary, a pioneer is one who goes before and leads or prepares the way for others coming after, specifically, the first or early explorer or experimenter in any department of human enterprise. Surely no one is better entitled to the honorable title of pioneer than is Joseph Henry.

Let us look a bit at what this country was about 100 years ago. The population of the United States in 1830 was 12,900,000. The largest city in the country, New York, had a population of 203,000. Philadelphia was the next largest city with 80,000. Washington, the capital of the nation, had a population of 18,800, which included 2,330 slaves. There were twenty-four states in the Union and of these the most westerly was Missouri. Chicago, now the second city of the country, was just being laid out near Fort Dearborn and was not organized as a village until 1833. Detroit, now the fourth city, had a population of 2,222 and Cleveland had 1,076.

Highways were largely trails or unpaved roads. Canals played an important part in the transportation system of the country. The first railroad in the United States began operation by steam in 1830. In 1836 trains between Albany and Schenectady were still pulled by horses. The first steamship, equipped with both sails and steam, had crossed the ocean in 1819, but it was not until 1838 that a ship depending primarily upon steam for its propelling power made the transatlantic trip. Communications were solely dependent upon transportation and subject to all of its uncertainties and lack of speed.

Mills and factories were just beginning to be operated by steam power, having previously been dependent upon water power or man power with occasional use of horses or windmills. Lighting was done principally by sperm oil lamps or by candles. Baltimore was the first American city to adopt gas lighting on a large scale in 1817. Gas was introduced in New York City in 1823, but even after 1830 many large cities went for years without a gas system. In 1833 a petition was addressed to the Common Council of Philadelphia protesting against the use of gas "as ignitible as gunpowder and as nearly fatal in its effects as regards the immense destruction of property."[1] There was no commercial application of electricity. At that time electricity was a matter of Leyden jars and of pith balls, of galvanic batteries and of twitching frogs' legs, of crude galvanometers, and of feeble magnets.

Such was the condition of this country when Joseph Henry was Professor of Mathematics and Natural Philosophy at the Albany Academy about 1830.

But "The old order changeth, yielding place to the new," and Joseph Henry was one of those who made major contributions to this change. Just what did Henry do that contributed to the development of the electric art of today? As you have heard from Professor Magie, we may properly claim priority for Henry for the following among his many electrical contributions:

Henry constructed powerful electromagnets by the use of insulated wire on the magnet core and by using more than one layer of winding. (1829 and 1830)

Henry indicated the proper proportioning of magnet windings, external circuit resistance and electrical battery arrangement for effective operation. (1830)

Henry constructed the first motor embodying an electromagnet and a commutator. (1831)

Henry constructed the first telegraph using an electromagnet as the receiving element and demonstrated its operation with a line wire over one mile long. (1831 and 1832)

Henry discovered the property of self-induction of electrical circuits. (1832)

Henry constructed and operated the first electromagnetic relay. (1835)

Henry determined that by the proportioning of the windings of two coils in inductive relationship the voltage in the secondary circuit could be stepped up or stepped down. (1838)

[1] "A Popular History of American Invention," W. Kaempffert, 1924, Vol. 1, p. 554.

Henry produced currents in distant circuits by oscillatory discharges and detected them when the two circuits were separated by several hundred feet. (1842)

These contributions by Henry to our electrical knowledge have been essential to the development of practically every commercial application of electricity. Let us now consider some of these.

The idea of the electric telegraph was not new when Henry did his work. It had been considered by others and in January, 1825, Barlow, an English scientist, wrote as follows: "In a very early stage of electro-magnetic experiments, it had been suggested, that an instantaneous telegraph might be established by means of conducting wires and compasses. The details of this contrivance are so obvious, and the principles on which it is founded so well understood, that there was only one question which could render the result doubtful, and this was, Is there any diminution of effect by lengthening the conducting wire? . . . I was, therefore, induced to make the trial, but I found such a sensible diminution with only 200 feet of wire, as at once to convince me of the impracticability of the scheme." [2] Even as late as 1837 Wheatstone, another distinguished British scientist, satisfied himself by experiment and convinced others that the development of electro-magnetism in soft iron at a distance was impracticable. This was six years after Henry's work on the proportioning of magnet windings and battery arrangement for maximum effect with line wires of substantial resistance had shown him the solution of the telegraph problem, and five years after he himself had constructed and demonstrated his electromagnetic telegraph over a line wire more than a mile long.

Henry's contributions to the telegraph were three in number. He demonstrated that magnetic action and magnetic control could be exercised at considerable distances if the battery and the magnet windings were suitably proportioned and this is the basis of all electric telegraphs of today. He abandoned the galvanometer or compass needle as a receiving device for the electrical impulses and substituted therefor a magnet operating a movable armature, this making possible rapid signaling and audible receiving. This has continued as the basic form of the telegraph circuit, even with the modern printing telegraph systems, in which electric typewriters are controlled by magnets of Henry's type. He constructed and operated the first electromagnetic relay, a device by which the current in the line circuit controls an armature which carries the contact of a local circuit so that the feeble line current, instead of directly controlling the receiving

[2] "On the laws of electro-magnetic action," *Edinburgh Philosophical Journal*, Jan., 1825, Vol. XII, p. 105.

mechanism, merely opens and closes a local circuit and a strong local current performs whatever functions may be necessary in the receiving mechanism.

These constitute the fundamentals of a complete magnetic telegraph system and left only its perfection in detail, the development of an alphabetical code in dots and dashes, and its commercial exploitation. In 1844 Morse opened his first telegraph line between Baltimore and Washington and in this line utilized the features referred to above, contributed by Henry. From this start the telegraph rapidly grew to a nation-wide and world-wide communication system.

The next important commercial application of electricity came about 30 years later when Bell invented the telephone. As in the case of the telegraph, important use was made of Henry's contributions to the art.

Bell's telephone makes use of Henry's work on magnets, as does every telephone receiver today. The telephone bell, with which each telephone is equipped to give an audible signal so as to attract the attention of the called party, consists essentially of a polarized ringer directly suggested by the receiving device employed by Henry in his first telegraph demonstration. But a telephone by itself, even equipped with a call bell, is merely an interesting scientific toy. The telephone is useful only as there are a number of them at the ends of telephone lines, these lines centering on telephone switchboards for the purposes of interconnection. In all telephone switchboards, whether of the manual or of the automatic type, there are multitudes of relays for the purpose of controlling circuits and signaling apparatus. There are perhaps seventy million telephone relays in the United States today and the prototype of all of these is Henry's electromagnetic relay, dating back to 1835.

Telephony owes still another debt to Henry and to his work. He discovered the characteristic of electrical circuits known as self-induction. This is a property of all electrical circuits unless especially designed to avoid it and self-induction must be taken into account in many phases of electrical design. In long telephone lines it was found to exercise a favorable effect upon telephonic transmission and about 1900 Dr. Michael I. Pupin, a distinguished member of the National Academy of Sciences, showed how self-induction could be added to long telephone lines so as to improve their talking efficiency. Today his invention is very generally used, not only in the lines of this country but throughout the world, and has been an important factor in the extension of long distance telephony and in making possible long telephone cables.

The start of commercial electric light and power systems and of electric traction came shortly after the beginnings of the telephone about 1880. These, likewise, built upon Henry's work. Powerful electromagnets are the basis of every generator and of every electric motor and it would be difficult for any one today to construct either a generator or a motor and avoid the ideas which were contributed by Henry. Commutators which appear first in Henry's motor are essential parts of every direct current generator or motor.

Henry's electric motor was not the first one to be built. Faraday built the first electric motor and it was interesting because it was a continuously rotating device. However, it had no commutator and did not employ electromagnets. Henry's motor was interesting because, while it was a reciprocating device, it was the first to employ a commutator and an electromagnet. A combination of these principles, that is, a rotating motor, electromagnets and commutation gives the basis of the modern electric motor of today.

Henry's comments in 1831 on his electric motor are interesting. "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 same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose." [3] Much later, in 1876, he writes: "I soon saw, however, that the application of this power was but an indirect method of employing the energy derived from the combustion of coal, and, therefore, could never compete, on the score of expense, with that agent as a means of propelling machinery, but that it might be used in some cases in which expense of power was not a consideration to be weighed against the value of certain objects to be attained." [4] Certainly a prophecy, when we consider today the extent to which this "indirect method of employing the energy derived from the combustion of coal" is utilized because of its convenience for lighting and because of its flexibility for the operation of power units through electric motors.

Modern electrical systems for power and light would be inoperative without the use of auxiliary circuits and equipment for their proper control. In these, extensive use is made of relays and also of other electromagnetic devices using Henry's magnet principle.

While every branch of the electric power art is indebted to Henry, the alternating current system now in such general use and universal for long distance power distribution owes him a peculiar obligation.

[3] "Scientific Writings of Joseph Henry," 1886, Vol. I, p. 54.
[4] "A Memorial of Joseph Henry," 1880, p. 149.

In his work in 1838 he demonstrated that through the proportioning of the windings of two coils in inductive relationship, the voltage in the secondary circuit could be stepped up or stepped down and here we find the genesis of the modern transformer. The transformer, a device without moving parts, is fundamental to every alternating current system, and it is the principal reason why alternating currents are so generally employed today. Through its use, it is possible to design dynamos for operation at the most effective generator voltage and then step up the voltage by means of a transformer to the most efficient level for use on the transmission lines and then at the distant end of these lines by means of other transformers step down the potential to the most efficient and convenient voltage for use on distributing systems.

So fundamental was Henry's work that in it we find contributions even to the youngest child of the electrical family, the radio communication art. Not only does it use his general contributions to the art because of the fact that radio communication is simply a specialized form of telephony or telegraphy employing a particular method of transmission, but Henry's work in detecting the discharges of Leyden jars at a distance of 30 feet and later at distances of several hundred feet certainly foreshadows radio transmission. In 1842 Henry wrote as follows in regard to his experiment in which he observed the inductive effects of a discharge of Leyden jars at a distance of 30 feet: ". . . when it is considered that the magnetism of the needle [his receiving device] is the result of the difference of two actions, it may be further inferred that the diffusion of motion in this case is almost comparable with that of a spark from a flint and steel in the case of light." [5] In the notes made early in 1844 by a student recording Henry's lectures on natural philosophy the following occurs: "Hence the conclusion that every spark of electricity in motion exerts these inductive effects at distances indefinitely great (effects *apparent* at distances of one-half a mile or more); and another ground for the supposition that electricity pervades all space. Each spark sent off from the Electrical Machine in the College Hall sensibly affects the surrounding electricity through the whole village. A fact no more improbable than that light from a candle (probably merely another kind of wave or vibration of the same medium), should produce a sensible effect on the eye at the same distance." [6]

It is certainly a far cry from Henry's observations of inductive effects at distances of a few hundred feet to the present use of radio for broad-

[5] "Scientific Writings of Joseph Henry," 1886, Vol. 1, p. 203.
[6] Notes of Wm. J. Gibson, entitled "Lectures on Natural Philosophy by Professor Henry," Feb. 28, 1844, p. 135.

casting and for transoceanic telegraph and telephone service, but a consideration of what he himself says about this and of the notes of his student, quoted above, indicates clearly that in his work is the germ of radio transmission.

Had not a fire in the Smithsonian Institution in 1865 destroyed so many of Henry's original records, there is but little doubt that in these records there would have been preserved many other interesting and suggestive things which he did and many significant comments on them. But the record as it is now known to us is sufficient to establish Henry's contributions as outstanding, and to more than justify this distinguished gathering tonight for the purpose of reminding us of our obligation to him.

Before Joseph Henry died in May, 1878, he had seen an extensive commercial application of telegraphy. He had seen the invention of the telephone but not its commercial application. As years have gone by since that date, a greater and greater superstructure of commercial application has been reared upon the foundations laid by Joseph Henry and the other distinguished scientific workers of his time. When writing as early as 1849, he said: "The only reward I ever expected was the consciousness of advancing science, the pleasure of discovering new truths, and the scientific reputation to which these labors would entitle me." [7] This he surely attained. Joseph Henry died with a national and international scientific reputation, Secretary of the Smithsonian Institution, President of the National Academy of Sciences, a friend of Abraham Lincoln and loaded with honors, both at home and abroad. Since then, as time has gone by, it has but added to his greatness, to the esteem in which he is held and to the value of the services which he has rendered to mankind through his work as an electrical pioneer.

[7] *Annual Report* of the Smithsonian Institution for 1857, p. 117.