STATEMENT IN RELATION TO THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.*

(From the Smithsonian Annual Report for 1857, pp. 99–106.)

A series of controversies and law suits having arisen between rival claimants for telegraphic patents, I was repeatedly appealed to to act as *expert* and witness in such cases. This I uniformly declined to do, not wishing to be in any manner involved in these litigations; but I was finally compelled under legal process to return to Boston from Maine—whither I had gone on a visit, and to give evidence on the subject. My testimony was given with the statement that I was not a willing witness, and that I labored under the disadvantage of not having access to my notes and papers, which were in Washington.

In the beginning of my deposition I was requested to give a sketch of the history of electro-magnetism having a bearing on the telegraph, and the account I then gave from memory I have since critically examined, and find it fully corroborated by reference to the original authorities. My sketch, which was the substance of what I had been in the habit of giving in my lectures, was necessarily very concise, and almost exclusively confined to one class of facts, namely, those having a direct bearing on Mr. Morse's invention. In order therefore to set forth more clearly in what my own improvements consisted, it may be proper to give a few additional particulars respecting some points in the progress of discovery, illustrated by wood cuts.

There are several forms of the electrical telegraph; first, that in which frictional electricity has been proposed to produce sparks, and motion of pith balls at a distance.

Second, that in which galvanism has been employed to produce signals by means of bubbles of gas from the decomposition of water; or by other chemical re-action.

*[Presented to the Board of Regents of the Smithsonian Institution, on their investigation (by a special committee) of certain publications touching the origin of the electro-magnetic telegraph.]

Third, that in which electro-magnetism is the motive power to produce motion at a distance: and again, of the latter there are two kinds of telegraphs, those in which the intelligence is indicated by the motion of a magnetic needle and those in which sounds and permanent signs are made by the attraction of an electro-magnet. The latter is the class to which Mr. Morse's invention belongs. The following is a brief exposition of the several steps which led to this form of the telegraph:

The first essential fact (as I stated in my testimony) that rendered the electro-magnetic telegraph possible was discovered by Oersted, in the winter of 1819–20. It is illustrated by figure 1, in which the magnetic needle is deflected by the

FIG. 1.

action of a current of galvanism transmitted through the wire *A B*. (See *Annals of Philosophy*, Oct., 1820, vol. XVI, page 274.)

The second fact of importance, discovered in 1820 by Arago and Davy, is illustrated in figure 2. It consists in

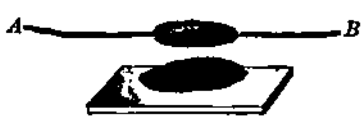

FIG. 2.

this, that while a current of galvanism is passing through a copper wire *A B*, it is *quasi* magnetic, that is, it attracts iron filings in a cylindrical sheath around it, and not those of copper or brass, developing magnetism in soft iron. (See *Annales de Chimie et de Physique*, 1820, vol. XV, page 94.)

The next important discovery, also made in 1820, by Ampère, was that two wires through which galvanic currents are passing in the same direction attract—and in the opposite direction repel each other. On this fact Ampère founded his celebrated theory that magnetism consists merely in the attraction of electrical currents revolving at right angles to the line joining the two poles of the magnet. The magnetization of a bar of steel or iron, according to this theory, consists in establishing within the metal by induction—a series of electrical currents, all revolving in the same direction at right angles to the axis or length of the bar.

It was this theory which led Arago, as he states, to adopt the method of magnetizing sewing needles and pieces of steel wire shown in figure 3. This method consists in trans-

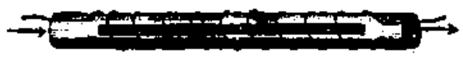

Fig. 3.

mitting a current of electricity through a helix surrounding the needle or wire to be magnetized. For the purpose of insulation the needle was inclosed in a glass tube, and the several turns of the helix were at a distance from each other to insure the passage of electricity through the whole length of the wire, or in other words, to prevent it from seeking a shorter passage by cutting across from one spire to another. The helix employed by Arago obviously approximates the arrangement required by the theory of Ampère in order to develop by induction the magnetism of the iron. By an attentive perusal of the original account of the experiments of Arago (given in the *Annales de Chimie et Physique*, 1820, vol. xv, pages 93–95) it will be seen that properly speaking he made no electro-magnet, as has been often stated. His experiments were confined to the magnetizing of iron filings, sewing needles, and pieces of steel wire of the diameter of a millimetre, or of about the thickness of a small knitting needle.

Mr. Sturgeon, in 1825, made an important step in advance of the experiments of Arago, and produced what is properly known as the electro-magnet. He bent a piece of iron wire into the form of a horseshoe, covered it with varnish to insulate it, and surrounded it with a helix, of which the spires were at a distance. When a current of galvanism was passed through the helix from a small battery of a single cup the iron wire became magnetic, and continued so during the passage of the current. When the current was interrupted the magnetism disappeared, and thus was produced the first temporary soft iron magnet.

The electro-magnet of Sturgeon is shown in figure 4, which is a copy from the drawing in the *Transactions of the Society for the Encouragement of Arts*, &c., 1825, vol. XLIII, pp. 38–52. By comparing figures 3 and 4, it will be seen that the helix employed by Sturgeon was of the same kind as that used by Arago; instead of a straight steel wire inclosed in a tube of glass however, Sturgeon employed a bent wire of soft iron. The difference in the arrangement at first sight might appear to be small, but the difference in the results produced was important, since the temporary magnetism developed in the arrangement of Sturgeon was sufficient to support a weight of several pounds; and an instrument was thus produced of value in future research.

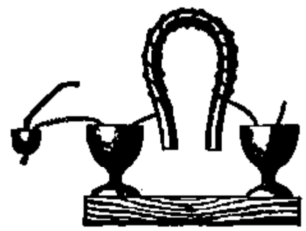

FIG. 4.

The next improvement was made by myself. After reading an account of the galvanometer of Schweigger, the idea occurred to me that a much nearer approximation to the requirements of the theory of Ampère could be attained by 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 coils, instead of a single helix of a few coils. (Fig. 5.)

FIG. 5.

In the arrangement of Arago and Sturgeon the several turns of wire were not precisely at right angles to the axis of the rod, as they should be—to produce the effect required by the theory, but slightly oblique, and therefore each tended to develop a separate magnetism not coincident with the axis of the bar. But in winding the wire over itself, the obliquity of the several turns compensated each other, and the resultant action was at right angles to the bar. The arrangement then introduced by myself was superior to those of Arago and Sturgeon, first in the greater multiplicity of turns of wire, and second in the better application of these turns to the development of magnetism. The power of the instrument, with the same amount of galvanic force, was by this arrangement several times increased.

The maximum effect however with this arrangement and a single battery was not yet obtained. After a certain length of wire had been coiled upon the iron, the power diminished with a further increase of the number of turns. This was due to the increased resistance which the longer wire offered to the conduction of electricity. Two methods of improvement therefore suggested themselves. The first consisted—not in increasing the length of the coil, but in using a number of separate coils on the same piece of iron. By this arrangement the resistance to the conduction of the electricity was diminished, and a greater quantity made to circulate around the iron from the same battery. The second method of producing a similar result consisted in increasing the number of elements of the battery, or in other words the projectile force of the electricity, which enabled it to pass through an increased number of turns of wire, and thus by increasing the length of the wire, to develop the maximum power of the iron.

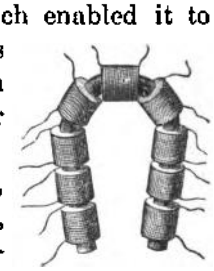

Fig. 6.

To test these principles on a larger scale, the experimental magnet was constructed, which is shown in figure 6. In this a number of compound helices was placed on the same bar, their ends left projecting, and so numbered that they could be all united into one long helix, or variously combined in sets of lesser length.

From a series of experiments with this and other magnets it was proved that in order to produce the greatest amount of magnetism from a battery of a single cup, a number of helices is required; but when a compound battery is used, then one long wire must be employed, making many turns around the iron, the length of wire and consequently the number of turns being commensurate with the projectile power of the battery.

In describing the results of my experiments, the terms "intensity" and "quantity" magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the *intensity* magnet I designated a piece of soft iron, so surrounded with wire that its magnetic power could be called into operation by an *intensity* battery, and by a *quantity* magnet, a piece of iron so surrounded by a number of separate coils, that its magnetism could be fully developed by a *quantity* battery.

I was the first to point out this connection of the two kinds of the battery with the two forms of the magnet, in my paper in Silliman's Journal, January, 1831, and clearly to state that when magnetism was to be developed by means of a compound battery, one long coil must be employed, and when the maximum effect was to be produced by a single battery, a number of single strands should be used.*

These steps in the advance of electro-magnetism, though small, were such as to interest and surprise the scientific world. With the same battery used by Mr. Sturgeon, at least a hundred times more magnetism was produced than could have been obtained by his experiment. The developments were considered at the time of much importance in a scientific point of view, and they subsequently furnished the means by which magneto-electricity, the phenomena of diamagnetism, and the magnetic effects on polarized light were discovered. They gave rise to the various forms of electro-

* [Silliman's American Journal of Science, Jan., 1831, vol. XIX, pp. 403, 404. See *ante*, vol. I, p. 42.]

magnetic machines which have since exercised the ingenuity of inventors in every part of the world, and were of immediate applicability in the introduction of the magnet to telegraphic purposes. Neither the electro-magnet of Sturgeon nor any electro-magnet ever made previous to my investigations was applicable to transmitting power to a distance.

The principles I have developed were properly appreciated by the scientific mind of Dr. Gale, and applied by him to operate Mr. Morse's machine at a distance.†

Previous to my investigations the means of developing magnetism in soft iron were imperfectly understood. The electro-magnet made by Sturgeon, and copied by Dana, of New York, was an imperfect quantity magnet, the feeble power of which was developed by a single battery. It was entirely inapplicable to a long circuit with an intensity battery, and no person possessing the requisite scientific knowledge, would have attempted to use it in that connection after reading my paper.

In sending a message to a distance, two circuits are employed, the first a long circuit through which the electricity is sent to the distant station to bring into action the second—a short one, in which is the local battery and magnet for working the machine. In order to give projectile force sufficient to send the power to a distance, it is necessary to use an intensity battery in the long circuit; and in connection with this at the distant station a magnet surrounded with many turns of one long wire must be employed to receive and multiply the effect of the current enfeebled by its transmission through the long conductor. In the local or short circuit either an intensity or quantity magnet may be employed. If the first be used, then with it a compound battery will be required; and therefore on account of the increased resistance due to the greater quantity of acid, a less amount of work will be performed by a given amount of material; and consequently though this arrangement is practicable it is by no means economical. In my original paper I state that the advantages of a greater conducting power, from using sev-

† [See Appendix A, at the end of this paper.]

eral wires in the quantity magnet may in a less degree be obtained by substituting for them one large wire; but in this case, on account of the greater obliquity of the spires and other causes, the magnetic effect would be less. In accordance with these principles, the receiving magnet, or that which is introduced into the long circuit, consists of a horseshoe magnet surrounded with many hundred turns of a single long wire, and is operated with a battery of from 12 to 24 elements or more, while in the local circuit it is customary to employ a battery of one or two elements with a much thicker wire and fewer turns.

It will I think be evident to the impartial reader that these were improvements in the electro-magnet which first rendered it adequate to the transmission of mechanical power to a distance; and had I omitted all allusion to the telegraph in my paper, the conscientious historian of science would have awarded me some credit, however small might have been the advance that I had made. Arago, and Sturgeon, in the accounts of their experiments, make no mention of the telegraph, and yet their names always have been and will be associated with the invention. I briefly called attention however to the fact of the applicability of my experiments to the construction of the telegraph; but not being familiar with the history of the attempts made in regard to this invention, I called it "Barlow's project," while I ought to have stated that Mr. Barlow's investigation merely tended to disprove the possibility of a telegraph.

I did not refer exclusively to the needle telegraph when I stated in my paper that "the *magnetic* action of a current from a trough is at least not sensibly diminished by passing through a long wire." This is evident from the fact that the immediate experiment from which this deduction was made, was by means of an electro-magnet and not by means of a needle galvanometer.

At the conclusion of the series of experiments which I described in Silliman's Journal, there were two applications of the electro-magnet in my mind: one, the production of a machine to be moved by electro-magnetism, and the other, the transmission of or calling into action power at a distance. The first was carried into execution in the construction of the machine described in Silliman's Journal in 1831;* and for the purpose of experimenting in regard to the second, I arranged around one of the upper rooms in the Albany Academy a wire of more than a mile in length, through which I was enabled to make signals by sounding a bell. (Fig. 7.) The mechanical arrangement for effecting this object was simply a steel bar, permanently magnetized, of about ten inches in length, supported on a pivot, and placed with its north end between the two arms of a horse-shoe magnet. When the latter was excited by the current, the end of the bar thus placed was attracted by one arm of the horse-shoe, and repelled by the other, and was thus caused to move in a horizontal plane and its further extremity to strike a bell suitably adjusted.

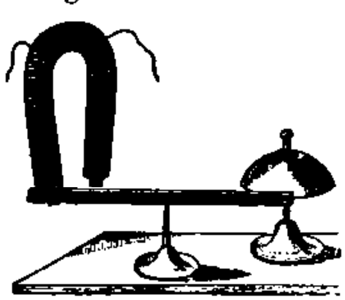

Fig. 7.

This arrangement is that which is alluded to in Professor Hall's letter† as having been exhibited to him in 1832. It was not however at that time connected with the long wire above-mentioned, but with a shorter one put up around the room for exhibition.

At the time of giving my testimony I was uncertain as to when I had first exhibited this contrivance, but have since definitely settled the fact by the testimony of Hall and others that it was before I left Albany, and abundant evidence can be brought to show that previous to my going to Princeton in November, 1832, my mind was much occupied with the subject of the telegraph, and that I introduced it in my course of instruction to the senior class in the Academy. I

* [Silliman's American Journal of Science, July, 1831, vol. xx, pp. 340–343. See *ante*, vol. I, p. 54.]

† [See Appendix B, at the end of this paper; and also Proceedings of the Albany Institute, January 13, 1858; vol. IV, pp. 244, 245.]

should state however that the arrangement I have described was merely a temporary one, and that I had no idea at the time of abandoning my researches for the practical application of the telegraph. Indeed, my experiments on the transmission of power to a distance were suspended by the investigation of the remarkable phenomena (which I had discovered in the course of these experiments) of the induction of a current in a long wire on itself, and of which I made the first mention in a paper in Silliman's Journal in 1832.*

I also devised a method of breaking a circuit and thereby causing a large weight to fall. It was intended to illustrate the practicability of calling into action at a distance a great power capable of producing mechanical effects; but as a description of this was not printed, I do not place it in the same category with the experiments of which I published an account, or the facts which could be immediately deduced from my papers in Silliman's Journal.

From a careful investigation of the history of electro-magnetism in its connection with the telegraph, the following facts may be established:

1. Previous to my investigations the means of developing magnetism in soft iron were imperfectly understood, and the electro-magnet which then existed was inapplicable to the transmission of power to a distance.

2. I was the first to prove by actual experiment that in order to develop magnetic power at a distance a galvanic battery of "intensity" must be employed to project the current through the long conductor, and that a magnet surrounded by many turns of one long wire must be used to receive this current.

3. I was the first to actually magnetize a piece of iron at a distance, and to call attention to the fact of the applicability of my experiments to the telegraph.

4. I was the first to actually sound a bell at a distance by means of the electro-magnet.

* [Silliman's American Journal of Science, July, 1832, vol. XXII, p. 408. See *ante*, vol. I, p. 79.]

5. The principles I had developed were applied by Dr. Gale to render Morse's machine effective at a distance.

The results here given were among my earliest experiments: in a scientific point of view I considered them of much less importance than what I subsequently accomplished; and had I not been called upon to give my testimony in regard to them, I would have suffered them to remain (without calling public attention to them) a part of the history of science to be judged of by scientific men who are the best qualified to pronounce upon their merits.

APPENDIX A.—*Letter from Dr. Gale.*

WASHINGTON, D. C., *April* 7, 1856.

SIR: In reply to your note of the 3d instant, respecting the Morse telegraph, asking me to state definitely the condition of the invention when I first saw the apparatus in the winter of 1836, I answer: This apparatus was Morse's original instrument, usually known as the type apparatus, in which the types, set up in a composing stick, were run through a circuit breaker, and in which the battery was the cylinder battery, with a single pair of plates. This arrangement also had another peculiarity, namely, it was the electro-magnet used by Sturgeon, and shown in drawings of the older works on that subject, having only a few turns of wire in the coil which surrounded the poles or arms of the magnet. The sparseness of the wires in the magnet coils and the use of the single cup battery were to me, on the first look at the instrument, obvious marks of defect, and I accordingly suggested to the professor, without giving my reasons for so doing, that a battery of many pairs should be substituted for that of a single pair, and that the coil on each arm of the magnet should be increased to many hundred turns each; which experiment, if I remember aright, was made on the same day with a battery and wire on hand, (furnished I believe by myself,) and it was found that while the original arrangement would only send the electric current through a few feet of wire, say 15 to 40, the modified arrangement would send it through as many hundred. Although I gave no reason at the time to Professor Morse for the suggestions I had proposed in modifying the arrangement of the machine, I did so afterwards, and referred in my explanations to the paper of Professor Henry, in the 19th volume of the American Journal of Science, page 400 and onward. It was to these suggestions of mine that Professor Morse alludes in his testimony before the Circuit Court for the eastern district of Pennsylvania, in the trial of B. B. French and others *vs.* Rogers and others. See printed copy of complainant's evidence, page 168, beginning with the words, "Early in 1836 I procured 40 feet of wire," &c., and page 169, where Professor Morse alludes to myself and compensation for services rendered to him, &c.

At the time I gave the suggestions above named, Professor Morse was not familiar with the then existing state of the science of electro-magnetism. Had he been so, or had he read and appreciated the paper of Henry, the suggestions made by me would naturally have occurred to his mind as they did to my own. But the principal part of Morse's great invention lay in the mechanical adaptation of a power to produce motion, and to increase or relax at will. It was only necessary for him to know that such a power existed for him to adapt mechanism to direct and control it.

My suggestions were made to Professor Morse from inferences drawn by reading Professor Henry's paper above alluded to. Professor Morse professed great surprise at the contents of the paper when I showed it to him, but especially at the remarks on Dr. Barlow's results respecting telegraphing, which were new to him; and he stated at the time that he was not aware that any one had even conceived the idea of using the magnet for such purposes.

With sentiments of esteem, I remain, yours truly,

L. D. GALE.

Prof. JOSEPH HENRY.

APPENDIX B.—*Letter from Prof. Hall.*

ALBANY, N. Y., *January* 19, 1856.

DEAR SIR: While a student of the Rensselaer School, in Troy, New York, in August, 1832, I visited Albany with a friend, having a letter of introduction to you from Professor Eaton. Our principal object was to see your electro-magnetic apparatus, of which we had heard much, and at the same time the library and collections of the Albany Institute.

You showed us your laboratory in a lower story or basement of the building, and in a larger room in an upper story some electric and galvanic apparatus, with various philosophical instruments. In this room, and extending around the same, was a circuit of wire stretched along the wall, and at one termination of this, in the recess of a window, a bell was fixed, while the other extremity was connected with a galvanic apparatus.

You showed us the manner in which the bell could be made to ring by a current of electricity, transmitted through this wire, and you remarked that this method might be adopted for giving signals, by the ringing of a bell at the distance of many miles from the point of its connection with the galvanic apparatus.

All the circumstances attending this visit to Albany are fresh in my recollection, and during the past years, while so much has been said respecting the invention of electric telegraphs, I have often had occasion to mention the exhibition of your electric telegraph in the Albany Academy, in 1832.

If at any time or under any circumstances this statement can be of service to you in substantiating your claim to such a discovery at the period named, you are at liberty to use it in any manner you please, and I shall be ready at all times to repeat and sustain what I have here stated, with many other attendant circumstances, should they prove of any importance.

I remain, very sincerely and respectfully, yours,

JAMES HALL.

Professor JOSEPH HENRY.