DEPOSITION OF JOSEPH HENRY, IN THE CASE OF MORSE *vs.* O'REILLY,

TAKEN AT BOSTON, SEPTEMBER, 1849.

[*From the Record of the Supreme Court of the United States.*]

1. Please state your place of residence and your occupation; also, what attention, if any, you have given to the subjects of electricity, magnetism, and electro-magnetism.

Answer.—I begin this deposition with the express statement that I do not voluntarily give my testimony; but that I appear on legal summons, and in submission to law. I am Secretary to the Smithsonian Institution, established in the city of Washington, where I now reside. The principal direction of the Institution is confided to me. As I do not expect to return to Washington until some time in October, I have been called upon to give my testimony here in Boston; on this account I labor under the disadvantage of being obliged to testify without my notes and papers, which are now in Washington.

I commenced the study of electro-magnetism in 1827; and since then have, at different times, [until] within the last two and a half years, when I became Secretary of the Smithsonian Institution, made original investigations in this and kindred branches of physical science. I know no person in our country who has paid more attention to the study of the principles of electro-magnetism than myself.

2. Please give a general account of the progress of the science of electro magnetism, as connected with telegraphic communication; and of any inventions or discoveries in electro-magnetism applicable to the telegraph, made by yourself.

Answer.—I consider an electro-magnetic telegraph as one which operates by the combined influence of electricity and magnetism. Prior to the winter of 1819–'20, no form of the electro-magnetic telegraph was possible; the scientific principles on which it is founded were then unknown. The first fact of electro-magnetism was discovered by Oersted, of Copenhagen, during that winter. It is this: A wire being placed close above, or below, and parallel to a magnetic needle, and a galvanic current being transmitted through the wire, the needle will tend to place itself at right angles to it. This fact was widely published, and the account was everywhere received with interest.

The second fact of importance was discovered independently, and about the same time, by Arago, at Paris, and Davy, at London. It is this: During the transmission of a galvanic current through a wire of copper, or any other metal, the wire exhibits magnetic properties, attracting iron, but not copper filings, and having the power of inducing permanent magnetism in steel needles. The next important fact was discovered by Ampère, of Paris, one of the most sagacious and successful cultivators of physical science in the present century. It is this: Two parallel wires through which galvanic currents are passing in the same direction, attract each other; but if the currents pass in opposite directions, they repel each other. On this fact Ampère founded his ingenious theory of magnetism and electro-magnetism. According to this theory, all magnetic phenomena result from the attraction or repulsion of electric currents, supposed to exist in the iron at right angles to the length of the bar; and that all the phenomena of magnetism and electro-magnetism are thus referred to one principle, namely, the action of electrical currents on each other.

Ampère deduced from this theory many interesting results, which were afterwards verified by experiment. He also proposed to the French Academy a plan for the application of electro-magnetism to the transmission of intelligence to a distance; this consisted in deflecting a number of needles at the place of receiving intelligence, by galvanic currents transmitted through long wires. This transmission was to be effected by completing a galvanic circuit. When completed, the needle was deflected. When interrupted, it returned to its ordinary position, under the influence of the attraction of the earth. This project of Ampère was never reduced to practice. All these discoveries and results were prior to 1823.

The next investigations relating to the magnetic telegraph were published in 1825; they were by Mr. Barlow, of the Royal Military Academy of Woolwich, England. He found that there was great diminution in the power of the galvanic current to produce effects with an increase of distance; a diminution so great in a distance of two hundred feet was observed, as to convince him of the impracticability of the scheme of the electro-magnetic telegraph. His experiments led him to conclude that the power was inversely as the square root of the length of the wire. The publication of these results put at rest, for a time, all attempts to construct an electro-magnetic telegraph.

The next investigations, in the order of time, bearing on the telegraph, were made by Mr. Sturgeon, of England. He bent a piece of iron wire into the form of a horse-shoe, and put loosely around it a coil of copper wire, with wide intervals between the turns or spires to prevent them touching each other, and through this coil he transmitted a current of galvanism. The iron, under the influence of this current, became magnetic, and thus was produced the first electro-magnetic magnet, sometimes called simply the electro-magnet. An account of this experiment was first published in November, 1825, in the Transactions of the Society for the Encouragement of the Arts in England; and was made known in this country through the Annals of Philosophy for November, 1826.

Nothing further was done pertaining to the telegraph until my own researches in electro-magnetism, which were commenced in 1828, and continued in 1829, 1830, and subsequently; Barlow's results, as I before observed, had prevented all attempts to construct a magnetic telegraph on the plan of Ampère, and our own knowledge of the development of magnetism in soft iron, as left by Sturgeon, was not such as to be applicable to telegraphic purposes. The electro-magnet of Sturgeon could not be made to act by a current through a long wire, as will be apparent hereafter in this deposition.

After repeating the experiments of Oersted, Ampère, and others, and publishing an account in 1828 of various modifications of electro-magnetic apparatus, I commenced in that year the investigation of the laws of the development of magnetism in soft iron, by means of the electrical current. The first idea that occurred to me in accordance with the theory of Ampère, with reference to increasing the power of the electro-magnet, was that of using a longer wire than had before been employed. A wire of sixty feet in length, covered with silk, was wound round a whole length of an iron bar, either straight or in the form of a U, so as to cover its whole length with several thicknesses of the wire.

The results of this arrangement were such as I had anticipated, and electro-magnets of this kind, exhibited to the Albany Institute in March, 1829, possessed magnetic power superior to that of any before known.

The idea afterwards occurred to me that the quantity of galvanism, supplied by a small galvanic battery, might be applied to develop a still greater amount of magnetic power in a large bar of iron. On experiment, I found this idea correct. A battery of two and a half square inches of zinc, developed magnetism in a large bar sufficient to lift fourteen pounds.

The next suggestion which occurred to me was that of using a number of wires of the same length around the same bar, so as to lessen the resistance which the galvanic current experienced in passing from the zinc to the copper through the coil. To bring this to the test of experiment, a second wire, equal in length to the first, was wound around the last mentioned magnet, and its ends soldered to the plates of the same battery.

The magnet with this additional wire lifted twenty-eight pounds, or, in other words, its power was doubled.

A series of experiments was afterwards made, to determine the resistance to conduction of wires of different lengths and diameters, and the proper lengths and number of wires for producing, with different kinds of galvanic batteries, the maximum of amount of magnetic development with a given quantity of zinc surface. For this purpose a bar of soft iron, two inches square and twenty inches long, weighing twenty-one pounds, and much larger than any before used, was bent in the form of a horse-shoe. Around this were wound nine strands of copper wire, each sixty feet long, the ends left projecting so that one or more coils could be used at once, either connected with a battery or with each other, thus forming several coils with several battery connexions, or one long coil with single battery connexions. The greatest effect obtained with this magnet, using a battery of a single pair, with a zinc plate of two-fifths of a square foot of surface, and all the wire arranged as separate coils, was to lift a weight of six hundred and fifty pounds; with a large battery the effect was increased to seven hundred and fifty pounds. In a subsequent series of experiments, not published with the preceding, the same magnet was made to sustain one thousand pounds. When a compound battery was employed of a number of pairs, it was found that the greatest effect was produced when all the wires were arranged as a single long coil. I subsequently constructed electro-magnets on the same plan, which supported much greater weights. One of these, now in the cabinet of Princeton, will sustain three thousand six hundred pounds with a battery occupying about a cubic foot of space. It consists of thirty strands of wire, each about forty feet in length.

The abovementioned experiments exhibit the important fact that when a galvanic battery of intensity (that is to say, a battery consisting of a number of pairs) is employed, the electro-magnet connected with it must be wound with one long wire, in order to produce the greatest effect; and that when a battery of quantity, (that is, one of a single pair,) is employed, the proper form of the magnet connected with it is that in which several shorter wires are wound around the iron. The first of these magnets, which is the one now employed in the long or main circuit of the telegraph, may be called an intensity magnet; and the second, which is used in the local circuit, may be denominated the quantity.

The quantity of electricity which can be passed through a long circuit of ordinary-sized wire is, under the most favorable circumstances, exceedingly small, and in order that this may develop magnetism in a bar of iron, it was necessary that it should be made to revolve many times around the iron, that its effects may be multiplied; and this is effected by using a long single coil. Hence it will be seen that the electro-magnet of Mr. Sturgeon was not applicable to telegraphic purposes in a long circuit.

Previous to making the last experiments above mentioned, in order to guide myself, I instituted a series of preliminary experiments on the conduction of wires of different lengths and diameters, with different batteries. In these experiments a galvanometer, or an instrument consisting of a magnetic needle freely suspended within a coil of wire, was first employed to denote, by the deflection of its needle, the power of the current. The result from a number of experiments, with a battery of a single pair, was the same as that obtained by Barlow, namely, that the power diminished rapidly with the increase of distance With the same battery, and a larger wire, the diminution was less. The galvanometer was next removed, and a small electro-magnet substituted in its place. With a single battery, the same result was again obtained—a great diminution of lifting power with the increase of distance. After this the battery of a single pair was removed and its place supplied by one of intensity, consisting of twenty-five pairs. With this the important fact was observed, that no perceptible diminution of the lifting power took place, when the current was transmitted through an intervening wire between the battery and the magnet of upwards of one thousand feet.

This was the first discovery of the fact that a galvanic current could be transmitted to a great distance with so little a diminution of force as to produce mechanical effects, and of the means by which the transmission could be accomplished. I saw that the electric telegraph was now practicable; and, in publishing my experiments and their results, I stated that the fact just mentioned was applicable to Barlow's project of such a telegraph. I had not the paper of Barlow before me, and erred in attributing to him a project of a telegraph, as he only disproved, as he thought, the practicability of one. But the intention of the statement was to show that I had established the fact that a mechanical effect could be produced by the galvanic current at a great distance, operating upon a magnet or needle, and that the telegraph was therefore possible. In arriving at these results, and announcing their applicability to the telegraph, I had not in mind any particular form of telegraph, but referred only to the general fact that it was now demonstrated that a galvanic current could be transmitted to great distances with sufficient power to produce mechanical effects adequate to the desired object.

The investigations above mentioned were all devised and originated, and the experiments planned, by myself. In conducting the latter, however, I was assisted by Dr. Philip Ten Eyck, of Albany. An account of the whole was published in the 19th volume of Silliman's Journal, in 1831, with the exception of the account of the large magnet afterwards constructed at Princeton in 1833, and the experiment mentioned of lifting a thousand pounds with one of my first magnets. While I was engaged in these researches, Prof. Moll, of the University of Utrecht, was pursuing investigations somewhat similar, and succeeded in making powerful electro-magnets, but made no discovery as to the distinction between the two kinds of magnets, or the transmissibility of the galvanic current to a great distance with power to produce mechanical effects. In fact, his experiments were but a repetition on a large scale of those of Sturgeon.

After completing the investigations abovementioned, I commenced a series of experiments on another branch of electricity closely connected with this subject. Among other things, I applied the principles above mentioned to the construction of an electro-magnetic machine, which has since excited much attention in reference to the application of electro-magnetism as a motive power in the arts.

In 1832 I was called to the chair of natural philosophy in the College of New Jersey, at Princeton, and in my first course of lectures in that institution, in 1833, and in every subsequent year during my connexion with that institution, I mentioned the project of the electro-magnetic telegraph, and explained how the electro-magnet might be used to produce mechanical effects at a distance adequate to making signals of various kinds. I never myself attempted to reduce these principles to practice, or to apply any of my discoveries to processes in the arts. My whole attention, exclusive of my duties to the college, was devoted to original scientific investigations, and I left to others what I considered in a scientific view of subordinate importance the application of my discoveries to useful purposes in the arts. Besides this, I partook of the feeling common to men of science, which disinclines them to secure to themselves the advantages of their discoveries by a patent.

In February, 1837, I went to Europe; and early in April of that year Prof. Wheatstone, of London, in the course of a visit to him in King's College, London, with Prof. Bache, now of the Coast Survey, explained to us his plans of an electro-magnetic telegraph; and, among other things, exhibited to us his method of bringing into action a second galvanic circuit. This consisted in closing the second circuit by the deflection of a needle, so placed that the two ends projecting upwards, *of* the open circuit, would be united by the contact of the end of the needle when deflected, and on opening or breaking of the circuit so closed by opening the first circuit, and thus interrupting the current, when the needle would resume its ordinary position under the influence of the magnetism of the earth. I informed him that I had devised another method of producing effects somewhat similar. This consisted in opening the circuit of my large quantity magnet at Princeton, when loaded with many hundred pounds weight, by attracting upward a small piece of moveable wire, with a small intensity magnet, connected with a long wire circuit. When the circuit of the large battery was thus broken by an action from a distance, the weights would fall, and great mechanical effect could thus be produced, such as the ringing of church bells at a distance of a hundred miles or more, an illustration which I had previously given to my class at Princeton. My impression is strong, that I had explained the precise process to my class before I went to Europe, but testifying now without the opportunity of reference to my notes, I cannot speak positively. I am, however, certain of having mentioned in my lectures every year previously, at Princeton, the project of ringing bells at a distance, by the use of the electro-magnet, and of having frequently illustrated the principle of transmitting power to a distance to my class, by causing in some cases a thousand pounds to fall on the floor, by merely lifting a piece of wire from two cups of mercury closing the circuit.

The object of Prof. Wheatstone, as I understood it, in bringing into action a second circuit, was to provide a remedy for the diminution of force in a long circuit. My object, in the process described by me, was to bring into operation a large quantity magnet, connected with a quantity battery in a local circuit, by means of a small intensity magnet, and an intensity battery at a distance.

The only other scientific facts of importance to the practical operation of the telegraph not already mentioned are the discovery by Steinheil, in 1837, in Germany, of the practicability of completing a galvanic circuit, by using the earth for completing the circuit, and the construction of the constant battery in 1836, or about that time, by Professor Daniell, of King's College, London. I believe that I was the first to repeat the experiments of Steinheil and Daniell in this country. I stretched a wire from my study to my laboratory, through a distance in the air of several hundred yards, and used the earth as a return conductor, with a very minute battery, the negative element of which was a common pin, such as is used in dress, and the positive element the point of a zinc wire immersed in a single drop of acid. With this arrangement, a needle was deflected in my laboratory before my class. I afterwards transmitted currents in various directions through the college grounds at Princeton. The exact date of these experiments I am unable to give without reference to my notes. They were previous, however, to the unsuccessful attempt of Mr. Morse to transmit currents of electricity through wires buried in the earth between Washington and Baltimore, and before he attempted to use the earth as a part of the circuit. Previous to this time, and after the abovementioned experiments, Mr. Morse visited me at Princeton, to consult me on the arrangement of his conductors. During this visit, we conversed freely on the subject of insulation and conduction of wires. I urged him to put his wires on poles, and stated to him my experiments and their results.

In the course of the years 1836 and 1837, various plans of more or less merit, were devised, and more or less fully carried into effect, for applying the principles already discovered to the construction of electro-magnetic telegraphs in different parts of the world, but of these I do not undertake to give any particular account. I would say, however, that of these plans that for which Mr. Morse subsequently obtained a patent was, in my judgment, the best.

3.- Please state whether or not you are acquainted with the electro-magnetic telegraph for which S. F. B. Morse obtained a patent in 1846. If you are, please state whether any, and if any, which of the principles or plans which you have described as discovered, or announced by yourself or others are used in the construction or operation of it. State also what principles used in the telegraph are, so far as you know, original with Professor Morse.

Answer.—I am acquainted with the principles and general mode of operation of the telegraph and improvement referred to. The telegraph is based upon the facts discovered by myself and others, of which I have already given an account.

The plan which was first described to me in the autumn of 1837 by Mr. Morse, or by Professor Gale, who was associated with him in the construction of the telegraph, was to employ a single entire circuit of wire, with an intensity battery to excite the current, and an intensity magnet to receive it and produce a mechanical action, which would work the recording apparatus. Mr. Morse afterwards employed the intensity battery in a long circuit, and an intensity magnet to receive its current at a distant point, and produce the mechanical effect of closing a secondary circuit. The secondary circuit may be either employed to transmit a second current to a distant point and there close a third circuit, and thus continue the line, or for working a recording apparatus in the secondary circuit, or it may be employed without reference to the continuation of the line, as a short local circuit to work a local magnet. In the first case, there must be in the secondary circuit an intensity battery and intensity magnet; in the last case, a quantity magnet and quantity battery are required.

I heard nothing of the secondary circuit as a part of Mr. Morse's plan until after his return from Europe, whither he went in 1838. It was not till long after this that Mr. Morse used the earth as a part of the circuit in accordance with the discovery of Steinheil.

I am not aware that Mr. Morse ever made a single original discovery, in electricity, magnetism, or electro-magnetism, applicable to the invention of the telegraph. I have always considered his merit to consist in combining and applying the discoveries of others in the invention of a particular instrument and process for telegraphic purposes. I have no means of determining how far this invention is original with himself, or how much is due to those associated with him.

4. Please state when you first became acquainted with Mr. Morse, and what knowledge he possessed of electricity, magnetism, and

electro-magnetism, and what information you or others communicated to him relating to the telegraph. State, also, all you know of the attempts of himself, and others associated with him, to construct an electro-magnetic telegraph, either from your own observation or from statements made by himself or by others in your presence. State particularly any conversation, if any, you may have had with him in reference to your own discoveries applied to the telegraph.

Answer.—Shortly after my return from Europe, in the autumn of 1837, I learned that Mr. Morse was about to petition Congress for assistance in constructing the electro-magnetic telegraph. Some of my friends in Princeton, knowing what I had done in developing the principles of the telegraph, urged me to make the representations to Congress, which I expressed some thought of doing, namely: that the principles of the electro-magnetic telegraph belonged to the science of the world, and that any appropriation which might be made by Congress should be a premium for the best plan, and the means of testing the same, which the ingenuity of the country might offer. Shortly after this I visited New York, and there accidentally made the personal acquaintance of Mr. Morse;* he appeared to be an unassuming and prepossessing gentleman, with very little knowledge of the general principles of electricity, magnetism, or electro-magnetism. He made no claims, in conversation with me to any scientific discovery, or to anything beyond his particular machine and process of applying known principles to telegraphic purposes. He explained to me his plan of a telegraph with which he had recently made a successful experiment; I thought this plan better than any with which I had been made acquainted in Europe; I became interested in him, and instead of interfering in his application to Congress, I [subsequently†] gave him a certificate, in the form of a letter, stating my confidence in the practicability of the electro-magnetic telegraph and my belief that the form proposed by himself was the best which had been published.

Mr. Morse subsequently visited Princeton several times to confer with me on the principles of electricity and magnetism which might be applicable to the telegraph. I freely gave him any information I possessed.

I learned in 1837, or thereabouts, that Professor Gale and Dr. Fisher were the scientific assistants of Mr. Morse in preparing the telegraph. Mr. Vail was also employed, but I know not in what capacity, and I am not personally acquainted with him. With Professor Gale I have been intimately acquainted for several years; he had been a pupil in chemistry of my friend Dr. Torrey, and had studied my papers on electro-magnetism, and, as he informed me, had applied them in the arrangement of the apparatus for the construction of Morse's telegraph.

My researches had been given to the world several years before the attempt was made to reduce the magnetic telegraph to practice. Mr.

* This meeting took place in the chemical store of Mr. Chilton, Broadway, New York, and the place and time are both indelibly impressed upon my mind.

† The word subsequently was accidentally omitted in giving my testimony. The omission, however, is of little importance.

Chilton, of New York, informed me that he had referred Mr. Morse to them previous to his experiments in the New York University. I was therefore much surprised on the publication, in 1845, of a work purporting to give a history of the telegraph, and of the principles on which it was founded, by Mr. Vail, then principal assistant of Mr. Morse, and one of the proprietors of his patent, to find all my published researches relating to the telegraph passed over with little more than the remark that Dr. Moll and myself had made large electro-magnetic magnets. Presuming that this publication was authorized by Mr. Morse and the proprietors of the telegraph, I complained to some of his friends of the injustice, and after his return from Europe, (for he was absent at the time the book was issued,) I received a letter, copied and signed by Mr. Vail, but written by Mr. Morse, as the latter afterwards informed me, excusing the publication, on the ground that he (Mr. Vail) was ignorant of what I had done, and asking me for an account of my researches. This letter was addressed to me after the book had been stereotyped and widely circulated. It has been translated into French, and, I believe, published in Paris. To the letter I did not think fit to make any reply. I afterwards received a letter from Mr. Morse, in his own name, on the same subject, to which I gave a verbal reply in January, 1847, in Washington. In this interview Mr. Morse acknowledged that injustice had been done me, but said that proper reparation would be made. Another issue of the same work was made, bearing date 1847, in which there is no change in the statement relative to my researches.

About the beginning of 1848 Mr. Walker, of the Coast Survey, in a report on the application of the telegraph to the determination of differences of longitude, alluded to my researches. A copy of this was sent to Mr. Morse, which led to an interview between Mr. Walker, Professor Gale, Mr. Morse, and myself. At this meeting, which took place at my office in Washington, Mr. Morse stated that he had not known until reading my paper in January, 1847, that I had two years before his first conception in 1832, settled the point of practicability of the telegraph, and shown how mechanical effects could be produced at a distance, both in the deflection of a needle and in the action of an electro-magnet; that he did not know, at the time of his experiments in 1837 that there had been any doubts of the action of a current at a distance, and that in the confidence of the persuasion that the effect could be produced, he had devised the proper apparatus by which his telegraph was put in operation. Professor Gale, being then referred to, stated that Mr. Morse had forgotten the precise state of the case; that he, (Mr. Morse,) previous to his, (Dr. Gale's,) connexion with him, had not succeeded in producing effects at a distance; that, when he was first called in he found Mr. Morse attempting to make an electro-magnet act through a circuit of a few yards of copper wire suspended around a room in the University of New York, and that he could not succeed in producing the desired effect even in *this* that circuit; that he (Dr. Gale) asked him if he had studied Prof. Henry's paper on the subject, and that the answer was "no;" that he then informed Mr. Morse that he would find the principles necessary to success explained in that paper; that instead of the battery of a single element, he should employ one of a number of pairs; and that, in place of the magnet with a short single wire, he should use one with a long coil. Dr. Gale further stated that his apparatus was in the same building, and that having articles of the kind he had mentioned, he procured them, and that with these the action was produced through a circuit of half a mile of wire.* To this statement Mr. Morse made no reply. The interview then terminated, and I have since had no further communication with him on the subject.

5. Please state whether or not you ever constructed any machine for producing motion by magnetic attraction and repulsion; if yea, what was it, and what led to the making of it.

Answer.—After developing the great magnetic power of the electro-magnet as already described, the thought occurred to me that this power might be applied to give motion to a machine. The simplest arrangement which suggested itself to my mind was one already referred to, namely, causing a movable bar, supported on a horizontal axis like a scale beam, to be attracted and repelled by two permanent magnets. This could be readily effected by transmitting through a coil of wire around the suspended bar a current of galvanism, first in one direction, and then in the opposite direction, the alternations of the current being produced by dipping the ends of wires projecting from the coils into cups of mercury connected with batteries, one on either side. An account of this was published in Silliman's Journal, for 1831, vol. xx., p. 340. It was the first successful attempt to produce a mechanical motion which might apparently be employed in the arts as a motive power. This little machine attracted much attention at home and abroad, and various modifications of it were made by myself and others. I never, however, regarded it as practically applicable in the arts, because of the great expense of producing power by this means, except, perhaps, in particular cases where expense of power is of little consequence.

6. Please look at the drawings of the Columbian telegraph, now shown you, marked G. W. B. and N. B. C., and certified by G. S. Hillard, Commissioner. Describe generally the apparatus represented and its mode of operation, and state in what respects, if any, it differs from the telegraphic apparatus patented by Mr. Morse.

Answer.—I have looked at the drawings, and I find, on examination, that it will be impossible for me to give a definite answer to the question, unless I have more time than is now at my disposal, and the means of examining and comparing the operations of the machines.

7. Please state, if you can, how many original experiments you have made in the course of your investigations in electricity, magnetism, and electro-magnetism.

Answer.—The experiments I have mentioned in this deposition form but a small part of my original investigations. Besides many

* See Dr. ale's letter of April 7, 1856, page 93.

that I made in Albany, which I have not mentioned, since my removal to Princeton, I have made several thousands on electricity, magnetism, and electro-magnetism, particularly the former, which have more or less bearing on practical applications of this branch of science, brief minutes of which fill several hundred folio pages. Many of these have not been published in detail. They have cost me years of labor and much expense.

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.

JOSEPH HENRY.

Sworn to before me, September 7, 1849.

GEO. S. HILLARD,
Commission