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THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—I.

BY

Mary A. Henry

WHILE reading Miss Henry's remarkable presentation of her father's great work in connection with the Electric Telegraph—remarkable in the power she has shown in grasping the essential features of her father's labors—I was reminded of my first interview with Joseph Henry. One morning he came into my laboratory at Cambridge, and, after I had shown him various pieces of scientific apparatus, he stood before an electro-magnet which was working a relay and looked long at the magnet, and then at the battery which was coupled for quantity, and remarked in a quiet tone, as if half to himself, "If I had patented that arrangement of magnet and battery I should have reaped great pecuniary reward for my discovery of the practical method of telegraphy."

Miss Henry can speak with authority upon her father's aims and labors, and the conclusions she draws from his conversations and from his notes and letters are in consonance with the belief which has been steadily growing, that Joseph Henry invented the essential features of telegraphy.

JOHN TROWBRIDGE.

THE ELECTRO-MAGNET.

Joseph Henry.

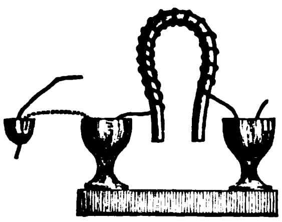
IN the civilized world is there anything which in this day contributes more to the comfort of man than the electro-magnet? Strike it out of existence and the electric telegraph would die. Its great network of wires would be as useless as the curious system of nerves which carries the message of the brain to the finger tips is useless when that mysterious principle which constitutes the life of the human being has departed. The telegraph gone, distant countries would unclasp hands, as it were, and the wide ocean roll again between. The eager world would be struck dumb in the midst of its innumerable political, commercial and social relations; or, rather, would be sent back to the stammering old time when months intervened in the exchange of thought, now possible in an hour. But not alone as the soul of the telegraph would the loss of the electro-magnet be felt; hardly a moment's thought is needed to realize the place it has gained, the importance its failure to meet the demands made upon it would be to the world. How did it come into existence—this electro-magnet? Perhaps, considering the importance of the subject, it may bear to be not merely a twice-told, but an oft-repeated tale.

What is a magnet? Our acquaintance with it began in our childhood: as a piece of steel endowed with a mysterious attractive power, it was among our toys; many a time have we held it over a pile of needles and laughed to see them leap to meet it, or with it we have drawn our little boats from the farther side of a mimic sea. How did it receive its name? It is pleasant in imagination to travel far away through the beautiful islands of the Ægean sea to the shores of Asia, and to believe in the romantic story which tells us that a Greek shepherd, Magnus by name, wandering over Mt. Ida with his sheep, found his crook suddenly and powerfully attracted by a mass of iron ore, and so attached his humble name to the loadstone or natural magnet. But fancy must yield with reluctance to the more prosaic assumption now generally adopted, that the name was derived from Magnesia, in Lydia, where the ore was first found.

For the word *electro* we must not only come down the mountain, but descend the stream of time to about five hundred years before Christ; then we must follow the undulations of the Ionian coast, to find, at the mouth of the river Meander, the city of Miletus. Walking her streets at this time, caring little for her magnificence or for the wars in which she was engaged, save to induce peace, was Thales, one of the seven wise men of Greece. Among the objects of trade in the magnificent city was the yellow amber; not an object of indifference to the philosopher, although as yet only of frivolous use as an ornament. Its color no doubt delighted his eyes but it had a deeper interest for him. Rubbing the stone one day—perhaps to make its yellow tint clearer—he found that he had endowed it with a curious power: a loose feather flew to meet it. This power seemed to Thales miraculous. He imagined there were spirits in the amber and so came to think that everything in the universe must be pervaded by spirits. Thus electricity was discovered, and it received its name, long afterwards, from the Greek word meaning amber.

It was at a very early period that the loadstone or natural magnet was discovered. Very early too was known the remarkable power it possesses of transmitting its properties to hard iron or steel when these bodies are rubbed, or even touched by it. Thus came into being the steel magnet—possessing not only the same power of transmitting its properties but also a quality lacking in the ore; turning north and south, when free to move, in obedience to the great magnet, the earth, it had a directive power which more than two thousand years before the Christian era directed the traveler over the land, as later it was to guide the mariner over the sea. From this remote period it is a long flight down the ages until in England, in the cabinet of the self-taught shoemaker-philosopher, Sturgeon, stood the first electro-magnet; that is, the magnet made by electricity.

Of the deepest interest to the scientific world was this little instrument. It consisted of a small bar of soft iron bent into the form of a horse shoe, with a spiral of wire wound loosely around it, the ends of the wire dipping into two cups of mercury. When into these cups the wires from a galvanic battery were also dipped, an electric circuit was formed and the electric current, passing through the spiral of wire, rendered the soft iron bar magnetic. It was very feeble, this magnet; it required a large battery to give it any strength. What advantage could it boast over the steel magnets which had served the world so many years?



Sturgeon's Magnet.

Some of these were very powerful; one in London at this time belonging to the Royal Society lifted one hundred pounds. These magnets were all permanent: steel when endowed with magnetism retains it; not so soft iron. This bent bar of Sturgeon's was a magnet only while the electricity was circulating through the wire around it; in this lay its advantage: *it was a magnet, or not, at the will of man.* It was not merely as a scientific fact that the world turned to it with such eagerness; it renewed an old hope that electricity might be made the messenger of man. The story of the electro-magnet is but a part of the story of the electric telegraph; we may not tell the one without reference to the other.

We cannot go back far enough in the history of man to find a time when the idea of the distant communication of intelligence did not exist. In the earliest childhood of the race even, beacon fires proclaimed from hill to hill tidings of weal or woe. In those early days man looked up with dread to the lightning, thinking it "the eye-flash of an angry god," not dreaming that it was the manifestation of the agent which was to satisfy his long-cherished desire for distant communication with his fellowman, that the very genius of the storm was one day to serve as his messenger.

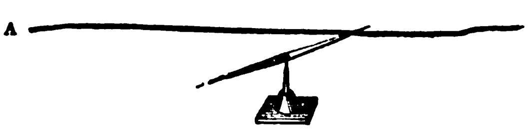
It is interesting to know that Hauksbee of England in 1705 was the first to suspect the identity of lightning and electricity. He produced a thunder-storm in miniature by drawing a piece of amber swiftly through a woolen cloth. He says "a prodigious number of little cracklings were heard, every one of which produced a little flash of light. This light and crackling seem in some degree to represent thunder and lightning." As man learned in various ways, by the rubbing of amber and other substances, to excite electricity, and learned also the value of the force thus produced, also that the electrical influence could be transmitted through several hundred feet of wire, there came to him the conception that by the friction of his machines he might, as Aladdin by the rubbing of his lamp, summon the slave of his will which was to serve in the transmission of intelligence. The first attempts to use electricity for this purpose began in 1753. Who was the first to suggest the idea it seems difficult to determine; it was such a natural idea after the experimental results which had been obtained that it probably occurred to many minds at the same time, and it is only surprising that it was not conceived earlier. We may not here notice any one of the efforts in this line founded thus on frictional or static electricity; they form one of three distinct, although overlapping, eras in the history of the telegraph. They had a measure of success. They were very interesting from a scientific point of view and they served certain ends, but they did not give the telegraph to the world.

[By the telegraph I mean here that system or combination by which mechanical effects can be produced at *great distances*—through seas, over continents—and I use the term in contradistinction to the many attempts towards this result, made at various times and in various places which if successful were so only in a limited degree, because the natural laws which control electrical action were undiscovered or unknown. Will the reader be so kind as to take especial notice of this remark; it is necessary for the proper understanding of my story.]

In Bologna, in the year 1753, a "religious youth of fourteen years was dreaming of church service, discouraged by his friends; while on the shores of Lake Como was playing a boy of eight;" these two were destined to make the discovery which was to form the second era in the history of the telegraph. In 1789, a dead frog's leg hanging upon a copper hook and kicking as though it were alive whenever the sportive wind blew it against an iron balcony—electricity at work, in what seemed almost the enjoyment of a jest—revealed to Galvani that by chemical action, as well as by friction, the genius of the thunder-storm might be evoked. Volta followed with his "couronne de tasses" and thus came into being the Galvanic or Voltaic battery, bearing the names of both men. So general and profound was the interest excited that Napoleon Bonaparte invited Volta to Paris, witnessed his experiments with the instrument in the presence of the National Institute, and loaded him with decorations.

More eager now grew the hope of means of distant communication. The electricity of the machine, that is, the electricity produced by friction, had answered for this purpose only in a very limited degree; but this battery,—might not its long wires be extended indefinitely? Might not this current of Volta's, easily excited, easily set at rest, by the mere making or breaking of the contact of those same long wires, at last be the messenger so long desired? Of the many efforts in this direction, led in by Sœmmering of Munich, we may not speak. Could we follow their fortunes, now in one country, now in another, we would find that, however ingenious, sooner or later they all ended in the same difficulty, viz.: *the failure of the electric force with increase in the extent of the conducting wire of the battery.* It was but a question of time, or rather of distance; each new effort met the fate of its predecessors. For a while the electric force seemed to lend itself to this service, only to escape and laugh, as it were, at the efforts of the impotent creature, man, to bring it under restraint.

We turn now again to the electro-magnet. In a former article we tried to tell, in these pages, how the world found out that electricity could produce magnetism; step by step, from Oersted swaying his needle through the influence of the electric current, down to Ampere magnetizing needles in a glass case by means of electricity; we come back to 1824–25, to the bent iron bar in Sturgeon's cabinet and to the interest it excited. Then indeed the telegraph seemed a thing of the near future. There was not only the wonderful Voltaic battery, there was this magnet ready to respond to the will of man; could it not be made thus to respond at a distance? Surely the desire of the world would now be accomplished!



OERSTED'S NEEDLE.

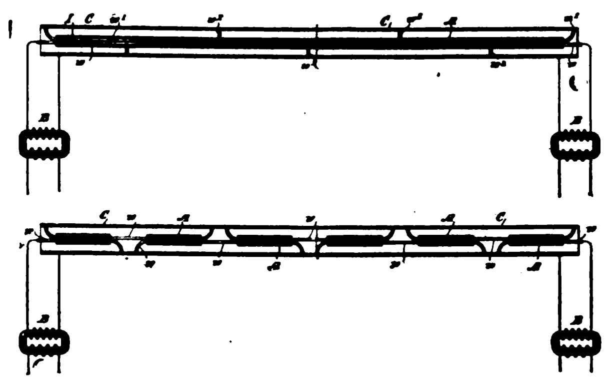
Barlow, a distinguished mathematician and engineer of England, essayed the practical experiment with the new instrument, while Europe waited, we might say, with bated breath, in confident expectation for the result. What was it? Again a disappointment. We will let Barlow speak for himself. "The details of the contrivance are so obvious, the principles so well understood, that there is only this one question which could render the result doubtful. *Is there any diminution of effect by lengthening the conducting wire?* I was therefore induced to make the trial, but *found such a sensible diminution with only two hundred feet of wire as at once to convince me of the impracticability of the scheme.*" It could not be possible! The experiment was repeated in various ways, in the same year, 1825, and in the following year, but with like result; each experiment confirmed the reluctant conclusion that after all the brilliant discoveries which had excited such eager expectation, an electro-magnetic telegraph was an impossibility. Since Sturgeon's magnet, as well as Volta's battery, had failed, there appeared to be no means of obtaining sufficient electrical force to act at a distance.

Had the hope of the telegraph indeed ended, and in disappointment? *For want of sufficient electric force the* *telegraph is an impossibility;* such seemed the verdict of the science of Europe, and with it we turn to America. Very brilliant was the old world of science, at that day represented in the line of physics by such men as Hansteen, studying the magnetism of the earth, Gay Lussac and Biot invading even the blue air in the search after the magnetic forces, the immortal Arago, the brilliant Ampere,—we can only mention a few of the names which, enrolled upon the lists of fame, have come down to us as household words. In America, to oppose that eminent array of veterans in this particular field of science there was only young Henry, in the Albany Academy.[1] He dared to brave the electric force and demand of it greater energy. Mr. E. N. Dickerson says of him—"He was but a youth and ruddy and fair of countenance, armed only with a simple sling of his own construction and pebbles from the brook of nature, but he was equal to the trained warriors of maturer growth and superior armor, waging war against the Goliath that guarded the unexplored regions of nature's secrets; and like the great king of Israel, after the hunt of the battle was over, he came to be leader of the hosts who once had been tending only a few sheep in the wilderness."

THE REED INDUCTION SYSTEM OF TELEGRAPHY.

In the operation of telegraph lines the amount of energy required for the transmission of signals is of little account as compared with the importance of securing high speed. Thus, were it possible to increase the commercial capacity of an Atlantic cable ten times by the continuous use of one thousand horse power in current, instead of that of a few cells of battery, it would be an economical step on the company's part to substitute the power plant. The static capacity of long cable, under existing conditions, however, prevents the possibility of transmitting any large quantity of energy or of making variations travel with the desired speed.

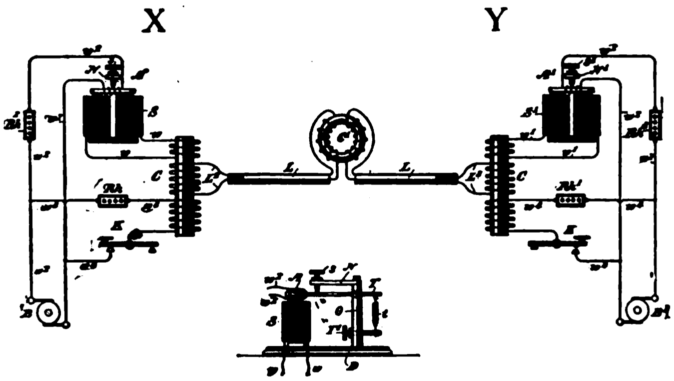
Some of the most distinguished electricians of the day have endeavored to overcome this difficulty. About twenty years ago Mr. Edison proposed to do away with static capacity almost entirely by breaking up a long line into shorter circuits and employing induction coils; but his system was confined to a dot and space code, and the



FIGS. 1 AND 2.

action of the armature was unreliable. Prof. S. P. Thompson's method of transmitting a current the whole length of the line and then overcoming static retardation distributively, is still fresh in the minds of those who listened to his paper at the recent Electrical Congress or read the published reports of the proceedings;[2] but while furnishing valuable food for thought, and much that was theoretically novel and valuable it seems to be open to several practical and mechanical objections. Other inventors have devised ingenious systems to overcome the difficulty but none has yet proved useful in practice.

Mr. C. J. Reed, of Philadelphia, has recently worked out a method embodying principles which seem to meet the requirements of the case and in a manner distinctly novel and to all appearances practically available. In his system he employs a true alternating current successively induced in separate metallic circuits which may be entirely insulated from one another. This enables him to use high



FIGS. 3 AND 4.

electromotive force and transmit large quantities of energy and reduce the static retardation practically to zero. At the same time almost any receiving instrument may be used, as it is only necessary to provide it with a local means of maintaining the temporary effects of an inductive impulse until the reverse inductive impulse arrives to destroy it.

In the accompanying illustrations, Figs. 1 and 2 show the form of cable employed. In Fig. 1, *w* and *w'* are insulated conductors lying side by side throughout the entire distance between two stations, the conductor *w* being connected at each end of the line directly to the terminals of the converters B and to the outer metallic coating C, while the conductor *w'* is connected at both ends directly to the metallic casing. w^2 w^2 are insulated branch conductors located at stated distances apart, those on the lower side of the drawings connecting the conductor *w* directly with the outer metallic casing C while those on the upper side and intermediate between those described connect the conductor *w'* with the metallic casing. I is a metallic sheathing of iron wound in layers around two parallel conductors *w* and *w'*, constituting an inductive field around them.

When an impulse is set up through the primary of, say, the left hand converter B, a secondary or induced impulse will be set up through the conductor *w* and the first one of the short conductors w^2 returning through the outer casing C, thus inducing in the first section of the conductor *w'* an impulse which in turn induces in the next succeeding section a corresponding induced impulse; and so on through the series until the final impulse is effected through the conductor *w* and its connections through the coil of the right hand converter B which in turn induces the working impulse in the receiving instrument.

In another form shown in Fig. 2 the continuous conductors are replaced by a series of short conductors *w w*, the ends of which project past each other in alternating order and are connected to the outer casing C, the parallel or inductive portions of the circuits being surrounded with iron wire, as shown at A, while the intermediate portions between these casings form the conducting parts.

In Fig. 3 are shown two main telegraph stations X and Y joined together by an intervening cable consisting of an internal conductor L^3 insulated from a surrounding conduct-

1. NOTE.—"On the shoulders of young Henry has fallen the mantle of Franklin" were the words of Sir David Brewster. It is true Cox had suggested a chemical telegraph and Hare made many improvements in galvanic apparatus, but no representative of Franklin, in a series of connected experiments, had entered the field of electric science in America, until Henry began his researches.

2. See THE ELECTRICAL ENGINEER, Aug. 30, 1893.

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—II.

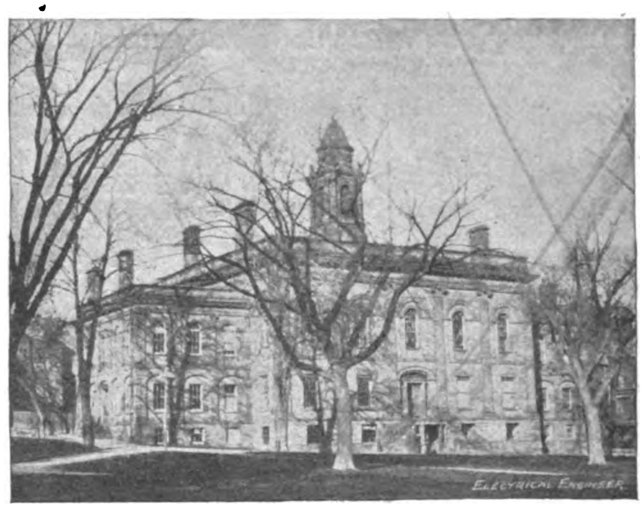
BY

Mary A. Henry

Barlow was right, the electro-magnetic telegraph was impossible when he made his discouraging assertion in regard to its impracticability. At the time he made that declaration a telegraph founded upon the electro-magnet was bound to be a failure, for the electro-magnet was not the instrument which could meet the demands for the telegraph, until Henry had taken it up and turned it into the sensitive magnet, which could respond to electrical influence at a distance. Until this instrument was made by Henry, the electromagnetic telegraph was an impossibility. The experimental telegraphic efforts founded upon electro-magnetism *prior to Henry's discoveries*, constituted a third era in the history of the telegraph They began shortly after Oersted's discovery that a magnetic needle was deflected when a wire, through which a galvanic current was passing was held above it. Schweigger of Halle, as we know, extended the discovery of Oersted, by bending the wire in several convolutions around the needle, increasing in this way the effect of the current and producing greater deviation of the needle. On this principle he made what is called his "multiplier," or the galvanometer. We give a sketch of it as it is represented in various electrical books—a wooden frame, the magnetic needle within it free to move, and around the frame several convolutions of the wire conducting the electrical current; we will have occasion to refer to the instrument again in this chapter. La Place was the first to suggest that the deflecting power of the electric current might be employed for telegraphic purposes and Ampere was the first to propose a plan for the practical application of this idea; then followed many very interesting attempts to make the moving needles speak for man at a distance. But the action of the wire transmitting the electrical current, which was coiled around the needle and necessary to move it, depended upon the same law which controlled the action of the electro-magnet. This law had not been discovered; was to be discovered by Henry Soon it was found that the deflection of the needles, like the action of the magnet, decreased with the increase in length of the galvanic circuit; the electromotive power failed to act at any great distance. How curious it is to see all these telegraphic efforts—whether founded upon static or frictional electricity, galvanism or electromagnetism, all starting with brilliant eclat, winning deserved admiration, all meeting the same fate, coming to the same apparently insurmountable obstacle,—the failure of the electric force. Some of them were actual working telegraphs, in the sense that they conveyed intelligence at short distances; eight, ten, even twenty miles perhaps, but as regards what in contradistiction to them we have called *the telegraph*, with which man might encircle the world, what did they do? They each and all in various ways only confirmed the same fact, that electricity might be made to produce mechanical effects, which could be used as telegraphic signals. They did not solve the problem how electricity could be made to produce these effects at a distance. They provided ingenious methods for the delivery of the message but did not secure the messenger. The Spirit of the storm was not yet bound to this service.

Sturgeon's magnet had been in his cabinet for four years when young Henry took it up; but, before we see what he did with it, it may not be amiss to follow the steps which led him to it. Let us go back to the year 1824, when it grew into being under Sturgeon's hands, and on the evening of October 30th of that year look into a room in the Albany Academy, where the Albany Institute is holding one of its regular meetings.[1] The president of the Society is the Patroon of Albany, Gen. Van Rensselaer, and as he is very regular in his attendance on its meetings we may suppose he is present on this particular occasion. He regards with paternal interest a young man of twenty-four years, who is delighting the assembly with some experiments designed to illustrate the "*great reduction of temperature in steam of high elasticity when suddenly expanded.*" Very attractive is the young man as he stands there, tall and slender, his intellectual and unusually handsome face flushed with enthusiasm.

He ends his lecture by boldy thrusting his hand into a jet of steam issuing from the stop cock of a copper boiler before him, to exhibit the curious paradox, that, at a prescribed short distance from its escape, steam will not scald provided *it is hot enough.* This was Henry's first communication to the Albany Institute. Were we to seek the same room a year later, on the evening of March 2d, 1825, we would find the young man again delighting the assembly with his experiments—this time on "the production of cold by the rarefaction of air"—producing a veritable snow storm within six feet of a large stove, and in a room at a temperature not less than eighty degrees Fahrenheit;



The Albany Academy.

while perhaps outside on that March night, Nature was producing the same phenomenon on a large scale.[2]

It was through Henry's great facility and pleasure in experimental illustration that he entered the field of science. In 1826 he was appointed Professor of Mathematics and Natural History in the Albany Academy. We have seen him exercising his ingenuity in devising experiments to illustrate his lectures before the Albany Institute; it

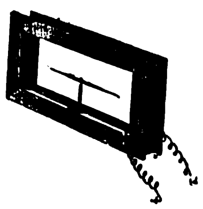
1. (This society had only recently been established by the union of an older one for the "Promotion of Useful Arts in the State of New York," organized Feb., 1791, and the "Albany Lyceum of Natural History," formed and incorporated April 23d, 1825.)

2. Half a pint of water was poured into a strong copper vessel. of a globular form, and having a capacity of five gallons; a tube of one-fourth of an inch diameter, with a number of holes near the lower end, and a stop-cock attached to the other extremity, was firmly screwed into the neck of the vessel; the lower end of of the tube dipped into the water but a number of holes were above the surface of the liquid, so that a jet of air mingled with with water might be thrown from the fountain. The apparatus was then charged with condensed air, by means of a powerful condensing pump, until the pressure was estimated at nine atmospheres. During the condensation the vessel became sensibly warm. After permitting the apparatus to cool down to the temperature of the room, the stop-cock was opened; the air rushed out with great violence, carrying with it a quantity of water, which was instantly converted into snow. After a few seconds, the tube became filled with ice, which almost entirely stopped the current of air. The neck of the vessel was then partially unscrewed, so as to allow the condensed air to rush out around the screw; in this state the temperature of the whole interior atmosphere was so much reduced as to freeze the remaining water in the vessel."—*Trans. Albany Institute*, Vol. 1, part 2, p. 36.

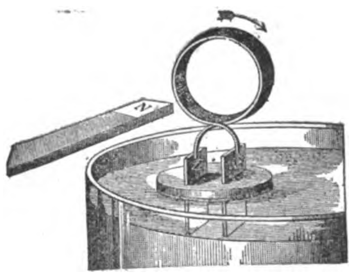
Although the principle on which this striking result was based was not at this time new, this particular application of it by Henry, thus publically exhibited, was long before any of the numerous patents were obtained for ice-making, not a few of which adopted substantially the same process.

was in connection with like efforts to exhibit strikingly to his pupils in classes the principles of electro-magnetism, that he made his first contribution to a science which, if we count from Oersted's experiments as its beginning, was at this time six years old. Not much had been done with the subject in America, Henry says, in a paper read before the Albany Institute, Oct. 10, 1827:

"The subject of electro-magnetism, although one of the most interesting branches of human knowledge, and presenting at the same time the most fruitful field for discovery, is perhaps less generally understood in this country than almost any other department of natural science. Our popular lecturers have not availed themselves of the many interesting and novel experiments with which it can so liberally supply them; and, with a few exceptions, it has not, as yet, been admitted as a part of the course of physical studies pursued in our higher institutions of learning. A principle cause of this inattention to a subject offering so much to instruct and amuse is the difficulty and expense which formerly attended the experiments—a large galvanic battery with instruments of very delicate workmanship being thought indispensible." Sturgeon had helped to obviate this difficulty. He had greatly improved lecture room apparatus for illustrating the electromagnetic reactions of rotation, etc. (where a permanent magnet is employed), by introducing stronger magnets and had thereby succeeded in exhibiting the phenomena on a larger scale and with less battery power. He was for this awarded the silver medal of the Society for the Encourage-



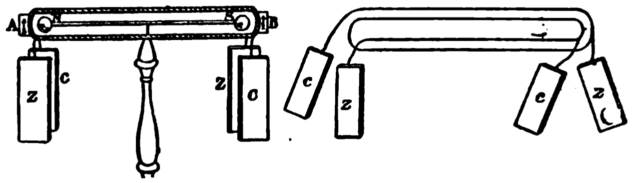
Schweigger's Multiplier.



De la Rive's Floating Ring.

ment of Arts. Henry, after repeating all the experiments of Oersted, Ampere and others, was, from his own experimental investigations, enabled to exhibit to his classes all the illustrations of Sturgeon on a much larger scale; with weak magnets, if necessary, and with still less battery power. These striking results were obtained by a simple expedient. Look again at Schweigger's multiplier. [See figure] Henry recognized the principle involved, viz., that in coiling the wire of a galvanic circuit the strength of the electrical current is increased, and in every case where a single wire circuit had been employed, he used a manifold coil of wire. By means of this coil Schweigger's multiplier became in Henry's hands an instrument of much greater delicacy and power; and Henry was not only able to produce with it more striking effects than Sturgeon had produced, but an apparatus capable of exhibiting phenomena of which Sturgeon's instruments were incapable. Henry says in his paper: "Mr. Sturgeon's suite of apparatus, though superior to any other as far as it goes, does not however form a complete set; as indeed it is plain that his principle of strong magnets cannot be introduced into every article required and particularly in those intended to exhibit the action of the earth's magnetism on a galvanic current, or the operation of two conjunctive wires on each other. To form therefore a set of instruments, on a large scale, that will illustrate all the facts belonging to this science, with the least expense of galvanism, evidently requires some additional modification of apparatus and particularly in those cases in which powerful magnets cannot be applied."

"In a paper published in the Transactions of the Albany Institute, June, 1828, I described some modifications of apparatus intended to supply this deficiency of Mr. Sturgeon by introducing the spiral coil on the principle of the galvanic multiplier of Prof. Schweigger, and this I think is applicable in every case where strong magnets cannot be used. The coil is formed by covering copper wire, from

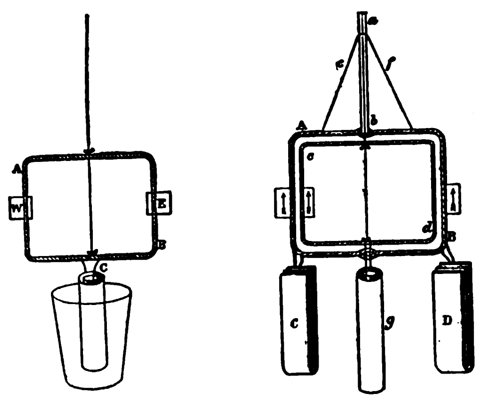


Figs. 1 and 2.—Henry's Modification of Schweigger's Multiplier.

$\frac{1}{40}$ to $\frac{1}{20}$ of an inch in diameter with silk; and in every case which will permit, instead of using a single conducting wire, the effect is multiplied by introducing a coil of this wire closely turned upon itself."

"The following description will render my meaning sufficiently clear:"

"Fig. 1, is an apparatus on the plan of the Multiplier, to show the deflection of a large magnetic needle. It consists of a coil of wire, A F, of an oblong form, about 10 inches in length and one and a half in width, with a small galvanic element attached to each end; the coil is formed of about twenty turns of fine copper or brass wire wound with silk, to prevent contact, and the whole bound together so as to have the appearance of a single wire. The attachment of the zinc and copper is more plainly shown in Fig. 2, which represents a coil of only two turns of the wire; on the left side of the figure the plates are soldered directly to the ends of the wire of the coil; on the right, the plate of zinc *z* is attached to the part of the wire ending with copper on the other side, while the plate of copper on the right corresponds to the zinc on the left. By this arrangement we can instantly reverse the direction of the currents and deflect the needle either to the right or left, by merely holding a tumbler of acidulated water so as to immerse one or the other of the double plates into the fluid. The arrows at A and B, formed of two pieces of card, are intended to show the direction of the currents, and they should point in the course of the wires going from the copper. N S, is the needle, about nine and a half inches long, made by binding together several watch springs, touched separately, so as to form a compound magnet; at



Figs. 3 and 4.—Henry's Modifications of De La Rive's Ring.

the end are two balls of pith, to show the movement of the needle more plainly. This instrument is complete in itself, and we receive the full effect of the instantaneous immersion of the galvanic element."

To show the advantage of the coil, take the little instrument called "De la Rive's ring," a modification of Ampere's ingenious and delicate experiment for showing the directive action of the earth as a magnet on a galvanic current when its conductor is free to move. (See representation of it.) C and Z are two plates, one of copper the other of zinc, connected by a loop of copper wire an inch or two in diameter and suspended in a little glass vase, containing acidulated water, which by the aid of a piece of cork D, floats in a vessel of water. The loop of wire is the circuit conveying the electric current C to Z and – free to move— it must, if the magnetism of the earth is produced by electric currents circulating from East to West around it, arrange itself at right angles to the magnetic meridian, and so it does. The effect of this experiment was strikingly enhanced by Henry's method of suspending by a silk thread a large coil thirty inches in length bent into a parallelogram the ends of the wire projecting, and soldered each to a pair of galvanic plates. By placing a tumbler of acidulated water beneath the galvanic plates so that they could dip into it, he caused the coil to assume, after a few oscillations its equatorial position, transverse to the magnetic meridian. We give his own illustration and description of the arrangement.

"Fig. 3 represents a modification of De la Rive's ring on a large scale. A B, is a coil about nine inches by six, with a small cylinder of copper, enclosing another of zinc, without bottoms, soldered to its extremities, which end at C, the whole being suspended by a fibre of raw silk, so as to swing freely in a cup of acidulated water. When this apparatus is made sufficiently light it invariably places itself, after a few oscillations, at right angles to the magnetic meridian. W and E, are two pieces of card, with letters on them, to show which side of the coil will turn to the East or West; they may be properly placed by recollecting that the current from the copper to the zinc has a tendency to circulate in a direction contrary to that of the sun."

By a similar arrangement of two coils of different sizes, the one suspended within the other, Ampere's fine discovery of the mutual action of two electric currents upon each other was as strikingly displayed. See Henry's figure and description of it, as follows:

"Fig. 4 is designed to show the action of two conjunctive wires on each other: A B, is a thick multiplying coil, with galvanic plates attached, in the same manner as shown in Fig. 2; *c d*, is a lighter coil with a double cylinder, precisely similar to Fig. 3, and suspended within the other by a fibre of silk, passing through a glass tube *a*, the end of which is inserted into an opening *b*, in the upper side of A B; *e f* are two wires supporting the glass tube. When the cylinder *g* and the plates C are placed in vessels of acidulated water, the inner coil will immediately arrange itself so that the currents in both coils will circulate the same way; if the vessel be removed from C, and D placed in the fluid, the coil *c d* will turn half way round and again settle, with the currents flowing in the same direction."

"With many other instruments of a similar character, Henry made visible to his classes the newly discovered principles of electro-magnetism, and it is safe to say that in simplicity, distinctness and efficacy such apparatus for the lecture room was far superior to any of the kind then existing. Should anyone be disposed to conclude that this simple extension of Schweigger's multiple coil was unimportant and unmeritorious, the ready answer comes that talented and skillful electricians, laboring to attain the result, had for six years failed to make such an extension. Nor was the result by any means antecedently assured by Schweigger's success with the galvanometer. If Sturgeon's improvement of economizing the battery size and consumption by increasing the magnet factor (in those few cases where available) was well deserving of reward, surely Henry's improvement of a far greater economy by increasing the circuit factor (entirely neglected by Sturgeon) deserved a still higher applause." (Taylor Memorial of Joseph Henry, pp. 215–216.)

THE LIMITATIONS TO LONG DISTANCE TELEPHONY.—III.

BY

We have now reached the third stated cause of the limitation to telephony and arrived at that cause which the engineer has always considered the vital one, that is, the absolute amount of decay in the amplitude of the vibration, caused by the capacity of the line, and increasing rapidly with the distance from the origin.

Again examining equation (4) we see that the effect of the capacity is first to increase the absolute value of the current at or near the origin, and, second, to cause a logarithmic decrement of its value with an increase in distance from the origin. The self-induction of the circuit causes first a decrease in the absolute value of the current at or near the origin, and, second, decreases the rate of decay caused by the capacity. Thus these two factors work in opposition and some relation must exist between them which will render I a maximum at the distant end.

Taking the first differential coefficient of I with respect to L, equating to zero and solving for L, will give us a value of L which on examination will be found to render I a maximum for any given set of conditions; that is, a definite length of line with a definite resistance, capacity and number of alternations.

$$I = -\frac{2\,E\,\sqrt{C\alpha}\qquad e^{\frac{pl}{2}}}{\sqrt[4]{R^2 + L^2\,\omega^2}\,(e^{pl}-1)} \text{ is a maximum when}$$

$$\frac{e^{\frac{pl}{2}}}{\sqrt[4]{R^2 + L^2\,\omega^2}\,(e^{pl}-1)} \text{ is a maximum.}$$

The term $(e^{pl}-1)$ becomes $(e^{pl}+1)$ when $l = \frac{1}{2}\,x_\lambda$, or an odd multiple of $\frac{1}{2}\,x_\lambda$ as previously stated. Therefore its mean value (e^{pl}) may be assumed with no error. (In all cases where the line is of considerable length the exponent pl becomes greater than unity and therefore the difference between $(e^{pl}-1)$ and $(e^{pl}+1)$ is slight.)

$$\frac{e^{\frac{pl}{2}}}{\sqrt[4]{R^2 + L^2\,\omega^2}\,(e^{pl})} \text{ is a maximum when } \sqrt[4]{R^2+L^2\,\omega^2}.\,e^{\frac{pl}{2}}$$

or $\frac{1}{4}\,log.\,(R^2 + L^2\,\omega^2) + \frac{pl}{2}$ is a minimum.

Differentiating with respect to L we have

$$\frac{L\,\omega^2}{2\,(R^2 + L^2\,\omega^2)} = \frac{l}{2}.\,\left(\frac{\omega\,p}{2\,\sqrt{R^2 + L^2\,\omega^2}}\right);$$

or $\left\{\,(R^2 + L^2\,\omega^2)^{\frac{1}{2}} - L\,\omega\,\right\}\,(R^2 + L^2\,\omega^2) = \frac{8\,L^2\,\omega^2}{C\,\omega\,l^2}.$

The term $\left\{\,(R^2 + L^2\,\omega^2)\,-L\,\omega\,\right\}$ has a maximum value of R and a minimum of 0 as L varies from 0 to infinity.

Designating it by R_o we have

$$R^2 = L^2\,\omega^2\left[\frac{8}{C\,\omega\,l^2\,R_o} - 1\right];$$

$$\text{or } L\,\omega = \frac{R}{\left[\frac{8}{C\,\omega\,l^2\,R_o} - 1\right]^{\frac{1}{2}}} \qquad (9).$$

This equation shows us that if $L\,\omega$ has a finite value the term $\frac{8}{C\,\omega\,l^2\,R_o}$ must exceed unity. Substituting the constants of the Chicago line we have

$$\frac{8}{C\,\omega\,l^2\,R_o} = \frac{8}{\frac{.017}{10^6} \times 1{,}000 \times 4 \times 10^6\,R_o} = \frac{2}{17\,R_o} \text{ at a fre-}$$

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THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—III.

BY

Mary A. Henry

HENRY used his coil not only in the instruments for experiment, described in his communication to the Albany Institute. He remarks, in a subsequent communication to *Silliman's Journal*; "Several applications of the coil, besides those described in that paper, were made in order to increase the size of electro-magnetic apparatus, and to diminish the necessary galvanic power. The most interesting of these was its application to a development of magnetism in soft iron, much more extensive than to my knowledge had been previously effected by a small galvanic element."[1] This "development of magnetism in soft iron," was the development of the electro-magnet which was to render the lagging force of Volta's battery sufficient for the telegraph.

Before we see how this was accomplished, let us pause for a moment and consider what are the two foundation elements of the telegraph, as it now exists, a thing accomplished. These are the magnet, and the battery with its long conducting wire; these form the magic circuit which in fact constitutes the telegraph. There may be innumerable ways of opening and closing the circuit at one end, and of receiving or recording the message at the other; they are only changeable accessories, which may vary in every country and period. It is the combination of magnet and battery, which gives the power to produce electro-mechanical effects at a distance and *he who brought these two in harmonious accord, so that the one responds to the influence of the other at any distance, is the real father of the telegraph.* Very earnestly would we now ask our readers to remember exactly the state of things when Henry took up this important matter. The battery was in existence, and in its circuit Sturgeon had placed his magnet; yet still the telegraph was an impossibility, pronounced so by eminent men. The electric force diminished with the lengthening of the conducting wire; and repeated experiments only tended to show the impracticability of the scheme. The telegraph is an impossibility on account of the failure of the electric current; such was the conclusion of men of science in 1825 and nothing had come to change this opinion in the three years which had followed.

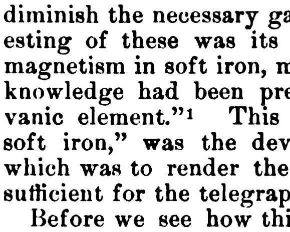


Fig. 1.—Sturgeon's Magnet.

We well remember, when approaching the great city of the past, the thrill with which we heard the cry, ringing out on the night air, "Il trano per Roma." It seems, in view of the long deferred hope of the world, now about to be realized, some such thrill might be felt as we see Henry taking up the feeble electro-magnet, destined under his hands to grow into the instrument which was at last to render the telegraph possible. Let us look again at Sturgeon's magnet, Fig. 1. According to Sturgeon's own description of it, in Nov. 1825, it consisted of a small bar of iron, bent into the form of a horse shoe, having a copper wire wound loosely around it in eighteen turns, with the ends of the wire dipping into mercury cups, the latter connected with the respective poles of a galvanic battery. Under the influence of a battery of *one hundred and thirty square inches of zinc surface, the magnet was capable of sustaining nine pounds.* Up to the year 1828, when Henry began his researches in regard to it, no improvement had been made in the instrument since Sturgeon's time; and if we consider the very large battery required to lift only nine pounds, we can understand the infant it was in strength and—while of undisputed value as a step in the progress of scientific investigation—how utterly unfitted it was for any actual service in either science or the arts.

Fig. 2.—Henry's Reproduction of Sturgeon's Magnet.

Henry's first acquaintance with the magnet was in New York, where he had seen it exhibited in some lectures given by Professor Dana. His first step was to reproduce it; we give a picture of the little instrument he made, preserved in Princeton as a relic, Fig. 2. While his hands were busy making it, his thoughts were much upon the theory Ampere had deduced from his brilliant experiments, viz.: that magnetism is produced by electricity, passing around in the magnet like rings at right angles to its length. According to this theory, Henry thought: To make a magnet is to produce these currents in it; and to make a magnet by means of a voltaic current is to lead this current around the iron core of the magnet, as nearly as possible at right angles to its length. Was this condition fulfilled in Sturgeon's magnet? The spirals of the wire were wide apart; they had to be so, otherwise the current would have leapt from one to the other and not have run its desired course through the length of the wire. The current was conducted, not at right angles, but like a corkscrew around the iron bar. What was the first thing Henry did? A simple thing it would seem, but most important. He *insulated the wire*, wound it with silk. "It occurred to me," he said, "that a much nearer approach to Ampere's theory could be attained by insulating the wire conductor and covering the whole surface of the iron with a series of coils in close contact." Following this idea Henry made a number of small magnets closely wound with silk covered wire, to exhibit to the Institute: we give his description of one of them. Its lifting power is not stated, but it was much greater than that of Sturgeon's.

"A round piece of iron about ¼ of an inch in diameter was bent in the usual form of a horse-shoe, and instead of loosely coil-

1. "Scientific Writings of Joseph Henry." Vol. 1, page 38. Smithsonian Institution, 1886.

ing around it a few feet of wire, as is usually described, it was tightly wound with 35 feet of wire covered with silk, so as to form about 400 turns; a pair of small galvanic plates, which could be dipped into a tumbler of diluted acid, were soldered to the ends of the wire, and the whole mounted on a stand. With these small plates, the horse-shoe became much more powerfully magnetic than another of the same size and wound in the usual manner, with the application of a battery composed of 28 plates of copper and zinc, each eight inches square."

This magnet "of the same size and wound in the usual manner" is Henry's copy of the Sturgeon magnet with its loose spiral. Henry must have been pleased with the success of his first steps in the improvement of the instrument. Think of the difference. To make this horse-shoe a magnet only two small plates, easily dipped into a tumbler of acidulated water, were needed; while for the Sturgeon magnet of the same size, a large and expensive battery was necessary. Then the difference in power was great. Henry continues:

"Another convenient form of this apparatus was contrived by winding a straight bar of iron 9 inches long with 35 feet of wire and supporting it horizontally on a small cup of copper containing a cylinder of zinc;—when this cup, which served the double purpose of a stand and the galvanic element, was filled with dilute acid, the bar became a portable electro-magnet."

These articles were exhibited to the Albany Institute in March, 1829.

Finding how much those little willing plates could do, Henry now called upon them for something more.

"The idea afterwards occurred to me," he said, "that a sufficient quantity of galvanism was formed by the two small plates to develop, by means of the coil, a much greater magnetic power in a larger piece of iron.—To test this a cylindrical bar of iron, ½ inch in diameter, and about 10 inches long, was bent into the form of a horse shoe, and wound with 30 feet of wire. With a pair of plates containing only 2½ square inches of zinc it lifted 14 pounds avoirdupois."

Surely the strength of the magnet was increasing rapidly.

Note: In Chapter II [The Electrical Engineer, January 10, 1894] the illustration of "De la Rive's ring" would have been better had it shown merely a turn of wire proceeding from the plates. The figure given shows a flat ring which might be taken to include a coil of many turns; whereas the "ring" was originally only a piece of wire bent in ring form.

ELECTRICAL UTILIZATION OF THE IRISH SEA TIDES.

BY W'R. LODIAN.

This is certainly the age of great engineering projects in bridge building, canal digging and tunnel cutting, while the later years of the century have seen the promotion of several notable schemes for power transmission, among which perhaps that at Niagara is the most conspicuous. The Niagara engineering enterprise rests upon the broadest grounds of feasibility, and the stability and skill with which its plans are being carried out give every promise of a brilliant and enduring success. Of some of the other projects, it is impossible to say as kind a word, strong as may be one's sympathies with daring and enterprise. In this category of the visionary, yet very interesting in its scope and suggestiveness and worthy of record, is the plan seriously proposed for the electrical utilization of the tidal currents of the Irish Sea.

Early in February last the writer concluded a series of hydrographic surveys on the Antrim coast of Ireland, and it was late in August ere a photographic acquaintance, Mr. R. Welch, of Belfast, fulfilled his promise to send views of

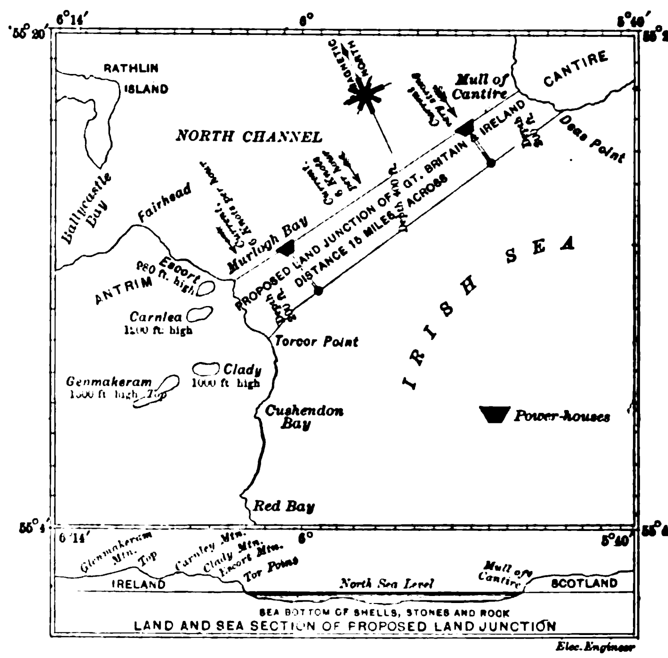
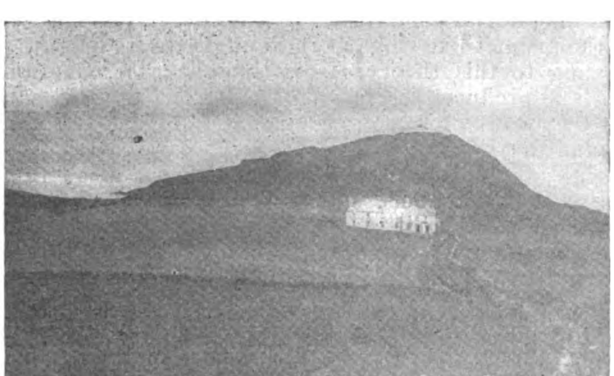


CHART SHOWING THE PROPOSED CAUSEWAY.

the ground covered. This delayed the publication of this report, which it was desired to illustrate.

The writer was specially detailed to report upon a project to connect Britain and Ireland by a land junction. It was pronounced practicable, but the question was asked: What is the use? That part of Ireland is as wild as Africa. Mr. King, the engineer, should build his land junction some hundreds of miles further south—between Calais and Dover. A land junction between France and England would be all above ground and of more stability than bridge or tunnel. As there could be three or four passages for vessels, marine traffic would not suffer interference. But unfortunately, Parliament would never sanction the construction of such an isthmus.

The primary feature of the projected land-junction will be its power-houses, and their use in the generation of electricity from the strong currents always prevailing in that part of the Irish channel. The water-power there running



TOR POINT, COUNTY ANTRIM, IRELAND.

FAIRHEAD, COUNTY ANTRIM, IRELAND.

that as soon as a trace of the blue copper containing liquid reaches the zinc plate, a black deposit of finely divided copper is immediately observed on the zinc. At this stage local action is set up between the trace of copper and the zinc plate, causing the zinc to oxidize and dissolve in the alkaline liquid, while gaseous hydrogen escapes freely from the deposited copper.[1]

The Desmazures Battery. With a view to facilitating the electrical regeneration of the Lalande battery, Mr. Desmazures has given it an entirely different construction and has been forced to alter every single part of it correspondingly. The anode or the copper part is made by compressing finely divided copper—as obtained for instance by mixing precipitated oxide of copper with zinc powder and pouring this mixture into a solution of caustic soda, or as obtained by certain galvanic reactions—on a network of copper-wire. The pressure is about 1,000 atmospheres.

In this way, a plate of porous copper is obtained, about 3 mm. thick, and of sufficient mechanical strength to stand all the handling and shocks of practical use. The specific gravity of this copper plate, although it is pretty firm and hard, does not exceed 4.1 (about one-half of the specific gravity of the solid copper) and absorbs with great facility the bodies deposited by the galvanic reactions on its surface. The plate is surrounded by a frame and provided with a proper connection and then put in an envelope of parchment paper. A grid of insulating material, such as whiting or similar substance, insoluble in the alkaline liquid, is put on both sides of the plate and again an envelope of parchment paper is applied around the whole structure. In this way, the total thickness of the anode is about 7 millimetres.

The cathode, or that electrode at which the zinc is deposited, consists of three pieces of steel wire network, held together by an outer frame of sheet steel and a connection piece on top of the plate, which is rivetted to the steel network. Plugs of insulating material are attached to the plate, in order to keep it at uniform distance from the anode. Instead of insulating plugs, a grid of ebonite may be laid on each side of the cathode, so that the thickness of this part amounts to about 8 or 9 millimetres.

The box is made of sheet steel of 1 mm. thickness. The copper plate and the steel wire plates are placed alternately in the box, and the plates pressed tightly together. The connections are made by screwing all the copper connectors together and the same is done with all the steel connectors. The box is provided with an air-tight cover of sheet steel, through which the two poles of the cell enter. A little valve for the outlet of gases is also fixed on the cover.

The electrolyte consists of a concentrated solution of caustic-potash with a certain percentage of zinc dissolved in it and containing also some mercury. Its specific gravity is about 1.6; the liquid is colorless and without any odor. It is covered with paraffine oil, to prevent the absorption of carbonic acid from the air. The addition of mercury to the liquid greatly facilitates the proper deposition of zinc and suppresses also part of the local action between the deposited zinc and the liquid.

It is claimed by the inventor of this battery that its efficiency is even superior to that of any type of the lead accumulator. No current is lost during the charging of the battery, since no gas is developed even by overcharging. The internal resistance of the cell is given as 0.35 ohm per square-decimetre surface of plates (average). The efficiency in watt hours is given as 80 per cent. under normal conditions. The reliability, durability and convenience in handling this battery are stated to be superior to that of a lead cell, while the output of electric energy per unit of weight is claimed to be at least 1½ times as great as that of the best and lightest lead cell.

1. Professor H. S. Carhart, in his book, "Primary Batteries," gives a splendid description with illustrations of three different types of the Lalande battery, and most careful and scientific tests of the Edison-Lalande type. The perusal of Professor Carhart's book is highly recommended to all interested in this subject.

It is important to keep this copper-zinc accumulator free from contamination with ammonia, nitric acid, chlorine, or any like substances, liable to attack the copper or steel in the cell.

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—IV.

BY

Mary A. Henry

Still brooding over the theory of Ampere, Henry was not content. The current was still led, although in a less degree, in an oblique direction, and not at right angles to the length of the iron bar. Sitting one evening at home in his study, lost in a deep revery, although a friend was with him, the idea came to him that he could obtain the condition the theory required by winding the wire backward and forward in several layers around the iron core.

"The successive spirals of wire, coiling first in one direction then in the other, would tend to produce a resultant action of the current at right angles to the core, and that furthermore in the great number of revolutions thus obtained the current would act on a greater number of molecules of the bar and so excite greater magnetism."

He sprang to his feet, and striking his hand upon the table near him exclaimed: "To-morrow I will make an experiment which in its result will astonish the world." "When the conception," he said, "came into my brain, I was so pleased with it I could not help rising to my feet and giving it my hearty approbation!" (If this seems at variance with Henry's well-known and great modesty it must be remembered that it was an involuntary expression of delight, uttered only in the presence of a very intimate friend. Even modesty could not blind his eyes to the value of his researches in their bearing on the telegraph, which at this time, as later, he fully recognized). He made the experiment the next day, and to his delight and encouragement success again rewarded him.

He tested his theory on the magnet we have just described as lifting fourteen pounds. Over the wire, which was already closely wound on the iron core, he wound another insulated wire, in such a way as to give the effect of a long continuous wire wound upon itself. He says:

"A second wire of the same length as the first was wound over it, and the ends soldered to the zinc and copper in such a manner that the galvanic current might circulate in the same direction, or, in other words, that the two wires might act as one; the effect by this addition was doubled, as the horse-shoe, with the same plates before used, now supported 28 lbs. With a pair of plates, 4 inches by 6 inches, it lifted 39 lbs., or more than *fifty times its own weight.*"

Where was Sturgeon's magnet now, lifting only its nine pounds with its battery of one hundred and thirty plates, in comparison with this magnet of Henry's sustaining fifty times its own weight under the influence of only a single pair of plates? Fig. 1.

"The same principle," Henry says "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."

"In the arrangements 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 upon and 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."

Was there a limit to the process; could the magnet already so strong continue to increase in power as more and more wire was wound in this way upon it? Henry found, after a certain length of wire had been coiled upon the iron, that the power diminished with the further increase of the number of turns. This was due "to the increased resistance which the longer wire offered to the conduction of the electricity." Had a limit indeed come to the power of the hitherto willing magnet to respond to the ever increasing demands of the young philosopher? No; Henry, undaunted, conceived a method of producing still greater power. He says:

"Two methods of improvement 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 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."[2]

In order to test the first method "a number of compound helices were placed on the same bar, their ends left projecting and so numbered, that they could be all united into one helix, or variously combined into sets of lesser length." So there came into being another magnet, shown in Fig. 2. The magnetic effect was greatly increased. We quote again from Henry:

"These experiments conclusively prove that a great development of magnetism could be effected by a very small galvanic element; and also that the power of the coil was materially increased by multiplying the number of wires, without increasing the length of each.

"The multiplication of the wires increases the power in two ways; first, by conducting a greater quantity of galvanism, and secondly, by giving it a more proper direction; for since the action of a galvanic current is directly at right angles to the axis of a magnetic needle, by using several shorter wires we can wind one on each inch of the length of the bar to be magnetized, so that the magnetism of each inch will be developed by a separate wire; in this way the action of each particular coil becomes very nearly at right angles to the axis of the bar, and consequently the effect is the greatest possible. This principle is of much greater importance when large bars are used. The advantage of a greater conducting power from using several wires might, in a less degree, be obtained by substituting for them one large wire of equal sectional area, but in this case the obliquity of

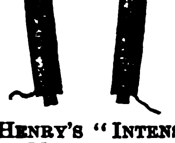


FIG. 1.—HENRY'S "INTENSITY" MAGNET.

FIG. 2.—HENRY'S "QUANTITY" MAGNET.

the spiral would be much greater and consequently the magnetic action less; besides this, the effect seems to depend in some degree on the number of turns, which is much increased by using a number of small wires. (Several small wires conduct more common electricity from the machine than one large wire of equal sectional area: the same is probably the case though in a less degree in galvanism.)"

In Henry's cabinet were now two distinctly different magnets, one with a long continuous coil of fine wire, wound back and forth on itself; the other with a number of short thick wires; the latter much the stronger. He called the one the "*Intensity*" the other the "*Quantity*" magnet. We will let him tell why he thus designated them.

"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.

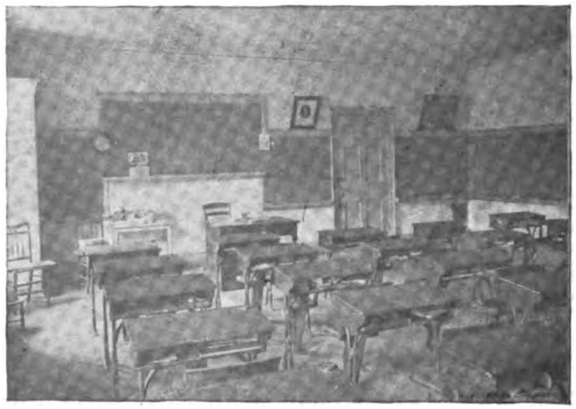


FIG. 3.—ROOM IN ALBANY ACADEMY, ORIGINALLY OCCUPIED BY HENRY.

"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 was to be employed, and when the maximum effect was to be produced by a single battery a number of single strands were to be used."

The Institute was not insensible to the value of Henry's contribution to science and art, as the young man appeared again and again before the society, each time with magnets more powerful. These were received with enthusiasm and the fame passed beyond Albany to give their maker distinction.

Let us glance at the room that Henry occupied while making these experiments. An item recorded in one of the books of the Academy, Sept. 8, 1826, when Henry entered the Institution as a professor, tells us which room was assigned him, a room which he retained until the latter part of the year 1829: "*Resolved* that Prof. Henry be allowed the use of the South West Room in the third story of the Academy during the pleasure of the Board." This was Henry's work room, school room, lecture room. A long table extended across one side, and from this a series of long benches, rising in tiers one above the other filled the room. The illustration we give, Fig. 3, is from a photograph of the room as it is now, still used as a school room by the Academy.

2. "Scientific Writings of Joseph Henry." Vol. II, p. 430.

AN ELECTRIC FREIGHT SERVICE BETWEEN ALBANY AND TROY, N. Y.

The express cars to be used by the Albany City railway company in carrying merchandise between Albany and Troy are equipped with motors and are ready to be placed in use on the road. The company have secured the building at the corner of Broadway and Nineteenth street, West Troy, for a depot, and as soon as an office shall be fitted in the building at the corner of State and Dean streets, Albany, the express line will be put in operation. It is expected the placing of the cars on the road will lead to a lively rate war with the owners of express wagons between Albany and Troy. The cars will commence running about April 1.

charging, at least the same durability, or even a greater, could be obtained than with the lead-accumulator. The handling of the Phillips-Entz cell is no doubt a little more complicated than that of a lead accumulator. Everything considered it must be said that the practical work of those batteries, installed for traction purposes by the inventors, alone can decide and prove the superiority of this type.

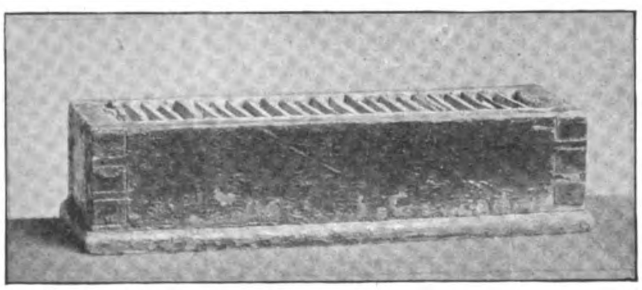
THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—V.

BY

Mary A. Henry

We have come to a very important day in the history of the telegraph.

We have seen in the last chapter how the magnet grew under Henry's hands until it could lift fifty times its own weight, and how, when it had seemed to come to the limit of its power, Henry had conceived another method of winding the wire on the iron, so as to form an instrument of still greater strength. Did Henry neglect his first child for this its new, strong brother? Not so, and it was well, for it had its secret, which on this day it revealed. When it failed to respond to his demands beyond a certain length of wire, the question of the relative capacity of different lengths of wire to transmit the electrical current immediately seized upon his mind, and it was to test this that he undertook a series of experiments on this memorable day.



PROF. HENRY'S "COMPOUND" BATTERY.

It was the year 1829, and July was just ending or August just begun. As Henry entered the Academy building he directed his steps to a long room or hall—used for the public ceremonies of the institution—where the experiments were to be made; and where, he says —"1060 feet, a little more than one-fifth of a mile of copper wire of the kind called bell-wire, .045 of an inch in diameter were stretched several times across the large room."[1] We may not attempt to give in detail all the experiments, although only a few of them were recorded. We confine our attention to one of them and the steps which led to it; the one in which Henry made the combination which constitutes the telegraph; the only combination possible for the telegraph, now as then. Not by accident was this combination made; it was the necessary result of the process of research. What was the combination? A magnet, a battery, and that long wire around the room. *The magnet*:—it was not the stronger one of many coils, but the first, of one long coil, with its secret which there and then it revealed, and this was the secret:—that it possessed the subtle power of being excited by electricity from a distant source. *The battery*:—it was not one of a single pair of plates, such as we have seen Henry using, but a compound battery of many plates, shown in Fig. 1. It too had its secret, which it too then revealed, viz.:—that a current of electricity from it could act upon a magnet through a wire of any length, as easily as if attached directly to the magnet, provided it had this particular magnet to act upon. But we are anticipating. Let us see how Henry made this combination.

We have seen that hitherto his attention had been confined to the lifting power of his magnets, and that his aim had been to produce the greatest magnetic effects with the smallest expense of galvanic power. We have seen him working constantly with a single pair of galvanic plates, and these very small. On this day he was to see how his magnets could act at a distance. The object of his experiments was to investigate—by means of different lengths of wire, and batteries of different strength—the resistance of the wire to the electric current. Besides single plates of various size, he had ready a compound battery of *twenty-five plates*, arranged in a trough, as we have said. The resistance of the wire to the electrical current! We recognize in it the old, old difficulty in the way of the telegraph. Henry about to investigate it, was in fact face to face with the recreant electricity, to demand of it why in all these years it had baffled the world by failing to act at a distance. His assistant in the experiments to be made was a young man of his own age Dr. Philip Ten Eyck, of Albany.

He began the experiments with the same small pair of plates we have seen serving him so well, two inches square. He used at first a galvanometer to tell whether the electric current could exert any effect, acting through a long wire stretched back and forth across the room.

"From the mean of several observations the deflection of its needle was 15 degrees." Then Henry substituted the magnet of a single coil. This magnet, so ready to respond hitherto to the action of these two plates—would it do so through this one-fifth of a mile of wire? "The magnetism was scarcely observable in the horse-shoe." Was the old world right; was the galvanic force unable to act through any great length of wire?

"The small plates were removed" and larger tried, "a battery composed of a pair of zinc plates 4 inches by 7 inches, surrounded with copper was substituted. When this was attached immediately to the ends of the 8 feet of wire wound round the horse-shoe, the weight lifted was 4½ lbs: when the current was passed through the whole length of wire (1060 feet) it lifted half an ounce."

Again the result seemed to say that galvanic power could not overcome the resistance of a long wire.

Did Henry try still larger plates? Had he made them many times the size, the result would have been relatively the same. He abandoned the battery of a single pair of plates; the compound battery of many plates stood there in its trough, and then was made the experiment which gave the telegraph. Let us give it in Henry's own words.[2]

"*Experiment* 7. The whole length of the wire was attached to a small trough on Mr. Cruikshank's plan, containing 25 double plates and presenting exactly the same extent of zinc surface to the action of the acid as the battery used in the last experiment. The weight lifted in this case was 8 oz.; when the intervening wire was removed and the trough attached directly to the ends of the wire surrounding the horse shoe it lifted only 7 oz. *From this experiment, it appears that the current from the galvanic trough is capable of producing greater magnetic effect on soft iron after traversing more than ⅕ of a mile of intervening wire, than when it passes only through the wire surrounding the magnet.* It is possible that the different states of the trough, with respect to dryness, may have exerted some influence on this remarkable result, but that the effect of a current from a trough, if not increased, is but slightly diminished in passing through a long wire, is certain. A number of other experiments would have been made to verify this had not our use of the room been limited, by its being required for public exercises.

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1. *Silliman's Journal*, Jan., 1831—Vol. XIX.

2. *Silliman's Journal*, Vol. XIX, or Writings of Joseph Henry, Vol. I., p. 41—Smithsonian Contributions.

"On a little consideration however, the above result does not appear so extraordinary as at first sight, since a current from a trough possesses more "projectile force," to use Prof. Hare's expression, and approximates somewhat in intensity to the electricity from the common machine. May it not also be a fact that the galvanic fluid, in order to produce the greatest magnetic effect, should move with a small velocity, and that in passing through one fifth of a mile, its velocity is so retarded as to produce a greater magnetic action: But be this as it may, the fact, that the magnetic action of a current from a trough is, at *least*, not sensibly diminished by passing through a long wire, is directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph; and it is also of material consequence in the construction of the galvanic coil. From these experiments, it is evident, that in forming the coil we may either use one very long wire or several shorter ones as the circumstance may require: in the first case our galvanic combinations must consist of a number of plates so as to give 'projectile force'; in the second, it must be formed of a single pair."

How simple are the words which tell, as if it were some unimportant matter, that the circuit was at last formed in which electricity would not fail; but not only had Henry's magnet responded to that battery through all that length of wire more easily than when magnet and battery were in immediate contact; the closing words of the paragraph quoted show that Henry had fully recognized the cause of the phenomenon. He had made the great discovery of the law of relation between the "projectile force" in the battery and the resistance in the coil.

He knew the importance of what he had accomplished; he says:—

"This was the first discovery of the fact that a galvanic current could be transmitted to a great distance with so little 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."

So they were brought together for the first time that day,—the battery which could act at a distance and the magnet which could be acted upon at a distance. The magent was Henry's; he had endowed it with its subtle power. The battery was not his; but he had discovered its latent power and how to awaken this by calling in the aid of his own child.

In the telegraph of to-day the magnet used to receive the message is the same as the magnet used in the combination formed that day in Albany. The battery is essentially the same, but the one fifth of a mile of wire has stretched to many miles, even to the three thousand that lie between the shores of the ocean; and Henry's magnet answers as easily to the electric effects of the battery through all this distance as it did there in that room. The discovery made that day was to effect the world.

How do we know the date of these experiments? Henry published his account of them in *Silliman's Journal* of Jan. 1, 1831. He does not say positively, in that paper, whether they were made in 1829 or 1830, and why we place it in 1829, we will tell a little later. For the month we refer the reader to a casual remark of Henry which we have quoted. He says: "A number of other experiments would have been made to verify this had not our use of the room been limited by its being required for public exercises." These public exercises took place on the annual exhibition day of the academy; they consisted in speeches and other exercises by the pupils; and were attended by the parents of the boys and the friends of the institution. It was the great day of the year for the Academy. According to the records it was the 9th of August in this year, 1829. The three or four days preceding it were devoted to examinations of the pupils, also open to the public. In was on the 5th of August this year that Henry's classes were examined. As in the interest of the experiments Henry, as he indicates, would have retained the room as long as possible, we place the experiments in one of the first two or three days of the month of August or in one of the very last days of July.

The small trough battery used is now in the National Museum at Washington. It not only told Henry that day that electricity could act at a distance; it led him to another discovery. In the course of the experiments, the poles of the battery had been connected with a long wire. As Henry detatched one end of this, from wire to battery flashed a brilliant spark. This was a beautiful invitation to research in a new field. It was Henry's first intimation of the phenomenon of self-induction or the "extra current" as it is called. Henry says: "My experiments on the transmission of power to a distance were superseded by the investigation of a remarkable phenomenon, which I had observed in the course of these experiments, of the induction of a current of a long wire on itself, and of which I made first mention in a paper in *Silliman's Journal* in 1832, Vol. xxii." As soon as he had made a practical test of his discovery in regard to the telegraph he accepted the invitation of the spark, and so began investigations, which were at intervals continued in Albany and Princeton, until he was called to the charge of the Smithsonian Institution. That bright spark is of particular interest just now, since it is on account of the investigations it prompted that Henry's name has been given to the unit of inductance.

The evening of the eventful day had come, and Henry went home to receive that sympathy which from the constitution of his nature was especially essential to him in everything. "Sympathy is, with the man of genius especially (and in a measure with all men) an intellectual want as necessary as the coarsest elements of existence. I can bear testimony to the truth of this saying." These are Henry's words.

BI-METALLIC TELEPHONE CONDUCTORS.

BY

A. E. Kennelly

Concerning bi-metallic telephone wires, it appears to the writer that any proposition which asserts that a combination of two metals in a conductor is superior for telephonic purposes to a similar conductor of either metal alone,—seems to be entirely new, deserves to be considered with circumspection, and lays the burden of proof entirely upon experimental evidence.

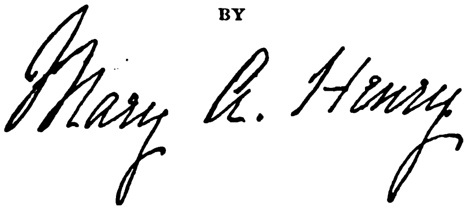
In the case of iron, however, it is orthodox to suppose that the inductance possessed by an iron wire is advantageous in long distance telephony within reasonable limits if the resistance of the conductor were at the same time capable of being sufficiently reduced. Also that when a definite adjustment between inductance, resistance, and capacity of the conductor has been attained, it is consistent with present recognized views to suppose that a comparatively low insulation can be permitted. In this connection lies the possibility for a superiority of a compound iron-copper wire over one wholly of copper or of iron; but even then the advantage, if due to these reasons, should attend definite relations of composition and disposition in the wires and not iron-copper wires indiscriminately.

MR. MAXIMILIAN MINTZ.

A CORRESPONDENT inquires for the address of Mr. Maximilian Mintz, representative of the Grob petroleum engine. Replies may be addressed to this office.

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—VI.

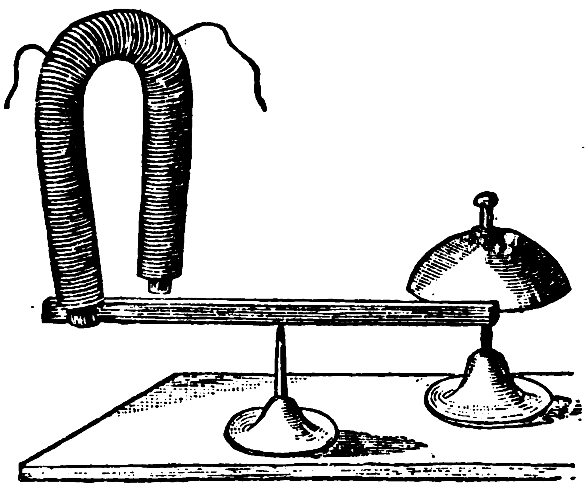
BY



We have seen Henry making that circuit in which electricity was willing to act at a distance and discovering the reason why the great motive force was at last so complaisant after baffling the efforts of man for more than a century; we have seen him making that combination of magnet and battery which in fact constitutes the telegraph. "A number of other experiments," Henry says, "would have been made to verify this had not our use of the room been limited by its being required for public exercises."[1] These were the exercises of the exhibition or Commencement day of the Academy. When that day was over there was quiet in the empty rooms; a vacation of three weeks was before Henry—a delightful, free time to devote to scientific research.

"At the conclusion of the series of experiments," Henry says, "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*, Vol. XX., 1831, and for the purpose of experimenting in regard to the second, I arranged, around one of the upper rooms of the Albany Academy, a wire of more than a mile in length, through which I was enabled to make signals by sounding a bell. 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."

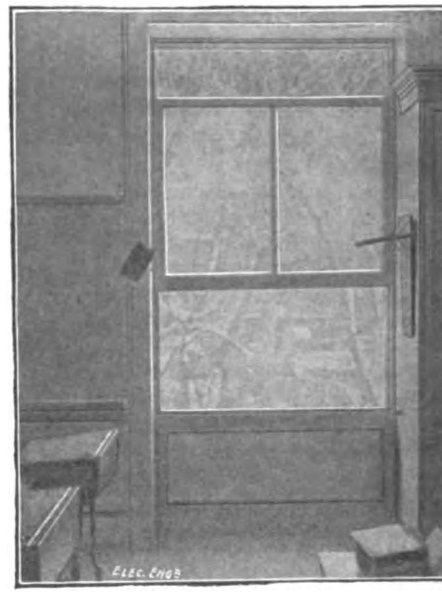
Surely it was another marked day in his life when Henry thus put to practical test the power of the circuit he had



HENRY'S ORIGINAL TELEGRAPH APPARATUS.

formed. We go back in imagination to see him make the trial. It is made in an upper room, the room appropriated to his use when he entered the Academy, his school room, lecture room and laboratory. His friend, Dr. Ten Eyck is his assistant. Around the wall passes the wire, a mile long. The battery is the same Cruikshank's trough, we saw him use on that memorable day in the long room.

The "intensity" magnet, if not the same, is of similar construction. In the recess of a window it is placed, and between its arms trembles the small steel magnet upon its pivot, while close at hand is the little bell. The magnet and battery are connected; the electric current begins;



THE STARTING POINT OF HENRY'S ORIGINAL TELEGRAPH LINE.

the mile of wire does not stop it; the iron horse-shoe wakes to life; the magnetic bar, ready to respond, springs to one pole, to strike with its free end the little bell; the bell rings. The telegraph has given its first signal. The first electro-magnetic telegraph is in existence.

(As we write these words we seem to hear a protest, and to see a finger pointed to some one or other of those telegraph efforts we have noticed in classes. We answer, perhaps with tedious repetition, those efforts, unable to surmount that great difficulty, the failure of the electric force, were not telegraphs in the sense that common use has given the term; they produced signals by means of electricity, which could be used to communicate intelligence, but they could not make these signals at any great distance. Henry, in the course of a few months had made the sensitive "intensity" magnet, the only intrument which could respond to electric influence at a distance; he had made the combination of magnet and battery, essential to the telegraph, and now, merging the discoverer in the inventor, he had made with that magnet and that combination, by the application of a mechanical contrivance, an apparatus capable of practical work. This telegraph in Henry's room, was not only the first, it was the first possible. It has been said it was not a telegraph, because it was not used commercially. Are our fingers not fingers, because we may not have used them for purposes of trade? This was an actual working telegraph, making sound signals exactly as the telegraph of to-day makes the sounds which give the telegraphic message; and later, in Princeton, Henry used the same arrangement in his philosophical hall to communicate with his wife in his residence, the wires stretching across the college grounds. But all this is a digression.)

Yes, the first telegraph in which there was no danger of the failure of the electric force was in existence. There was only a mile of wire around that room, but with no change in the principles there exhibited; in accordance with the laws there illustrated, that wire was to extend until it connected the Old World with the New, finding not even then a limit to the power of the electric current to act at a distance. We are told that a sound never is lost,

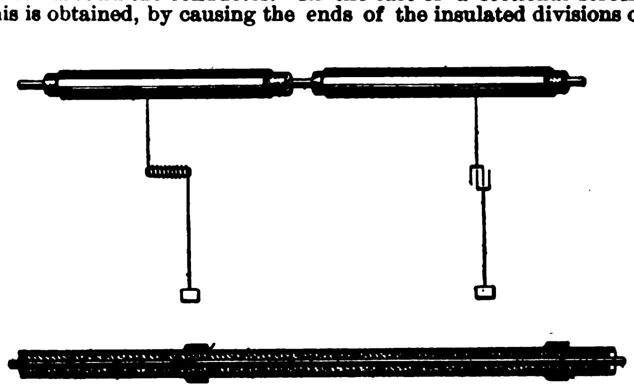
1. Writings of Joseph Henry, vol. 1, p. 42, or *Silliman's Journal*, Jan. 1831, vol. XIX.

that with the new phonetic instruments of the day, the falling stream may give back the words spoken near it, and what we say to-day may be repeated a century hence. There may come a time when history will be read by the ear, instead of the eye; when man may go back to the past, not to search in dusty archives, and among prejudiced records, but to wring from the air each sound that has broken it since it was first breathed by the human race; then this little bell will ring again and tell how and where this telegraph was born—the telegraph which could meet the long cherished desire for distant communication. It had made its first sound; there was its birthplace in that upper room of the Albany Academy, where the holes in the walls, only a few years ago showed where the wires were fastened. Do we say this was the birthplace of the telegraph? We must make here the distinction we have made elsewhere; the ringing of the bell was only one mode of using that combination of magnet and battery, which we have said really constitutes the telegraph. The long exhibition room, where that combination was first made, is the real birth place of the telegraph.

THE TESLA HIGH POTENTIAL CONDUCTOR.

In order to prevent loss by dissipation or interference by induction on line conductors carrying high potential alternating currents they have in some instances, such as at Deptford, London, been insulated and inclosed in a continuous conducting sheathing which is connected with the ground by a good conducting path.

While conducing to the safety of the system, Mr. Tesla has found that the use of a conducting sheath or screen around the line conductors and well grounded, or even brought into proximity to external conductors or large bodies is attended by an actual, and generally a serious, loss of energy which is the greater, the greater the number of alternations and the higher the potential. He therefore maintains the sheath either entirely isolated or connected directly or inductively to the ground, through a path which will practically prevent the passage of currents over it. He has also found that when a continuous isolated sheath or screen is employed, there is greater liability to loss of energy by inductive action; for, unless the sheath or screen be considerably shorter than the current waves passing in the conductor, electromotive forces will be set up between different points in the sheath, which will result in the passage between such points of induced currents. Mr. Tesla therefore, divides up the sheath or screen into short lengths, very much shorter than the wave lengths of the current used, so that the grounding of any one of such lengths or the approach thereto of a large body will result in an inappreciable loss, or at most a small local draining of the energy, while the tendency of currents to flow between different points in the sheath is effectually overcome. The function of the sheath as a static screen for preventing the dissipation of the electric energy, however, requires for its complete effectiveness an uninterrupted conducting partition or screen around the conductor. In the case of a sectional screen, this is obtained, by causing the ends of the insulated divisions or



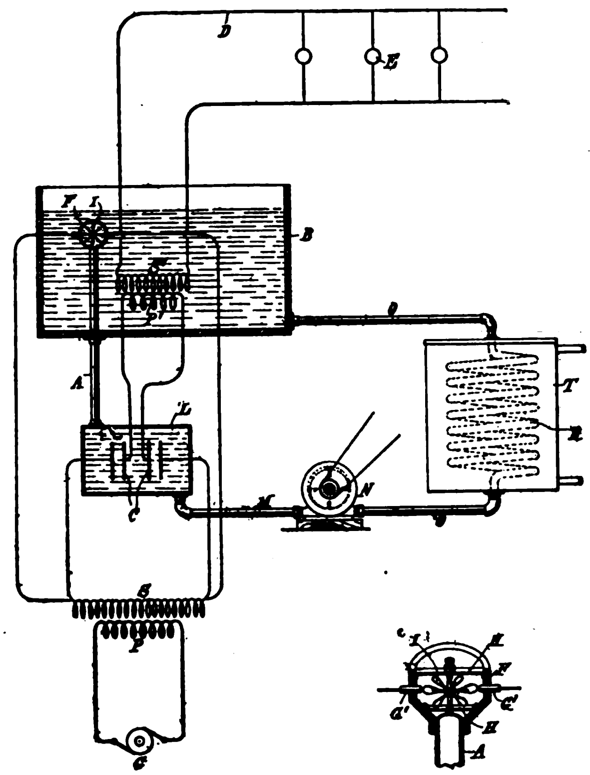
FIGS. 1 AND 2.—THE TESLA HIGH POTENTIAL CONDUCTOR.

sections to overlap, and interposing insulating material between the overlapping portions.

For transmitting currents of very high potential and very high frequency, Mr. Tesla provides between the sheath and the ground a path of very high ohmic resistance, or one containing a self-induction coil properly determined with respect to the existing conditions so that it will effect the desired result, or a condenser of very small capacity, as shown in Fig. 1. In such cases the sheathing or screen for practical purposes may be regarded as isolated from the ground, since by the character of the connection employed no appreciable loss results from the passage of current from the sheath to the ground. Fig. 2 shows the construction of an actual conductor of embodying the idea.

TESLA'S AUTOMATIC FLUID INTERRUPTED FOR PRODUCING HIGH FREQUENCY CURRENTS.

The Tesla system of lighting and power transmission with high frequency and high potential currents, as is now well known, involves the maintenance of an intermittent or oscillatory discharge



TESLA'S AUTOMATIC FLUID INTERRUPTER.

of a condenser or circuit of suitable capacity into a working circuit containing lamps or other devices. In systems of this character when the high frequency of the currents employed is due to the action of a disruptive or intermittent discharge across an air gap or break at some point of the circuit, Mr. Tesla has found it to be of advantage not only to destroy the least tendency to continuity of the arc, but to control the period of its re-establishment, and from investigations made with this object in view he has found that greatly improved results are secured by causing the discharge to take place in and through an insulating liquid, such as oil, and, instead of allowing the terminal points of the break to remain at a uniform distance from each other, to vary the distance by bringing them periodically in actual contact or sufficiently near to establish the discharge and then separating them, or what is the equivalent of this, throwing in and out of the gap or break a conducting bridge at predetermined intervals. To obtain the best results, moreover, Mr. Tesla finds it essential to maintain at the point of discharge a flow of the insulating medium, or, in general, such a circulation of the same as will constantly operate to cut off or break up the discharge as fast as it is established. The accomplishment of this latter result involves the employment of some mechanism for maintaining the flow or circulation of the insulating medium past the points of discharge, and he takes advantage of the presence of the same device to maintain the circulation of the insulating liquid in which the converter for raising the potential and the condenser plates are immersed; by this means the liquid is prevented from heating.

All this is accomplished by a pumping arrangement shown in Fig. 1, the spark gap being controlled by a small turbine which is shown enlarged in Fig. 2. When the pump is started up and the turbine I revolves, the blades bridge the space between the two terminals, nearly or quite touching the terminals in their movement. If now the tank B be filled with oil and the latter permitted to flow off through the tube A, the turbine will be rotated by the flow, the rate of rotation being dependent upon the rate of flow. By this means the arc or discharge is periodically established through a flow of oil, which secures in the most satisfactory manner the conditions best adapted for practical results. The flow of oil is regulated by the speed at which the pump N is driven, and by this means the period of re-establishment of the arc is controlled. A cooling tank T may be provided if necessary.

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—VII.

BY

Mary A. Henry

It should be remembered that Henry had not only discovered the relation between the intensity magnet and battery, but also that between the quantity magnet and battery. The arrangement just described was an intensity combination; Henry also tested the quantity combination. The apparatus for this, made jointly by Dr. Ten Eyck and himself, is in existence. It consists of a wooden frame, in which hung one of Henry's earliest quantity magnets now detached, but with the apparatus on a shelf attached to the frame is an insulated solid coil of short, very thick wire; there are two little magnets, with armatures so arranged that they can strike a hollow metal cone, used instead of a bell. This formed a convenient portable means of exhibiting the action of the electrical current. When Henry left Albany it was used by his successor, Dr. Ten Eyck, to illustrate Henry's discoveries, and was given by Dr. Ten Eyck to a favorite pupil, who is still the owner of the interesting relic. The reader knows the place the short quantity circuit holds in the telegraph.

We have glimpses of the telegraph in 1830 and the two following years through the eyes of Mr. Orlando Mead, late of Albany, who was one of Henry's pupils; he says:

"The older students of the Academy in the years 1830, 1831 and 1832, and others who witnessed his experiments, which at that time excited so much interest in this city, will well remember the long coils of wire which ran, circuit upon circuit, for more than a mile in length around one of the upper rooms in the Academy, for the purpose of illustrating the fact that a galvanic current could be transmitted through its whole length, so as to excite a magnet at the farther end of the line, and thus move a steel bar, which struck a bell. This, in a scientific point of view, was the demonstration and accomplishment of all that was required for the magnetic telegraph. The science of the telegraph was here complete. * * * Let us not forget that the click of the telegraph which is now heard from every joint of those mystic wires which now link together every city, and village, and post and camp, and station all over this continent is but the echo of that little bell first sounded in the upper room of the Academy."[1]

The following is another testimonial of an eye-witness to the operation of this telegraph. The Hon. Alexander W. Bradford, also a pupil of the Academy under Henry in 1831, says in an address, on the same occasion.

"And there is another professor, whose life has been spared, who rose with the sun to instruct his pupil, eager for knowledge; who, giving his heart and soul to the duties of the school, had yet time for exploring the deep paths of science; who, with his wires and silk thread, winding wires of insulated copper in the Commencement Hall of the Academy, patiently toiled his way to the demonstration of the magnetic power of the galvanic battery; and years before the introduction of the telegraph proclaimed to America and Europe the means of communication by the electric fluid. I was an eye-witness to those experiments and to their eventual demonstration and triumph."

Dr. James Hall, the distinguished geologist, (in the year he was president of the American Association) in a letter to Prof. Henry dated January 19, 1856, gives the following reminiscence.

1. Address on the celebration of the Semi-Centennial Anniversary of the Albany Academy, June 23, 1863.

Dear Sir:—While a student of the Van Rensselaer School, in Troy, New York, in August, 1832, I visited Albany with a friend having a letter of introduction to you from Prof. 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[2] room in an upper story some electric and galvanic apparatus. 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 the electric telegraph, I have often had occasion to mention the exhibition of your electric telegraph in the Albany Academy in 1832. (*Smithsonian Report*, 1857.). 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 stated, with many other attendant circumstances should they prove of any importance.

I remain very sincerely and respectfully yours,

James Hall.

Professor Joseph Henry.

This telegraph of Henry's was properly an acoustic telegraph. The telegraph when first introduced into general use, in various ways, by dots and lines or printed letters, recorded its message on a moving slip of white paper; but the operator of to-day listens to its sound, and writes the message, and so it has come to pass that the telegraph is to-day again an acoustic telegraph, and its click heard everywhere is, in Mr. Mead's expressive phrase, *functionally and in truth* but the echo of that little bell which first sounded in that upper room in the Albany Academy.

BRENNER'S ONE-VOLTMETER METHOD OF SWITCHING DYNAMOS IN PARALLEL.

In order to ascertain when the voltage of a dynamo is at the right point for switching it on to a line in parallel with others, one of two methods is employed. In the first, two voltmeters are used, one to indicate the voltage of the line and the other that of the dynamo. Both of these instruments must be calibrated so that their readings correspond, and, if one of them give a false reading, as might easily happen, the generator may not be thrown on to the line at the right moment. In the second method, one voltmeter only is needed, which is connected alternately with the line and the dynamo by a switch. Though this method has an advantage over the first in requiring but one voltmeter, it has the disadvantage that the voltage of the line may change while that of the dynamo is being measured. This is a serious objection in electric railway power stations where the pressure on the line is continually fluctuating.

The advantages of each of these methods are retained and their defects overcome by an ingenious system devised by Mr. W. H. Brenner, the electrical engineer of the Montreal Street Railway Co., of Montreal, Canada. His arrangement, which requires but one voltmeter, has been used for some time in the Cote Street power station of the company, where it has given great satisfaction owing to its convenience and accuracy. By this system the generator to be switched in is connected temporarily to the line in series with the voltmeter in such a manner that the voltage of the dynamo opposes that of the line. The voltmeter then indicates the difference between the two voltages and thus the proper time to throw in the generator is ascertained.

The system as arranged at Montreal is shown in the accompanying diagram which represents the four generators in the station ready to be switched on to the line.

2. The rooms are about the same size, the upper one seemed larger, probably, because the lower was filled with raised seats.—M. A. H.

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—VIII.

BY

Mary A. Henry

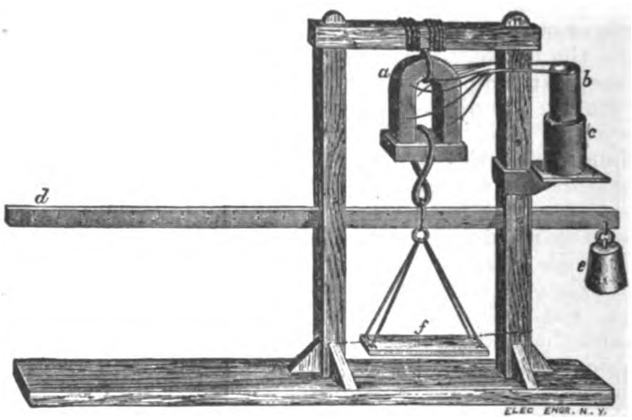
The telegraph in Henry's room was sufficiently complete in all essential particulars to be prepared for public use; but Henry says, of the arrangement we have described, "it was merely a temporary one, I had no idea of abandoning my researches for the practical application of the telegraph." The bell rung by electricity attracted great attention; Henry's friends urged him to take out a patent for his apparatus, but he refused. On a paper lying on my desk are these words in his handwriting:—"Why did not I take out a patent for my application of the electro-magnet to the telegraph? * * * * *I thought it unbecoming the dignity of true science to curtail the use of a discovery to personal and selfish ends; on the contrary I thought it right to give it to the world, as a means of advancing humanity.*" When Henry had proved that his experiments had solved the problem of distant communication, he left the telegraph, for a time, to investigate the curious phenomenon of the induction of an electrical current in a long wire, which he had observed in the experiments in the long room.

It was a brilliant spark, it may be remembered, which, as Henry was disconnecting one end of a long wire uniting the poles of a battery, drew his attention to this phenomenon. The discovery to which it led him, of self-induction, or the "extra current," as it has been called, opened a new field of science; that of the induction of currents. In this field Henry's name and that of Faraday must be always associated; for these two men were the first to enter it; but it should be noticed that it was Henry who opened the field and that in this year 1830 he was alone in it. Faraday entered with the discovery of magneto-electricity but not until August 1831. And it was not until the summer of 1834, four years after Henry, that he made the same discovery of the extra current, to investigate which Henry now leaves the telegraph.

It is November 1830 before we find Henry at work again on his magnets. He is in a new room in the basement of the Academy; it is more comfortable in many ways than the upper room, since it is provided with a furnace and other conveniences for research, while a room in the rear is useful for many laboratory purposes. The intensity magnet of a long single wire has proved its value, in its power to act at a distance, and Henry has now turned his attention to the quantity magnet with its many coils. When we left it, the reader will remember, it was lifting fifty times its own weight with only two very small galvanic plates, leaving far behind the feeble Sturgeon magnet with its large battery. Henry is now making, on the same plan, a larger magnet, winding as before on an iron bar a number of separate coils which could all be united so as to form one single coil while each could be used separately or in combination.

The bar of soft iron was two inches square and twenty inches long; it weighed twenty-one pounds; it was wound with copper bell wire in nine coils of sixty feet each. It was in the form of a horse shoe and was suspended in a rectangular wooden frame three feet nine inches high. An iron bar was suspended below the magnet so as to act as a lever and the different weights supported were estimated by a sliding weight in the same manner as with a steel-yard. The picture of the magnet given is from Henry's paper.

Henry experimented in various ways, attaching the wires, now in one combination now in another, to the battery until, when "all the wires (nine in number) were attached, the maximum weight lifted was 650 lbs." and this result "was produced by a battery containing only two-fifths of a square foot of zinc surface and requiring only half a pint of diluted acid for its submersion." Not content with this result Henry forced the magnet at last to sustain "750 lbs." "In this case a plate of zinc, 12 inches long and 6 inches wide and surrounded with copper, was substituted for the galvanic elements before used." There stood then in Henry's room the most powerful magnet in the world, we quote again from his paper. "The strongest magnet of which we have any account is that in the possession of Mr. Peale of Philadelphia; this weighs 53 lbs. and lifted 310 lbs., or about six times its own weight. Our magnet weighs 21 lbs. and consequently lifts more than thirty-five times its own weight; it is probably then the most powerful magnet ever constructed." In speaking thus of his magnet Henry was comparing it with the permanent steel magnets which had been so long in existence, in which magnetism had been produced by rubbing or by contact with another magnet; the only electro magnet with which Henry at that time could compare it was the feeble instrument of Sturgeon.



HENRY'S MAGNET OF 1830.

This is Henry's first quantity magnet of any considerable size, but it has a much deeper interest, for it is the one with which we first see Henry producing the phenomenon of magneto-electricity. He carried it one day to that long exhibition room, where we have before seen him at work. "A piece of copper wire about thirty feet long and covered with elastic varnish was closely coiled around the soft iron armature" the ends of which were connected with a galvanometer forty feet away. The question to be asked—an experiment is always a question—was:—can magnetism produce electricity? This was an old question, asked first a decade before, when Oersted found out the opposite;—that electricity could produce magnetism. Henry's magnet answered *yes* to the question; for when it was excited a current of electricity was produced in the wire around the armature, as the moving of the needle of the galvanometer indicated. Faraday later obtained the phenomenon much in the same way, but he published first, and so Henry in accordance with scientific codes laid down all claim to the discovery. Henry had at that time, beside Dr. TenEyck, another assistant, Mr. George W. Carpenter. The following extract from a letter written by him last Fall are interesting, in connection with this matter.

"I was a pupil of Professor Joseph Henry, in the year 1826, when he was appointed to take charge of the mathematical department in the Albany Academy. Subsequently I was an associate teacher with him in the same institution. * * * * It was my pleasure to aid him in his new and wonderful experiments in magnetism and electricity. * * * * In a well remembered

conversation with me * * * * he alluded to an incident in his own experience. After retiring one night he worked out mentally how he could probably draw a spark from the magnet. Upon rising in the morning he hurried to his working room, arranged the apparatus, tried the experiment, when success crowned his labor. He had accomplished what had never been done before. Unfortunately he failed to publish his discovery. In continuing his remarks he added that Faraday, the great European philosopher, some time after, successfully tried the same experiment, and at once announced it, unfortunately before Professor Henry's success was publicly known. Mr. Henry regretted, that through his own negligence, he had been deprived of the honor awarded to Faraday."
GEORGE W. CARPENTER.

ALBANY, N. Y., Nov. 15, 1893.

Let us now look again at the picture of the magnet. There is only one battery. In the picture this rests on a bracket on one side of the frame. Sometimes Henry attached another exactly similar to the other side of the frame, and we ask our reader's especial attention to this, for here is the beginning of pole-changers, duplex telegraphs and all the electric motors which now so excite public attention. Henry attached the wires of his magnet to these two batteries in such a way that he could use either battery and so send the electric current in one direction or the other according to his pleasure. Did it make any difference to the magnet if the direction in which the electricity came to it was changed ? Yes, for it changed the poles.

Let us look at Henry as he lifts the galvanic element b from the cup c, the current is broken, the magnet is dead, the weights ought to drop, but so quickly does Henry put the opposite battery into its cup, that the weights have not time to fall before the magnet is a magnet again. The magnet has been unmade and remade in an instant; but it has undergone a change, its + pole has become a — pole; its — pole a + pole. This pleased Henry ; sometimes before his classes he performed the operation slowly, so that the weights would drop a little from the magnet to be caught back by it before the limits of the attractive power were passed. It really seemed as if an invisible supernatural power were at work, dropping and lifting the weights and the experiment never failed to excite the enthusiasm of the class. How Henry used this pole-changing to make really the first electric motor we will see a little further on.

Want of space forbids the notice of many other interesting experiments Henry made with his new strong magnet. He named his magnet of a single coil, an *intensity* magnet, because it must be used with a battery of many plates, called an intensity battery. His magnet of many coils he called a *quantity* magnet, because it must be used with a battery of a single pair of plates known as a quantity battery.

It should always be remembered that he not only made these two magnets, he discovered the law which controlled their indispensible connection with their respective batteries. Prof. Lovering says, "The fertile principle he deduced from his experiments, his distinction between quantity and intensity magnets, and between quantity and intensity batteries, although now differently expressed, is all important and of manifold application. Every experiment with electro-magnetism in the laboratory, in the lecture-room and in the arts, is a success or a failure in proportion as this law is obeyed or ignored."

This law of electric flow and electric resistance is now expressed in units by ohms, this brings us to the position in which Henry and Ohm stand to this law. In far distant Nuremburg, Ohm devised a theory of such a law, in other words suggested that such a law might exist and expressed this idea in a mathematical formula. Henry discovered the law. We would here as in our former articles ask our readers to consider the difference between a theory and a discovery. A theory suggests *what may be ; it may or may not be true ;* however ingenious, it affords at best only an intelligent mode of asking Nature a question. *A discovery finds out what actually exists.* Ohm's mathematical formula cannot be too highly prized ; but it should not outrank the discovery. It was not until 1836 that it came into notice ; at that time the practical results of the discovery, Henry's means of magnetization, introduced through the medium of Silliman's journal in 1831 had been five years in use. They had been so quickly and widely disseminated that the world had already accepted them as a matter of course, as the sunshine and the rain, unmindful almost, as of these blessing, that they must have had a giver. In 1834 we find Henry in a letter to Dr. Bache asking "Who is Ohm ? What is his theory ?" but it was not until 1837, when he was in London, that he obtained a sight of it, only to find that it was his own discovery mathematically expressed. The two men should always be associated, Henry the discoverer wresting from Nature the law, by patient labor and entelligent experiment ; Ohm giving the mathematical formula which facilitates its use.

Absorbed in the interest of his experiments and in the various duties of the Academy, Henry had not considered the importance of publishing the results of his researches. While engaged in these last investigations, the last number of the Edinburg Journal arrived. Opening this Henry found in it a paper from Prof. Moll of Utrecht, describing some experiments made with magnets, similar to those he had made two years before. To be thus superseded, although only in part, in publication, if not in experiment, was a trial ; but the researches made by the two men were very different and in no way comparable. Henry says of Prof. Moll, "he succeeded in making powerful magnets, but made no discovery as to the distinction between the two kinds of magnets or the transmission of the galvanic current to a great distance with power to produce mechanical effects. In fact his experiments were but a repetition on a larger scale of those of Mr. Sturgeon. He endeavored to produce greater power in the magnet simply by using a larger quantity battery." Then compare the magnets ;— "Henry's of Nov. 1829, lifted *fifty times* its own weight ; Moll's, twice the size, lifted only *fifteen times* its own weight. Moll's greatest success was in lifting one hundred and fifty-four pounds with a twelve and one-half inch magnet : he was justly proud of it. Henry's magnet, nine and one-half inches high, lifting now seven hundred and fifty pounds, subsequently was made to lift *three thousand and fifty*. Surely it had nothing to fear in competition with those Utrich magnets. Then there was enormous difference in battery power. Moll pushed his up to seventeen square feet. Henry reduced his to a square inch."[1]

Seeing the necessity for publication Henry immediately prepared a paper for Silliman's *Journal*—which was only just in time to be published in the following number for January. (This is the paper from which we have so frequently quoted.) The *Journal* was then published quarterly. He sent with his paper a copy of Prof. Moll's, and he closes his paper with these words. "The only effect Prof. Moll's paper has had on these investigations is to hasten their publication. The principle upon which they were instituted was known to us nearly two years since, and at that time exhibited to the Albany Institute."

ELECTRIC BUOYS FOR MOBILE BAY.

Capt. W. S. Schley, and Lt.-Com. C. H. West., U. S. Navy, accompanied by Mr. Ira W. Henry, Elec. Eng. of the Bishop G. P. Co. have started for Mobile, Ala., to make a topographical survey of Mobile Bay and the adjacent shores to ascertain the practicability of lighting the thirty mile channel with electric buoys and the erection of the necessary generating plant.

The successful operation of electric buoys for the last six years in New York Bay and the fine showing in Lake Michigan during the Fair has proved the adaptability of this work to harbor lighting, and opens a new branch of Lighthouse engineering. All interested in electric work look forward to a favorable report from the party and wish them success.

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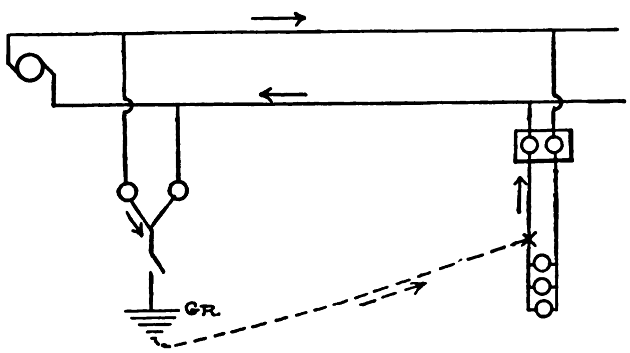
1. W. B. Taylor, Scientific Writings of Joseph Henry.

caused by contact with the iron pipes in the building. They are concealed, and electrical methods must be used for their detection and location. The larger wires, carrying heavy currents, are generally run in places where they are not apt to be disturbed and their extra thickness of insulation is more or less a protection against mechanical injury. The result is, that most of the grounds occur in fixtures or in drop cord sockets resting against gas fixtures or steam pipes.

In practice it is usually better not to test large sections of the installation at one time when the current is on, because of the burning of connections when circuits carrying, say, ten amperes or more are opened. The wires too are heavy and frequent bending is liable to break them.

Testing with a magneto, or with a galvanometer and battery generally necessitates a search for something on which to ground one side of the testing apparatus and running a wire to it, all of which takes time. On alternating current circuits this is of course the best method, as there is no electrical connection between the primary and secondary circuits. But in direct current plants the ground detector may be used as the necessary ground. When current is on, the only apparatus needed is a socket wired with a few feet of wire or cord and a 16 c. p. lamp. When current is off, a magneto must be used instead.

Referring to the accompanying diagram, let the cross denote a ground on the negative side of the system. When the ground detector switch is closed, current flows from the dynamo through the ground detector lamp to ground, entering the system through a ground at some unknown



LOCATING A GROUND.

point. Now if a lamp be placed anywhere in this circuit, say at the cutout, it will light up and indicate the faulty circuit.

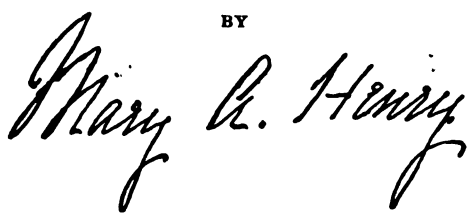
If the circuit is broken at the cutout and the lamp cut in, the lighting up of the lamp to low incandescence will locate the ground on that particular branch. Taking one cutout at a time, both sides are opened and the lamp placed in the negative side of the cutout, assuming of course that the ground has been shown to exist on the negative side of the circuit. The lamp will show at once whether that branch is clear or not. If no lamps are burning on that circuit, the positive wire need not be opened. Each circuit is tested in a like manner until the trouble is located in some one of them when it can be further located by the usual methods. Of course the absence of results shows that it is somewhere on the mains and feeders.

Testing may be begun by testing the main cutouts. The arcs formed when the heavier currents are broken burn the binding posts. The wires are No. 12 and larger and frequent bending is apt to break them off; besides, the trouble will usually be found in the end on the smaller branch circuits. In central station work the building should of course be located first. Where plug cutouts of the Edison type are used, the testing lamp may be screwed directly into the cutout. In city plants there are always a few lamps burning and it is very desirable to interrupt the service as little as possible. One man can cover as much ground with a lamp as two can with a magneto. If the ground is of very high resistance, a cheap galvanometer should be used instead of the lamp. The time at each test is small, but for an entire plant, it amounts to a surprising difference.

It may be urged that grounding the system in this way in order to test it, is bad practice on account of fire from the heat generated at the point of trouble; this is true, but the danger is more apparent than real. A dead ground, or one of above 1,000 ohms resistance would not be apt to give any trouble by fire. How many plants run along with grounds on both sides of the system? It would take time to develop a fire from this cause, and the testing of the largest isolated plant need not exceed two hours. At the end of the test the men would have located the ground and an incipient fire would run an exceedingly small chance of getting a good start. In any case the chance of danger can be avoided by making the artificial ground of high resistance and using a galvanometer, which, after all, is the better way. Right in here comes the subject of blowing out grounds. *Don't*; at least, don't make a practice of it. It is at best a heroic remedy. In any event the general location of the ground should be ascertained first and a careful watch kept for fire for some hours afterwards.

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—IX.

BY



Henry's paper was in print.[1] In the wide circulation of Silliman's Journal it was carried abroad to place Henry at once among the scientific men of Europe. "At one bound" says Prof. Lovering "he came to the front. He had introduced his magnetic children into the world; had sent them forth to do their important work and how were they received? With surprise, nay with astonishment."

Mr. William B. Taylor says, "The magnetic 'spool' of fine wire, of a length tens and even hundreds of times that ever before employed for this purpose, was in itself a gift to science which really forms an epoch in the history of electro-magnetism. It is not too much to say that almost every advancement which has been made in this fruitful branch of physics since the time of Sturgeon's happy improvement, from the earliest researches of Faraday downward, has been directly indebted to Henry's magnet. By means of Henry's 'spool' the magnet almost at a bound was developed from a feeble childhood to a vigorous manhood. And so rapidly and generally was the new form introduced abroad among experimenters, few of whom had ever seen the paper of Henry, that probably very few indeed have been aware to whom they were really indebted for this familiar and powerful instrumentality.[2]"

"But in addition to this large gift to science Henry (as we have seen) has the pre-eminent claim to popular gratitude of having first practically worked out the differing functions of two entirely different kinds of electro-magnet; the one surrounded with numerous coils of no great length, designated by him the *quantity* magnet, the other

1. It was printed Jan. 1st. 1831.

2 Henry's spool magnet appears to have been introduced into France by Pouillet in 1832. *Nouveau Bulletin de Science*: Publié par la Societé Philomatique de Paris, of 23 June 1832 p. 127. In Pouillets Éléments de Physique. 3rd Edition Vol. 1, p. 572 the date of this magnet is given as 1831—In the second Edition, 1832, no allusion to the magnet occurs.

surrounded with a continuous coil of very great length, designated by him the *intensity* magnet.

"Here for the first time is experimentally established the important principle that there must be a proportion between the aggregate internal resistance of the battery and the whole external resistance of the conjunctive wire or conducting circuit.

"Never should it be forgotten that he who first exalted the *quantity* magnet of Sturgeon, from a power of twenty pounds to a power of twenty hundred pounds, *was the absolute creator of the intensity magnet*, and that the principles involved in this creation, constitute the indispensable basis of every form of the electro-magnetic telegraph since invented."

Faraday, working away at an experiment that had failed him again and again, immediately adopted the new method of obtaining magnetic force, to make, in this same year, 1831, that discovery of magneto electricity I have noticed in the last chapter, and by its means also his subsequent discoveries of dia-magnetism and the magnetic effects on polarized light were made.[3]

A very pleasant welcome to the magnets was the generous tribute to them of Sturgeon. He says, "Henry has been enabled to produce a magnetic force which totally eclipses any other in the whole annals of magnetism, and no parallel is to be found since the miraculous suspension of the celebrated oriental imposter in his iron coffin.[4]

At home Dr. Hare, of Philadelphia, received with enthusiasm the new means of producing magnetic force. He says in a letter to Sturgeon, the following year April 5, 1832: "As soon as I heard of the wonderful magnets of Prof. Henry, I repeated his magnetic experiments, and I have recently made a magnet by means of copper wire shell-lac varnish and paper, surrounding the iron, which in proportion to its weight holds more than his." Prof. Silliman evinced his appreciation of the magnets by ordering the powerful one which continued to be an object of veneration and pride at the University of New Haven until last year, when it was sent to the National Museum for exhibition.

This magnet was nearly twelve inches high and was made to lift 2,035–2,063 lbs. A number of very interesting experiments were made with it before it was sent to New Haven. "To test its power of producing magnetism in soft iron, two pieces of iron ¼ of an inch in diameter and 12 inches long, were interposed between the extremities of the magnet and the armature, and these when the battery was immersed became so powerfully magnetic as to support 155 lbs. To exhibit the effects produced by instantaneously reversing the poles—the armature was loaded with 56 lbs. which added to its own weight made 89 lbs. One of the batteries was then dropped, when the weight of course continued to adhere to the magnet. The other battery was then suddenly immersed when the poles were changed so instantaneously that the weight did not fall. That the poles were actually reversed in the experiment was clearly shown by a change in the position of a large needle placed at a small distance from the side of one extremity of the horse-shoe."[5]

In his letter accompanying the account of the magnet in his journal Prof. Silliman says :—

"The magnet is now arranged in its frame, in the laboratory of Yale College. There has not been time, since the magnet came just as this number was finishing, to do anything more than make a few trials which have, however, fully substantiated the statements of Prof. Henry. He has the honor of constructing by far the most powerful magnets that have ever been known. And his last, weighing, armature and all, only 82½ lbs. sustains over a ton. It is eight times more powerful than any magnet hitherto known in Europe and between six and seven times more powerful than the great magnet in Philadelphia."[6] July 21, he writes—"Your magnet performs admirably well and excites great interest among the students. A favorite mode of exhibiting the magnet is to allow a number of young men to stand upon the scale, as the weight lifted then appears more striking. This never fails to excite the astonishment of the spectators."

The venerable president of Yale thus speaks of the magnet :—

"There was nothing to be said when, as the plunger went down into its bath, the impotent bar of iron became possessed of a giant's strength and could pick up and hold a weight of more than a solid ton, and as the same plunger was lifted this gigantic energy vanished as at the word of an enchanter. The speaker well remembers the excitement which this discovery occasioned when the first experiment was tried at Yale College, in the presence of a few spectators who casually met at the call of Prof. Silliman, who was glowing with animation and delight. The ponderous platform was loaded with pig-iron and other heavy weights, with a few slight additions of living freight. Among the last was the speaker, being the lightest of all, and therefore convenient to serve on the sliding scale. It is more than fifty years ago but the scene is as vivid as the events of yesterday. The question went around who is Professor Henry, and how did it happen that nature revealed to him one of her choicest secrets. Thoughtful men asked what is this wonderful protean force which he was the first to follow in its sinuous hiding places and evoke by a magician's wand; and what are its relations to its kindred agents, and, above all, to the matter about us which we can measure and weigh and see and handle. To some it seemed but a successful guess by a daring adventurer. A lucky accident like the drawing of a prize in a lottery. It was not so with those who retraced the successive steps of close observation, of sagacious interpretation, of boundless invention, of ingenious construction, of patient trial, of loving sympathy which preceded this single achievment and all of which combined lifted at once this youth, hitherto unknown, into the rank of the most eminent discoverers, brilliant as was their company, then and since."

Innumerable applications for magnets now poured in upon Henry, and for other magnetical apparatus. A powerful magnet equal to the one sent to New Haven was ordered by Prof. Cleveland for Bowdoin College, Brunswick, Maine.

The making of the magnets consumed much time and labor but Henry in every case refused remuneration for his personal labor, charging only the actual cost of materials and hired work. "I consider it," he says, "below the dignity of science to take pay for my knowledge." (Letter Nov. 4, 1831.)

Not only these new galvanic magnets occupy Henry's attention: we find him engaged in preparing a large steel permanent magnet for use in the separation of iron from ore. This inspires him with the desire to bring his own electro-magnets into the work. In a letter sending this to Mr. Rogers, Nov. 4, 1831, for whom it was constructed, he says, "I am confident I can form a galvanic machine which will effect powerfully the separation of iron, and upon this effort he spends much time and thought.

A detailed description by Professor Henry of his mode of constructing an electro-magnet may be interesting. I give part of a draft or copy of a letter to Professor Cleveland :—

ALBANY, May 8, 1832.

After a delay, which I fear has nearly exhausted your patience, I have at length sent off your magnet according to the direction given in your letter of the 8th of Dec. I can get nothing done in Albany in the philosophical line except I stand over the workman continually myself, or which is most often the case, do the work entirely myself. * * * *

The following is a particular description of the construction of the magnet. * * * *

The horse-shoe is formed of a bar of American iron, which ac-

3. See Faraday's Researches.

4. *Phil. Magazine*, March, 1832.

5. Henry's paper in *Silliman's Journal*, for April, 1831.

6. Prof. Silliman is here alluding to permanent magnets.

cording to the mechanic's account was unusually hard. It was not selected on this account, but was taken because it was the only piece of iron of the proper size to be procured at that time in Albany. After bending it into the proper form, the edges were first rounded with the hammer and afterwards with a file, and in order to prevent the wires, to be coiled around it, from slipping off the legs, a deep groove was filed into each, about half an inch from the end.

The horse-shoe, when it came from the hands of the finisher, weighed 60 lbs.—the armature about 20 lbs., and these are almost precisely the weights of the magnet and armature of Yale College. The winding on of the wires was done with great care, and under my constant inspection, according to a method which I think much preferable to any I have before adopted. Instead of covering the wires with cotton or silk-thread, I gave them several coats of varnish made of shell-lac and mastic, and in order to render the insulation of the several wires still more perfect a thickness of silk was woven as it were, between every *spire* or turn of each wire, and the several layers of wires were separated from each other by a covering of silk and varnish.

The operation was as follows: The iron horse-shoe was, in the first place, covered with a coating of varnish, and while this was yet soft, the whole was wound with strips or ribbons of silk. A coating of varnish was then given to the silk and suffered to dry before the winding of the wire was commenced.

In coiling on the wire, one *spire* was passed around the horse-shoe, with the end of a long and broad flap of silk between it and the iron: the flap was then turned back so that the second *spire* should pass under the silk—the third spire passed over the silk—and the fourth again under it—and so on in this way until the whole surface of the horse-shoe was covered with one thickness of wire. A coating of varnish was then given to this surface of wires, and the whole covered with ribbons of silk. Another coating of varnish was given to the silk, and after this became hard a second layer of wires was coiled on in the same manner as the first.

This process was a very tedious one, and occupied myself and two other persons every evening for two weeks. It is, however, one which insures success if the iron and other circumstances are favorable. The iron is entirely covered with four thicknesses of wire, and near the ends with five. There are in all 30 strands, each 35 feet long, so that exclusive of the projecting ends there are about 1,000 feet of wire actually coiled around the magnet. It is necessary to be very cautious that in the arrangement of the several wires there are none which will conduct the galvanic current in an adverse direction, or that will suffer it to pass from one wire to the other without circulating throught the entire length around the magnet. I have failed in this respect in some instances to produce any effect when I expected a very great one. * * * *

To exhibit the experiment of the instantaneous change of polarity, a second battery must be attached by means of the thimbles of mercury, in such a manner that the galvanic current from this battery will circulate in an opposite direction to that from the battery attached permanently to the magnet. Load the armature with two or three hundred pounds and excite the magnet by the second battery; let an assistant be ready to raise the vessel from immersing the first battery. Let this be done suddenly, and at the same time quickly withdraw the wires or poles of the second battery from the two thimbles—the weight will still continue to adhere. To render the fact evident of the change of polarity, I place two magnetic needles one on each side of the magnet, and these, by reversing their position relative to the magnet will indicate in a very striking manner the change of polarity. I find it most convenient to make these needles each of two pieces of watch-spring, about ten inches long, touched separately, and then with their north poles joined together by a silk thread with a little brass cap between them. A small piece of light cord is placed on each end with the letter N on one and S on the other.

In the box containing the battery you will find two pieces of round iron; these are for showing induction of magnetism in soft iron. They must be placed upright on the face of the armature, at such a distance from each other that their axes will be in the centre of the faces of the horseshoe. While in this position immerse the battery and the two iron cylinders will adhere to the magnet and the armature to them, as firmly almost as if they all were but one piece.

N. E. L. A. STANDARD RULES.

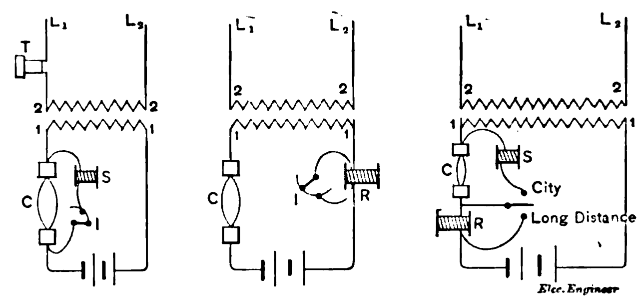
We have received copies of the new N. E. L. A. Standard rules for lighting, wiring, &c., put up in a very neat pocket size, 32 pages, 9 by 5¾ in. They are supplemented by the report on arc lamp rating and by a glossary of electrical terms. There are also a preface and an index. These rules represent a great deal of work and are a great credit not only to the Association but to the successive committees, Mr. W. J Hammer being the active and efficient chairman of the one reporting to the Washington convention. Work of this kind still remains to be done, and it is but to be hoped that the Association will continue to enjoy such devoted and intelligent assistance.

THE MERCADIER AND ANIZAN MICROPHONE REDUCER.

Taking the condition of telephony as we find it to-day in different countries, and considering the progressive development of long distance lines, transmitters ought to be so arranged that one subscriber shall be able to talk as well with another in the same city as with one a hundred or two hundred miles off. Necessarily it is the microphone which ought to be studied in order to obtain as good talking for short as for long distance.

With microphones embodying carbon pencils it is necessary that the microphone contacts be very sensitive and very light when used for long distance work. One would then be quite limited by the noise caused by the too sensitive microphone in the telephone of the person talking; but this can be counteracted by means of a differential winding. To communicate over a short distance in a city district with copper wires it would be necessary, on the contrary, to have the microphonic contacts not very sensitive. In granulated carbon microphones one could vary at the same time the surface contact of the carbon electrodes and their distance, according to whether one desired to use the microphone for long or short distance.

Finally, whatever be the type of microphone, whether carbon rod or granules, one can also for a given regulation of the microphone contacts make the same microphone serve for long distances by taking a thin diaphragm of large diameter; and for short distances by mounting the microphone on a thick diaphragm of very small diameter. One can get an analogous result by taking diaphragms



Figs. 1, 2 and 3.

of the same dimensions, but of different materials, such as iron and wood. In the United States the American Bell Telephone Company use two types of microphone transmitters, one for city and one for long distance work. In Europe there are still employed microphones regulated in such a way that they can serve either for short or long distance, but, as indicated above, these microphones do not give all that could be got out of them for long distance work, in order not to impair too much their clearness for short distances, and vice versa. It will thus be seen that the two desirable qualities in the regulation of the microphone, loudness and clearness, are opposed to each other, and that one can be obtained only at the expense of the other.

The microphone reducer of MM. Mercadier and Anizan has for its object, first, to give to a microphone its maximum intensity when used for long distances, and, second, to obtain from the same microphone a proper loudness and clearness when it is used for short distances. The diagram, Fig. 1, represents diagrammatically the arrangement which consists simply in placing for a given time a resistance in shunt to the carbons. This shunt S has about three ohms resistance. I is an ordinary switch for opening and closing the shunt circuit. The whole can be placed inside the transmitter boxes with a small handle projecting through the lid, which operates the switch I. When the index on the handle points to "City" the switch is closed, and when pointing to "Long Distance" the switch is open.

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—X.

BY

Mary A. Henry

There were two practical applications of his electro-magnets that Henry had in mind; one the telegraph, the other the machine described in *Silliman's Journal*, Vol. XX., 1831. This should be of interest to the reader since it is the first *electro-motor*. This crude instrument, made by Henry's own hands, has been preserved by Princeton College as an historical relic.[1] Let us read Henry's description of it in *Silliman's Journal* (Vol. XX., pp. 340–348).

"To the Editor:

Sir:—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. It is well known that an attractive or repulsive force is exerted between two magnets, according as poles of different names, or poles of the same name, are presented to each other. In order to understand how this principle can be applied to produce a reciprocating motion, let us suppose a bar magnet to be supported horizontally on an axis passing through the centre of gravity, in precisely the same manner as a dipping needle is poised; and suppose two other magnets to be placed perpendicularly, one under each pole of the horizontal magnet, and a little below it with their north poles uppermost; then it is evident that, the south pole of the horizontal magnet will be attracted by the north pole of one of the perpendicular magnets, and its north pole repelled by the north pole of the other; in this state it will remain at rest, but if, by any means, we reverse the polarity of the horizontal magnet, its position will be changed and the extremity which was before attracted will now be repelled; if the polarity be again reversed, the position will again be changed, and so on indefinitely. To produce therefore, a continued vibration, it is only necessary to introduce into this arrangement some means by which the polarity of the horizontal magnet can be instantaneously changed, and that too by a cause which shall be put in operation by the motion of the magnet itself. How this can be effected will not be difficult to conceive when I mention that instead of a permanent steel magnet in the movable part of the apparatus a soft iron galvanic magnet is used.

The change of polarity is produced simply by soldering to the extremities of the wires which surround the galvanic magnet two small galvanic batteries in such a manner that the vibrations of the magnet itself may immerse them alternately into vessels of diluted acid; care being taken that the batteries are so attached that the current of galvanism from each shall pass around the magnet in an opposite direction.

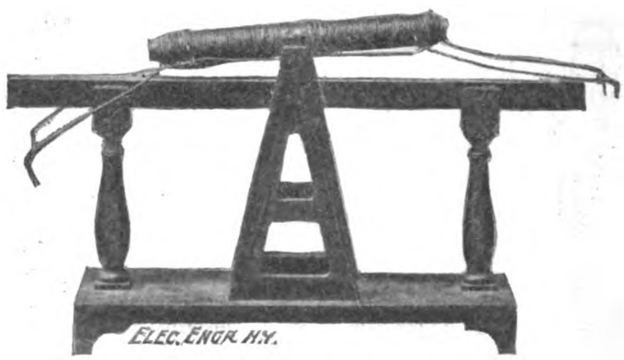
Instead of soldering the batteries to the ends of the wires, and thus causing them at each vibration to be lifted from the acid by the power of the machine, they may be permanently fixed in the vessels, and the galvanic communication formed by the almalgamated ends of the wires dipping into cups of mercury."

If the tumblers be filled with strong diluted acid, the motion is at first very rapid and powerful, but it soon almost entirely ceases. By partially filling the tumblers with weak acid, and occasionally adding a small quantity of fresh acid, a uniform motion, at the rate of seventy-five vibrations in a minute, has been kept up for more than an hour; with a large battery and very weak acid, the motion might be continued for an indefinite length of time.

The motion here described is entirely distinct from that produced by the electro-magnetic combination of wires and magnets; it results directly from the mechanical action of ordinary magnetism: galvanism being only introduced for the purpose of changing the poles.[2]

It is easy to see how motion could be given by this arrangement to a wheel or other mechanical apparatus. "This simple but original device comprised the first automatic pole-changer or commutator ever applied to the galvanic battery—an essential element not merely in every variety of the electro-magnetic machine, but in every variety of magneto-electric apparatus and in every variety of the highly useful induction apparatus."[3]

If Henry could have looked up with pardonable pride to the wires of his telegraph stretched around that upper room in the Academy at Albany, surely he might have regarded with some elation the see-saw motion he had been able to produce and have allowed his imagination to dwell upon the future represented by his machine. The introduction of steam as a motor was an era in the world's history; this use of electricity as a motor was another era; but not for a moment in the enthusiasm of his success was Henry led to believe that the one would supersede the other. He recognized from the first the place of the electro-motor. He considered the source of the power of the machine, namely, the oxidation or burning up of the zinc in the battery; and immediately concluded that the coal required for the preparation of zinc would, if directly applied, give a much greater amount of power at much less expense; but he predicted for his engine a useful and important future in applications where economy is not the consideration. He sums up the question later in these words: "All attempts to substitute electricity or magnetism for coal power must be unsuccessful since these powers tend to an equilibrium, from which they can only be disturbed by the application of another power, which is the equivalent of that which they can subsequently exhibit. They are however, with chemical attractions, etc., of great importance *as intermediate agents in the application of the power of heat as derived from combustion.* Science does not indicate in the slightest degree the possibility of the discovery of a new primary power comparable with that of combustion as exhibited in the burning of coal. We therefore do not hesitate to say that all declarations of the discovery of a new power which is to supersede the use of coal as a motive power, have their origin in ignorance or deception and frequently in both." Mr. Taylor says, "In Henry's deliberate contemplation of his own achievement his remarkable sagacity and propriety of judgment were conspicuously displayed."



THE FIRST ELECTRO-MOTOR.

Henry sent his little machine, as he had his magnets, out into the world, through *Silliman's Journal.* It received, as the magnets had before, an enthusiastic welcome from Sturgeon, who immediately constructed a rotary engine, exhibited in 1833 in London to a large audience. We have here a glimpse of a noble soul: for, when hailed on account of this machine as pioneer in the field, and by an American, Sturgeon took pains to contradict the statement and to give to Henry the priority; worthy of praise, he could not take praise which was not his due. This is especially gratifying since Henry's discoveries were as a general thing taken up and used, as a matter of course, without any reference to himself. In 1834, Davenport of Vermont, an ingenious blacksmith, made a rotary machine; but I may not follow closely the history of the electro-motor; I refer my readers to Mr. F. L. Pope's well known and interesting article upon this subject.[4] The problem of the appli-

1. The picture given is from a photograph.
2. Silliman's American Journal of Science, Vol. XX, pp. 342 and 343.
3. Edward N. Dickerson: "Joseph Henry and the Magnetic Telegraph."
4. THE ELECTRICAL ENGINEER, Jan. 7, 14, 21, 28 and Feb. 4, 1891.

cation of electricity as a universal motive power was taken up with great zeal both in Europe and this country; and contrary to Henry's fundamental and, as time has shown, prophetic conception of the field of the electro-motor, it was everywhere confidently supposed that in time it would supersede steam. In this expectation the misunderstood electro-motor disappointed the hopes reposed in it and for a time it was in disgrace; but, not a success certainly as a prime mover, it has found its place and it is exactly the place to which it was assigned by Henry; it is the assistant of steam, not its rival. Its value lies in its capacity to receive power from a distant source and to transfer it without waste immediately to where it is needed. Mr. Pope says: "Henry accurately foretold the true place, in the domain of industry, of the electric motor. Much confusion of thought exists in the popular mind of the present time in reference to this very point. * * * * Electricity, in its important application to machinery, is never in itself a source of power. It is merely a convenient and easily managed form of energy, by which mechanical power is transferable from an ordinary prime motor, as a steam engine or a water wheel, to a secondary motor which is employed to do the work. It performs an office precisely analogous to that of a belt or line of shafting, which, however useful in conveying power from one point to another, can, under no conceivable circumstances, be capable of originating it."[5]

In comparison with other modes of transmitting power the electro-motor is well nigh indifferent to the extent of the distance from the source of its power. Who made the instrument thus indifferent to distance? Let us go back to it as it was in its infancy in 1831, in Henry's cabinet. Henry knew that his magnet, in the telegraph in the upper room, could respond as easily to its battery if that one mile of wire stretched around those walls were extended to hundreds; and he knew as well that his little machine could be made to work if its batteries were equally far away. The means of producing electro-mechanical effects at a distance, this was what Henry had discovered, and in this machine he showed how the power might be used in other ways than in the telegraph.

"In 1834 Dr. Edmonston of Baltimore published a description of the rotary motor, a modification of Henry's arrangement, and these two forms are the prototypes of all the electro-motors, which have been constructed from that day to this."—(Frank. L. Pope.)

Henry's friends urged him, not only to take out patents for his magnets and his telegraph, but also for this machine. Hundreds of patents have been granted in this country for modifications of the electro-magnetic-telegraph, and as many for varieties of the electro-magnetic machine; all of which would have been tributary to Henry as the original patentee. His constant answer to all such solicitations was, "My desire is to add to the sum of human knowledge; what I give, I wish to give freely."

PUBLIC SPIRITED JOURNALISM.

It will be remembered that some time ago the London *Electrical Review* assumed the uphill task of endeavoring to expose the tricks and wiles of "electric belt" quackery, and as a result became involved in lawsuits for libel, which it had the deserved good fortune to win, although as might have been expected, the quacks are still rampant, for the general public rarely reads technical literature and the daily papers persist in printing the quacks' advertisements.

The *Electrical Review* obtained damages, with *Science Siftings*, its colleague in the fight, and Mr. J. Swinburne now has returned to the subscribers to its Defence Fund the entire amount of their subscriptions less a small percentage to cover expenses of printing, stationery, postage, etc. The *Review* is entitled to the congratulations of the electrical profession on its success in this fight, and to admiration for its honorable and public spirited action throughout.

5. *Electricity in Daily Life*, Chas. Scribner's Sons, New York, 1891, page 41. (Reprinted from *Scribner's Magazine*.)

LITERATURE.

Elektrotechniker's Literarisches Auskunftsbüchlein. By F. Schmidt-Hennigker. 2d Edition. Leipzig, 1894. Oskar Leiner. 48 pages. 5½ x 8 inches. Price, 40 cents.

This is an index of the works published in the German language between 1884 and 1893 on the subjects of electrotechnics, electricity, electro-chemistry, magnetism, telegraphy, telephony and lightning protection. The works are indexed alphabetically, by authors and by subjects. Each reference is accompanied by the number of pages, size and place of publication.

Electricity Up to Date. By John B. Verity. London and New York. F. Warne & Co. Paper, 226 pp. illus. Price, 75 cents. (Fourth Edition).

Mr. Verity's useful and handy little book reaches us again, and we can only repeat of this what has been said of previous editions, namely, that it is one of the best of the popular books. There is nothing pedantic about it, yet nothing foolish or inaccurate. It tells the story clearly and plainly, and every page is interesting. Such a book ought to reach its fortieth edition, with constant and careful revision.

Premiers Principes d'Electricité Industrielle. By Paul Janet, Paris, Gauthier-Villars et Fils. 1893. 275 pages, 5½ x 8½. Price $2.

This is a reproduction of a course of lectures delivered by the author at the Faculté Des Sciences of Grenoble, and is intended therefore, more particularly for students. It carries the reader through the study of batteries, including primary, secondary and thermo cells, dynamos and transformers. The book is devoted more to inculcating the principles of these various types of apparatus, giving only such details of construction as to enable the student to form a fair idea of the actual apparatus, all the standard types of which are illustrated. The book is well up to date and the explanations are quite lucid.

Reference Book of Tables and Formulas for Electric Street Railway Engineers. By E. A. Merrill, Author of "Electric Lighting Specifications." New York. The W. J. Johnston Company, Ltd., Flexible Morocco, Pocket Size. Price, $1.

The appearance of this little reference book is very timely as it puts in the hands of the electric railway constructor and superintendent a considerable amount of valuable information. The author has followed the plan of beginning with the steam plant and passing successively through the subject of cars and their equipment, overhead work, track work and miscellaneous tables and formulas. While the works of the best authorities have been consulted, a number of tables and formulas are original, and many others have been modified and extended to adapt them to the conditions imposed in electric street railway work.

Standard Tables for Electric Wiremen, With Instructions for Wiremen and Linemen, Underwriters' Rules, and Useful Formulæ and Data. By Chas. M. Davis. Fourth Edition. Thoroughly revised and edited by W. D. Weaver. Flexible morocco. 128 pages. Price, $1.

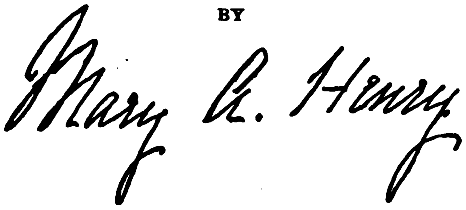
This very handy little work has recently received a thorough revision at the hands of Mr. W. D. Weaver, and among the new things embodied in it is the calculation of alternating current wiring. These include tables of alternate current wiring coefficients, those on alternating currents for exterior wiring and on the candle power of arc lamps, and tables enabling those for the three standard lamp voltages to be used for any voltage or drop; as well as several others, including a complete set of wiring tables calculated on a uniform basis of 55 watt lamps. In addition we find a good deal of valuable miscellaneous information in the book.

Dynamo and Motor Building for Amateurs, with Working Drawings. By Lieut. C. D. Parkhurst, U. S. A. New York. The W. J. Johnston Company, Ltd., 1893. 163 pages. 5 x 7 inches. Price. $1.

Although the continued manufacture of electric motors of small sizes has brought their price down much below what it was some years ago, there are still not a few who prefer to gain the practice which only actual work *propriis manibus* can afford. The amateur will find here little or no theory to embarrass him, but straightforward descriptions with diagrams and working drawings, which will enable him to construct three or four kinds of machines, ranging from a small electric motor, driven by battery current, to a 50-light incandescent dynamo. The book has

THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—XI.

BY



We hope the reader is not tired of Henry's electro-magnets. A little more we have to tell about them. In 1832 Henry left the Albany Academy to accept a professorship in the College of New Jersey, and in Princeton he made his last and largest magnet. It was called "Big Ben" by the students. It was made in 1833, and when a big battery, commenced the same year as a companion for it, was completed, it was made to lift upwards of six thousand pounds. It took a prominent part in Henry's lectures, which were not only attended by the students of the college but by the élite of the town. In these days the power of the electro-magnet has ceased to excite surprise, but very wonderful it seemed to Henry's delighted audiences when he made his bar of iron lift and drop heavy weights. Sometimes, as in Albany, he suspended a haymaker's scale to the armature and several of the young men standing in it were sustained by the attractive power of the magnet; sometimes also, as in Albany, breaking the connection with the battery and suddenly reversing the galvanic current, he allowed the armature with its weights attached to drop a little, to be caught back by a sudden reversal of the galvanic current or suspended in mid air,—an experiment which always excited great applause. There was no end to the ways in which it pleased Henry to exhibit the strength of his great magnet.

In 1846, ten years later, a reference to this magnet was made in the book in which Henry recorded his experiments.

LIFTING POWER OF THE LARGE MAGNET CONSTRUCTED IN 1833.

Tried to-day the lifting power of the large magnet belonging to the apparatus of the college, constructed by myself in 1833. This lifted at the time of its first construction 3,600 lbs. with the large battery of 88 zinc plates, arranged as 4 plates; but I had supposed that the insulation had been injured by some accident in moving the apparatus.

In this, however, I was mistaken, for it was found on trial to-day that it was still capable of sustaining 3,500 lbs. The estimation was roughly made, but the sum stated is within the truth. Eighteen men stood on the plank placed across the scale pole and three men pressed by their weight on the end of the iron lever.

The magnet, in this experiment, was excited by two parts of the large plate battery arranged as one piece. The acid was very strong and formed at least $\frac{1}{10}$ of the liquid. When the poles of the battery were disconnected, or in other words, the galvanic current broken, the magnet sustained for a few minutes upwards of 1000 lbs. The same retaining power supports the keeper from year to year, and between 200 and 800 lbs. pressure is required to pull off the iron after it has remained in contact for 12 months.

I have never published an account of this magnet, although it is the most powerful yet made.

This magnet exhibits the curious phenomenon of persistence in polarization. If it be magnetized, so that, say, the right leg is a north pole, and afterwards the current be changed so as to make the same leg a south pole, after the current is stopped the first polarity returns, although the action may have been very intense.

HENRY'S HOUSE, PRINCETON COLLEGE, SIXTY YEARS AGO.

If "Big Ben" exhibited well the power of the magnetism its maker could produce, it was used in a way so important in its bearing, not only upon the telegraph, but other magneto-mechanical contrivances, that we must ask for it especial attention. First should be remembered the difference between the two magnets Henry made; between the *intensity* magnet with one long thin wire, influenced by an intensity battery of many plates—which possessed the subtle power of being influenced at a distance—and the *quantity* magnet of many separate coils of thick wire, influenced by a battery of a single pair of plates, which was much more powerful, but not affected at a distance. Henry conceived a method of combining the individual qualities of the two brothers. When the weaker, sensitive, intensity magnet received the distant message he made it call into action the stronger quantity magnet by a simple expedient. He says this "consisted in opening the circuit of my large quantity magnet in Princeton, when loaded with many pounds weight, by attracting upward a small piece of movable wire by means of 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 effects could be produced; such as the ringing of church bells at a distance of a hundred miles or more. I frequently illustrated the principle of transmitting power to a distance to my class, by causing a thousand pounds to fall on the floor my merely lifting a piece of wire from two cups of the mercury closing the circuit." Mr. Dickerson says:

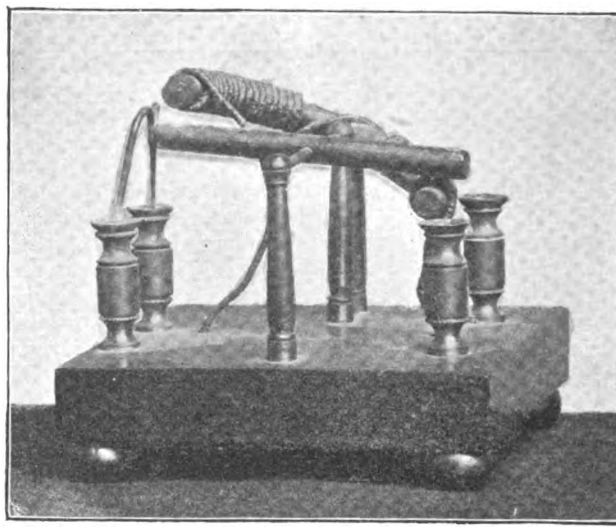
"Of the utmost importance has this combination proved to the telegraph—its principle underlying all the various forms and uses of the relay magnet and the receiving magnet and local battery since employed. He thus made the powerful magnet at short range the servant of the weak one at long range, and left the problem (of the telegraph) entirely solved to those who could procure the money to apply his discoveries to the commercial uses of man."

The following is another quotation from Henry in regard to the arrangement described:

The local circuit devised by me was connected with a quantity battery and large electro-magnet, loaded with several hundred pounds. When the ends of a fork-shaped wire were drawn up from the surface of mercury, contained in two cups (thimbles were used), the circuit was broken, and the weights fell to the floor. This part of the combination and action was actually and repeatedly exhibited in my lectures at Princeton, from 1833 to 1848. I also accompanied the exhibition with the statement that the same effect could be produced by the action of a battery at a distance for ringing bells and other mechanical effects. The results of my first experiments in causing an electro-magnet to act through a long wire furnished me with the means of accomplishing this. For this purpose it was only necessary to attach the forked wire to the armature of a small intensity magnet connected with the long circuit, in which was also an intensity battery. When the current was passed through the long wire the armature would be attracted upwards, the short circuit would be broken and the weight would fall. I do not recollect to have exhibited the last part of this arrangement in my lectures, or remember when I invented it, but the invention was made and explained before the publication of Mr. Morse, relative to the telegraph. The object of this invention was to illustrate the production of a mechanical effect at a distance, by means of a long circuit being made to open a short circuit. From my previous experiments, in the transmission of electricity through long wires I was well aware of the fact that I could not cause the large quantity magnet to act by a battery at a distance directly through a long wire, and hence the necessity of this invention to produce the effect which I always stated I could produce.

Henry used his contrivance for the opening of the circuit of his great magnet by means of another magnet and circuit as early as 1833; that is, very soon after the great magnet was made. The instrument he used to exhibit his device was in my possession until a short time ago, it is now in the National Museum. (The picture given of it is from a photograph.) It consists, as the reader may see, of a metal rod, suspended so that it can move freely, and ending in a wire fork. The ends of this fork are seen dipping into mercury cups, and they thus closed the circuit of the large magnet. When the circuit of the small electro-magnet, seen in the picture, was formed, and the magnet excited by an electrical current, it attracted upward the end of the metal rod carrying the fork, the ends of the fork were lifted out of the mercury cups, and the circuit of "Big Ben" was broken. Then the great magnet dropped the three thousand pounds it was holding, while Henry explained that the little bar with its fork could be lifted up in exactly the same way by a magnet in a long circuit, and thus the great power obtained by the dropping of the heavy weights might be called into play for mechanical purposes at a distance. Henry is not sure when he actually opened the circuit of "Big Ben" by means of a long intensity circuit, but this does not matter; he did not need to prove at this time that his intensity combination could lift that little fork as easily at a distance as a short circuit could lift it there in his laboratory; he had been showing its power to produce such an action at a distance since 1830. What concerns us to know is: that as early as 1833 he conceived the device exhibited by this little instrument, of opening one circuit by means of another, and distinctly explained that it could be used, with his intensity combination, to bring into play great power at a distance; his object in making the device was to show this.

The significance should be distinctly understood of what Henry accomplished when, there in his Princeton laboratory, he showed, how the great strength of his powerful quantity magnet could be called into action at a distance by means of the subtle susceptibility of his more sensitive intensity magnet in its long circuit. He had made his intensity magnet deliver the distant message of the telegraph,



Henry's Circuit Breaker.

he had given his little machine to show how the distant electro-mechanical effects could be used in other ways—and now he had shown how very great was the power which might be called into action at a distance.

I quote again from Henry:—

"The only other scientific facts of importance to the practical operation of the telegraph, not already mentioned, are the discovery of Steinheil, in 1837, in Germany, of the practicability of completing a galvanic circuit by using the earth for the return conductor, 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 singe drop of acid. With this arrangement a needle was deflected in my laboratory before my class."

Henry stretched a wire, in accordance with the above arrangement, across the college grounds immediately after his return from a trip to Europe in 1837. He used the wire every year after until he left Princeton, in a certain part of his course of lectures, to show his classes how communication could be held at a distance by means of electricity, receiving and answering, in his laboratory, messages from Mrs. Henry, stationed in the study of his dwelling house across the college grounds. The Rev. M. B. Grier lets us see him still using it in this way five years later :—

In the winter of 1842–43 I was a student in the Theological Seminary in Princeton, N. J. I was in the habit of visiting occasionally in the home of Joseph Henry, then Professor of Natural Science in the College of New Jersey. One evening, when I was leaving the house, Prof. Henry gave me an invitation to attend the Course of lectures which he was delivering, I believe to the Junior Class of the College. I readily accepted the invitation and was often present in his lecture room. At the close of one of his lectures, I remember that he gave notice that he would, on the next class day, demonstrate the practicability of using the magnetic current as a means of communication between two persons at a distance from each other. The next lecture was fully attended by the class and by all who had the privilege of being present by invitation. I noticed that a wire was passed through one of the upper windows of the laboratory, which ran along the ceiling, then dropped about halfway to the floor and was there put in communication with a triangle (or, as some say, a bell). The professor introduced the demonstration with an exposition of the scientific principles which he was about to illustrate and then informed the class that he would communicate with a person stationed in his study, in his own home, which was on the other side of the campus, and which was distant from the point where he stood probably one hundred and fifty yards. He made a communication as he announced, and the whole class turned their eyes to the

"OLD NASSAU" IN 1760.

triangle to watch for the response from the person stationed in the Professor's study, understood to be Mrs. Henry. We waited in earnest expectancy for three or four minutes, when the little triangle rang out the news that the Professor's signal had been received at the other end of the wire, and an answer returned. As the rapid sounds came from the triangle the demonstration seemed to be so complete that the class broke out into applause. Prof. Henry simply remarked that the possibility of transmitting messages by the use of the magnetic current seemed to be established.

This is my recollection of a very interesting scene in the Professor's classroom.

M. B. GRIER.

PHILADELPHIA, August, 1893.

The following is a letter to the Rev. M. B. Grier, dated Madison, Wis., Aug. 25th, 1893.

I remember the event you describe and often recall it with much interest. I am not positive whether a bell or a triangle was used, but think it was the latter. It was Mrs. Henry, who answered the call. It was at that or a succeeding lecture that Prof. Henry stated, with evident satisfaction, that a wire for the return current was not needed and proved it, by having one end of the single wire end in the well at the laboratory building (Clow's refectory also) and the other end of the wire in the well of his home.

I am sorry, that I have not preserved my full notes and drawings of Prof. Henry's lectures. I yet feel something of the thrill that went through us at that (then wonderful) experiment of the great philosopher. Very fraternally yours,

A. V. C. SCHENCK.

Henry continued in Princeton not only the developement of his magnets and his contributions to the telegraph ; his researches in regard to electrical induction were also continued. He resumed the subject of the extra current in 1834, experimenting again with wires long and short, coiled and uncoiled, and also with flat ribbons of metal. If we could go back to certain summer days, somewhere about this time, we would find Henry in the pleasant college ground flying kites. "From the clear blue sky, with two kites, one above, assisting the other, held by a delicate wire wound on an insulated reel," he drew down streams of brilliant sparks, intensified by the self induction of the wire itself. With some coils of insulated copper ribbon (now at Princeton) he discovered that one induced current could induce another and that another and so on ; also that a current of *quantity* could produce one of *intensity ;* also that these currents could be induced at a distance. He obtained currents in his lecture hall, induced by primary currents obtained in an adjoining room, "*with no connection, merely by the disturbance of the electrical plenum*" I use his own words, taken from letters to friends. He obtained the same result between an upper room of the Philosophical Hall and the cellar of the same building, receiving shocks in the cellar from the induced current. In this case there were two floors and ceilings intervening. Then he stretched two parallel wires across the college grounds, several hundred feet apart, to find that an electrical current in one would exite an induced current in the other. Finally he turned the roof of his house into an induction plate and magnetized needles in his study by induction from a thunder cloud *eight miles away*, the storm thus telling him of its approach while yet the sky was clear. These experiments are given in the laboratory books in which he recorded his experiments. "There is a device in operation by which telegraphic communication is kept up between running cars on railroads and the stations, so that the positions of all the trains may be at any time known, and protection against collisions be assured. For this purpose the metallic roof of the car is used as an inductive plate, just as was the roof of Henry's house, and a wire passes from it through a signaling coil to the ground by way of the metal wheels and track. Near the roof outside an electric wire is stretched on poles, through which electric flashes are sent, and they set up by induction in the roof electrical currents similar to those passing in the wire, which are read as signals by the observer; and conversely signals are sent from the roof to the wire, by induction coils in the cars. Thus the effects obtained by Henry long ago now throw a safeguard around our lives."[1] The comparatively recent projects for telegraphing across streams by means of electrical induction, with, to use Henry's words, "no connection, only by the disturbance of the electrical plenum," have received deserved attention. The storm sent its telegraph message to Henry in this way in 1842, a distance of eight miles.

INTRAMURAL CARS FOR BROOKLYN.

THREE of the motor cars of the World's Fair Intramural Railway have been purchased by the Atlantic Avenue Railway Company of Brooklyn. They will be remodeled to the extent necessary to operate them as trolley cars, and will be used to haul open cars from Thirty-ninth Street Ferry to and from Coney Island, obviating the employment of locomotives.

The cars, it will be remembered, have each a seating capacity for ninety passengers, and will draw four passenger cars of equal capacity.

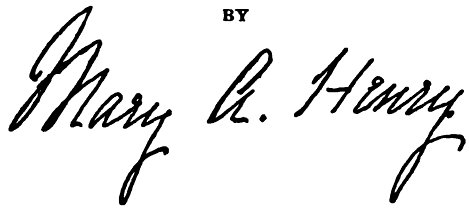
The cars will be put in service shortly before the opening of the regular season, and if they are found to answer the purpose it is probable that additional purchases will be made by the company.

1. E. N. Dickerson "Henry and the Telegraph."

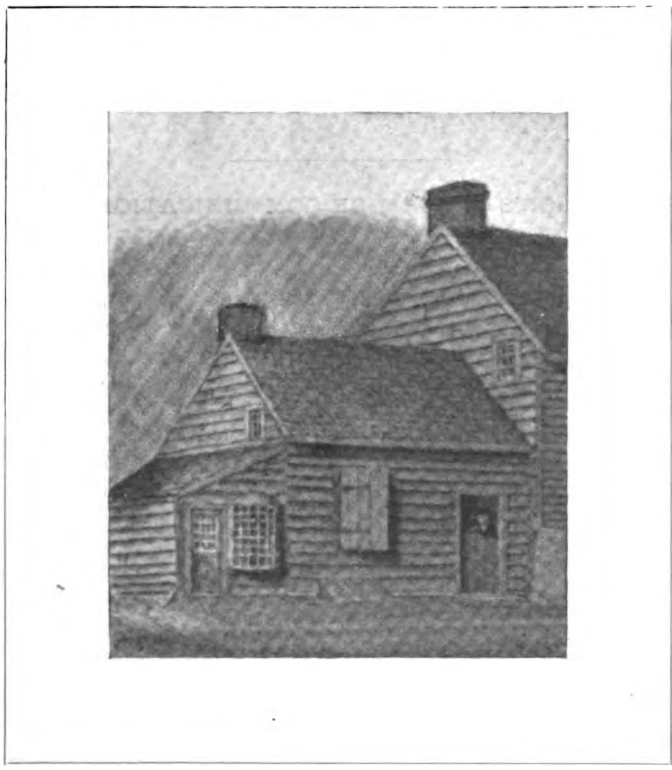
THE ELECTRO-MAGNET; or JOSEPH HENRY'S PLACE IN THE HISTORY OF THE ELECTRO-MAGNETIC TELEGRAPH.—XII.

(Concluded.)

BY



Our story of Henry's magnets is completed; that is, of the construction of them. Each century will furnish a new chapter in the history of their use. "Big Ben" stands in one of the halls of Princeton College, and there too is the sensitive *intensity* magnet, which gave to the world the telegraph, and the *quantity* magnet which led to the great discovery of magneto-electricity; all honored relics. The busy brain which conceived them, the hands which formed them, are no more; but they wake to life under the influence of the electric current as readily as when Henry made them.



South Pearl Street, Albany, where Henry was Born.

(From an old water color drawing).

The magnets in the world of to-day are only these, Henry's children grown larger; more pounds of iron in the core, more wire in the coil; this is all, there is no other difference. They are Henry's children still, obeying always the law of construction and the law of the relative electric flow and resistance which he discovered for them. Henry bent the iron of the magnets into the form of a horseshoe for the purposes of convenience, the instruments are now often used in the form of a spool; everything is the same as in the other form except that the bar is straight: one of Henry's earliest magnets was made with a straight bar. All over the world, wherever there is any application of electro-magnetism, are these same spool or horseshoe magnets: in the physical laboratory, in the observatory where electricity records the observations of the astronomer, in the manufactory, in the home where the sewing machine turns its busy wheel. The philosopher, the artisan, who uses them, may have forgotten or never have known their origin; nevertheless the indispensable servants of mankind everywhere in the civilized world are these electromagnets made first by Henry in 1829 and 1830.

"Come with us now into the telegraph office and let us see what we find there;" again we quote from Mr. Dickerson, "if the line be a short one—say thirty or forty miles—you will see but one of Henry's spools fixed to a table, having a piece of iron called an 'armature,' capable of vibrating in front of its poles, and so arranged that when the 'spool magnet' attracts it, it will vibrate and strike a sounding bar of sonorous metal, which gives out distinctly the sound of the tap. The 'spool' is wound spirally in layers with several hundred feet of fine copper wire, covered with silk, in the manner specified by Henry in 'Silliman's Journal.' At the other end of the line is a battery, composed of a number of cells in series, called by Henry for distinction an 'intensity battery;' and the wire circuit is supplied with a simple device, so that it may be opened or closed by the operator's finger. When he closes it, a current of electricity flows from the 'intensity battery' along the wire, and around the coil of the 'intensity magnet,' and the armature strikes the sounder and gives the signal. The listener hears it; and as the order of the taps progresses in accordance with a pre-arranged artificial code, to express the letters of the alphabet by combinations of successive taps—just as the old visible signals were arranged by combinations of the successive movements of the vanes, or afterwards of the needle of the Gauss and Weber telegraph—he hears letter after letter tapped out and the message is understood.

"*Now that apparatus has nothing about it more than was in Henry's Albany telegraph of* 1831[1]; *nor could it operate if it omitted any one of the inventions, either singly or together, which were then for the first time combined. It depends entirely upon the discoveries made by Henry before* 1831; *and it could not have existed in the world earlier than those discoveries, by the use of any means then known to man; nor since by any other means than those discovered by Henry.*

"Henry used a bell as a sounder; they now use a metal bar and a sounding box. Henry reversed the battery current, whereby no spring is needed to withdraw the armature for the purpose of vibrating it; and that is the common practice in English and German telegraphs. Here they generally merely interrupt the circuit, and the armature is withdrawn from the magnet by a spring, although Henry's device is also used here largely, and is essential to the quadruplex instruments.

"If, however, the telegraph line is a long one—it may be a thousand miles or more—then you will see two sets of Henry's spools, and two batteries. One is the 'intensity battery and spool' first described; and the coil of fine wire may be, and often is, several thousand feet long—while the battery is composed of more than a hundred cells. The distance being so great, they do not attempt to send force enough through the intensity circuit to operate a sounder, but only to open and close the local circuit of Henry's quantity battery and spool. That circuit consists of a battery of but one or two cells of large surface, and a spool with about a hundred feet of coarse wire wound around its core. The intensity combination opens and closes this quantity circuit, whose armature strikes the sounder, just as the intensity armature itself does on shorter lines. *This obvious plan Henry described and exhibited in Princeton to his classes, long before any magnetic telegraph was ever commercially constructed.*

"Upon that apparatus there are four names to be written. Oersted, who discovered the effect of the voltaic current upon the magnetic needle; Arago, who discovered that the voltaic current could generate magnetism; Sturgeon, who

1. Mr. Dickerson has not given quite an early enough date for the Albany telegraph. It was in existence as early as 1830.

produced the first electro-magnet; and Henry, who discovered the conditions under which an electro-magnet might be operated at a distance—who invented the devices by which it could so operate—and who applied those devices to an operative telegraph, of the same form and substance as that now in use all over the world. Beyond their discoveries and inventions nothing is essential to the present telegraph, except that which was of common knowledge when those discoveries were completed, and that ordinary mechanical skill which is far below the level either of discovery or invention."

Oersted, Arago, Sturgeon: honored be their names, but we have seen that in their hands the telegraph was an impossibility. They planted their mile stones on the road towards it, but did not reach this goal. Again I would ask the reader to consider what constitutes the telegraph. It is that magic circuit in which the electro-magnet, indifferent to distance, responds to the influence of the galvanic battery. Whoever gave this circuit to the world is the father of the telegraph. Look at it; the magnet is Henry's. Mr. Taylor says, "Let it never be forgotten that he who first exalted the quantity magnet of Sturgeon * * * was the absolute creator of the intensity magnet: that magnet which alone 'is able to act at a great distance from its exciting battery'—that magnet which 'is alone applicable to the uses of the telegraph.'" But not only is the sensitive magnet with its subtle power Henry's gift; the law which tells what kind of battery must be its coadjutor is Henry's by discovery. He gave the magnet, he brought the magnet and battery into harmonious accord. This circuit is Henry's.

The important device of bringing into play one circuit by means of another, this too is Henry's. What remained then to be discovered in regard to the telegraph after Henry left it? Nothing. The electromotive force secured, the well-known mechanical appliances for the use of force, might be employed in various ways. Very clear, I would repeat, should be the distinction between the telegraph itself—that is the means of obtaining electromotive power at a distance—and methods of receiving and recording the message, or in other ways using the power. These clever contrivances may in every country be different, and may change every year; they may be very ingenious but they do not constitute the telegraph; strike out Henry's magic circuit, and they are useless bits of wood and metal. The dots and lines and the printed forms which first appealed to the eye, have long been superseded by intermittent sounds which address the ear. In fact even Henry's mechanical method of employing the electrical force now prevails.

"Let us now consider" (I quote again from Mr. Dickerson) "what would have been the position of Henry in the world, if at any time before his inventions had been so long in public use that he had lost his rights, he had taken a patent for :—

First, his magnetic spools pure and simple;

Secondly, the combination of a magnetic spool of long fine wire, with an "intensity battery" for the purpose of producing a practical magnetic effect at great distances;

Thirdly, the combination with such an apparatus of a quantity battery, operating upon a spool magnet of coarse and short wire, at a distance from the intensity battery; whereby the great lifting power of the quantity magnet might be controlled by the intensity combination;

"And *finally*, the combination of the intensity battery and spool, with a vibrating armature, so arranged as to strike a sounder when the circuit is closed or opened at the sending end, for the purpose of transmitting intelligible messages, telegraphically.

"All these he might have patented in the United States at any time during several years after his discoveries and inventions were made; and he could have held them against the world. That he was the first man to do these things is not in doubt any where. If he had taken such a patent, as late as 1837, he would have controlled the telegraph in this country, certainly until 1851; and unless he had then been adequately rewarded for his great inventions, his term would have been extended till 1858.

"Imagine the good he would have done to science had the wealth which this would have produced been poured into his purse! But listen to his noble words: 'At the time of making my original experiments in electro-magnetism in Albany, I was urged by a friend to take out a patent, both for its application to machinery, and to the telegraph; but this I declined on the ground that I did not then consider it compatible with the dignity of science to confine the benefits which might be derived from it to the exclusive use of any individual.'

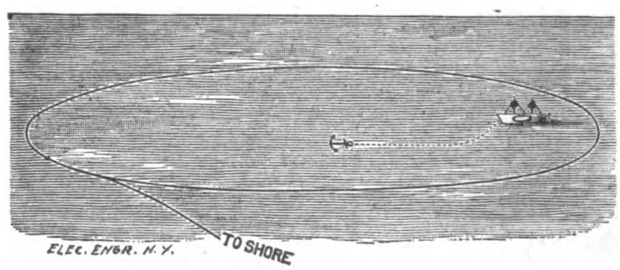
"Pure science was his beloved, and he could not make merchandise of *her*.

"When that sentence was written, other eminent scientists had thought differently of this question, and had patented their discoveries; and lest he might seem to cast a reproach upon them, and to say 'I am holier than thou;' his humble spirit added these words: 'In this *perhaps* I was too fastidious.'

"It must have occurred to him at times when he needed money for his experiments, and when he saw the fruits of his labor enriching the world, that he might have taken some share of the wealth; but he would not taint with selfishness his generous gift."

STEVENSON'S SYSTEM OF COMMUNICATION WITH LIGHTSHIPS.

MENTION has already been made in these columns of the method devised by Mr. Charles A. Stevenson for effecting



STEVENSON'S SYSTEM OF COMMUNICATION WITH LIGHTSHIPS.

constant electric communication between lightships and the shore. This method is based upon the simple induction between wire and wire and is illustrated in the accompanying engraving appearing in the London *Electrical Review*.

A cable is laid from the shore out to the vessel, where it makes one or more turns round the area over which it is possible for the lightship to travel, which is, of course, governed by the length of her chain cable. On board the ship there is an insulated coil of a number of turns of thick copper wire and entirely insulated from the sea. On each of these two circuits there are the batteries and telephones. Now, it is evident that the two coils, that on board the ship and that on the bottom of the sea, must generally be close to each other, say, within 100 yards, and the coils, moreover, must always be in a strong magnetic field with respect to each other, as the one is always inside, so that very little battery power will be requisite. Mr. Stevenson has already made coils work at 600 yards *outside* each other with only eight turns on each coil, and five cells as a battery power, the coils being about 200 yards diameter, so that it is evident that but a very feeble battery power will be necessary with the increase in the number of turns on board the lightship, and from the fact that they lie inside one another in place of outside.