THE

Electrical Engineer.

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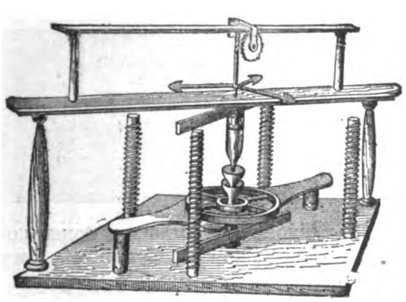
THE INVENTORS OF THE ELECTRIC MOTOR.—I.

WITH SPECIAL REFERENCE TO THE WORK OF THOMAS DAVENPORT.

BY

To rightly appreciate a discoverer we should not look at his work from our time; we should not judge of his work in the fullness of the light of present knowledge, but in the dim twilight which alone illuminated him to then unknown—but now well-known—facts and laws.—ALFRED M. MAYER.

THE electric motor, which but a few brief years ago, was regarded as but little better than a philosopher's plaything, has, with almost startling suddenness, assumed its position as one of the potent factors of modern industrial development. The story of the birth of this great invention has hitherto been given to the world only in part, and even such fragments of its early annals as were once known are now well-nigh forgotten; they linger only in fast fading written records, and in the memories of an earlier generation, of which the scattered survivors are rapidly passing from the stage. I have sought, therefore, while trustworthy evidence is yet accessible, not only from the testimony of the few witnesses yet living, but from the time-worn and crumbling pages of contemporaneous manuscripts, to rescue from impending oblivion the true story of the invention of the electric motor.



STURGEON'S APPARATUS FOR ELECTRO-MAGNETIC ROTATION.

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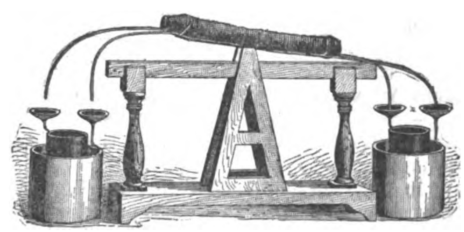
It is eminently desirable that we enter upon the field of research with a definite conception of what is meant when we speak of the electric motor in the sense of a concrete organization, in other words as an invention. What, then, let us inquire, is the essence, the fundamental principle, which finds its necessary embodiment in each and every one of the thousands of electric motors which are doing such an important and increasing share of the world's work to-day? The question happily, is not a difficult one to answer. If an expert, skilled in the law of patents, were asked to formulate in legal phraseology a definition which should concisely sum up the new and useful invention embodied in the machine which we know as the electric motor, it might be couched in language something like the following:

The method of producing mechanical power by the application of electro-magnetism, which consists in combining with a suitable source of electricity, two systems of electro-magnets; one system mounted upon a shaft rotating continuously in one direction; the other fixed in relation thereto, and a commutator actuated by the rotation of said shaft, acting to instantly reverse the polarity of one of said systems, when by reason of their mutual attraction, the revolution of the shaft has brought the poles of the moving magnetic system into coincidence with the poles of the fixed sytem.



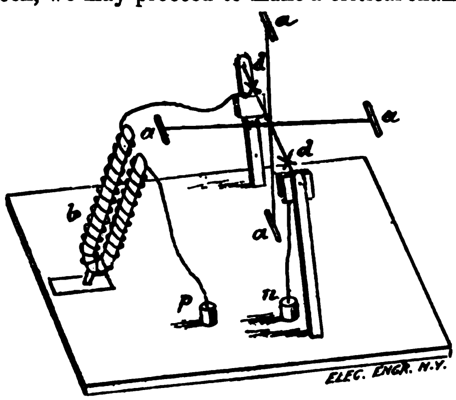
HENRY'S APPARATUS FOR PRODUCING MOTION BY ELECTRO-MAGNETISM.

[*By permission of Charles Scribner's Sons.*]

The above definition, formulated in the semblance of a patent claim, will at once be recognized as embracing the essential characteristics of the practical electric motor as we find it at work in the world to-day. On the other hand, it will be observed that the definition excludes certain special organizations, among which may be mentioned the rotary motor having a field induced by the permanent magnetism of steel; the rotary motor in which the intermittent attraction of electro-magnets is exerted upon a succession of non-polarized soft iron armatures arranged upon the periphery of a wheel, and the reciprocating motor in which masses of soft iron are dragged back and forth by the alternately intermittent attraction of electro-magnets or of solenoids. While it may be admitted that these and some other less well-known devices are not without a certain utility in minor and special applications of electric power, nevertheless, in a broad sense, it may be stated without qualification, that the machine of which a definition has just been given, has no less surely proven its right to be regarded as the accepted type of the modern electric motor than has the double-acting cylinder, piston and crank to be regarded as the accepted type of the modern steam engine.

As in the æolipile of Hero of Alexandria we had an example of rotary mechanical motion by the energy of steam before the advent of the double-acting cylinder and crank, so likewise did we have rotary motion by electro-magnetism before the combination of the reversible and the non-reversible electro-magnets in the magnetic engine. But it was not until the unerring inspiration of the master mind of Watt had grasped the true combination, that the world was put in possession of the steam-engine, that mighty agent which was destined to work its industrial regeneration. It has been my endeavor in the present investigation, to determine to whom should be accorded the distinction of being rightfully regarded as the Watt of the electric motor.

Having gained a clear conception of that for which we are to seek, we may proceed to make a critical examination



EDMONDSON'S APPARATUS FOR ELECTRO-MAGNETIC ROTATION.
[*From Silliman's Amer. Jour. Science.*]

of the history, written and unwritten, of the childhood of the electric motor.

Faraday, in 1821, demonstrated for the first time the possibility of producing continuous rotary motion by electro-magnetism—not by the electro-magnet, for this instrumentality had yet to be invented—but by the movement of a magnetized needle in a field of force.[1]

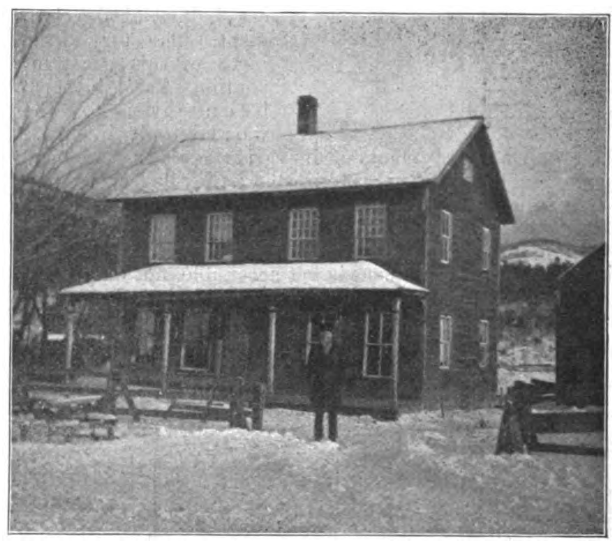
Barlow, in 1826, produced his rotating spur-wheel; founded upon the principle of the movement of conductors traversed by electric currents in the field of a permanent magnet.[2] These experiments were repeated with variations by many others. In 1825, Sturgeon[3] discovered the electro-magnet. In his hands, however, it was but a feeble instrumentality; a few turns of wire arranged in a single layer upon a bar of soft iron.[4]

In 1831, Henry's celebrated paper appeared, containing an account of his improvements in the electro-magnet and his experiments therewith.[5] The results which he described literally threw the scientific world of both hemispheres into a paroxysm of amazement; it marked perhaps the most brilliant epoch in the whole history of electro-magnetism. By winding the soft iron of the magnet with many superposed turns of silk-insulated copper wire, this experimenter succeeded in sustaining, solely by the force of magnetic attraction, a mass of iron weighing more than a ton. The accounts of Henry's discoveries, given to the world in a scientific journal of established reputation, were soon in possession of the eminent physicists of the European capitals, and ere long many busy brains were at work, each in an endeavor to add something, however little, to the masterly researches of the American philosopher.

In the same year, 1831, Henry published another paper commencing with these words:

> I have lately succeeded in producing motion in a little machine by a power which I believe has never before been applied in mechanics—by magnetic attraction and repulsion.
>
> Not much importance however is attached to the invention, since the article, in its present state, can only be considered a philosophical toy; although in the progress of discovery and invention it is not impossible that the same principle, or some modification of it on a more extended scale, may hereafter be applied to some useful purpose.[6]

The piece of apparatus referred to by Henry in this communication has been carefully preserved, and now forms one of the most valued treasures of the cabinet of the College of New Jersey, at Princeton. We give an illustration of it, made from a photograph, from which its construction may be readily understood. A straight horizontal electro-magnet, wound with three insulated copper wires, is pivoted at its centre, so as to be capable of a limited vertical reciprocating motion. Just beneath and parallel to this, a permanently magnetized steel bar is fixed in a horizontal position. The ends of the respective wires of the electro-magnet being properly connected, are arranged to alternately dip into mercury cups affixed to the poles of two opposing voltaic cells, and thereby to reverse the direction of the current through the helix at end of each stroke. The contrivance illustrated the principle upon



SHOP IN WHICH DAVENPORT AND SMALLEY CONSTRUCTED THEIR FIRST ELECTRIC MOTOR; NOW OCCUPIED AS A DWELLING.
[*From a recent photograph by F. L. Pope.*]

which Henry thought an electro-magnetic machine might be worked out, but having satisfied his scientific curiosity with this demonstration, he, like Faraday,[7] was quite willing

1. *Quarterly Jour. Science.* xii, 74. TYNDALL: *Faraday as a Discoverer*, p. 12.

2. BARLOW: *Essay on Magnetic Attractions, etc.* (2d Ed.) London, 1823, part iii., p. 280.

3. WILLIAM STURGEON, a celebrated English electrician, born at Whittington, Lancashire, in 1783; was apprenticed in his youth to a shoemaker, but disliking the occupation enlisted in the militia at the age of 19, and two years afterwards in the Royal Artillery. While in this corps he devoted his leisure to scientific investigation and made himself familiar with the leading principles of electricity and magnetism so far as they had then become known to the world. His scientific papers are numerous and of great value, but were sometimes characterized by an amusing exuberance of diction. When writing of his own discovery, the electro-magnet, he was always at his best, as the following extract will bear witness:—

"The superlative intensity of electro-magnets, and the facility and promptitude with which their energies can be brought into play, are qualifications admirably adapted for their introduction into a variety of arrangements in which powerful magnets so essentially operate, and perform a distinguished part in the production of electro magnetic rotations; whilst the versatilities of polarity of which they are susceptible are eminently calculated to give a pleasing diversity in the exhibition of that highly interesting class of phenomena, and lead to the production of others, inimitable by any other means."—*Annals of Electricity*, etc., x., 223.

He was for many years professor of experimental philosophy in the East India Company's military academy at Addiscomb, and in the latter part of his life lecturer on science at the Royal Victoria Gallery, Manchester. Died at Manchester, in December, 1850.

4. *Trans. of Soc. of Arts*, etc., vol. xliii, pp. 38–52.

5. Silliman's *Am. Jour. Sci.* xix, 400.

6. Silliman's *Am. Jour. Sci.* xx, 201.

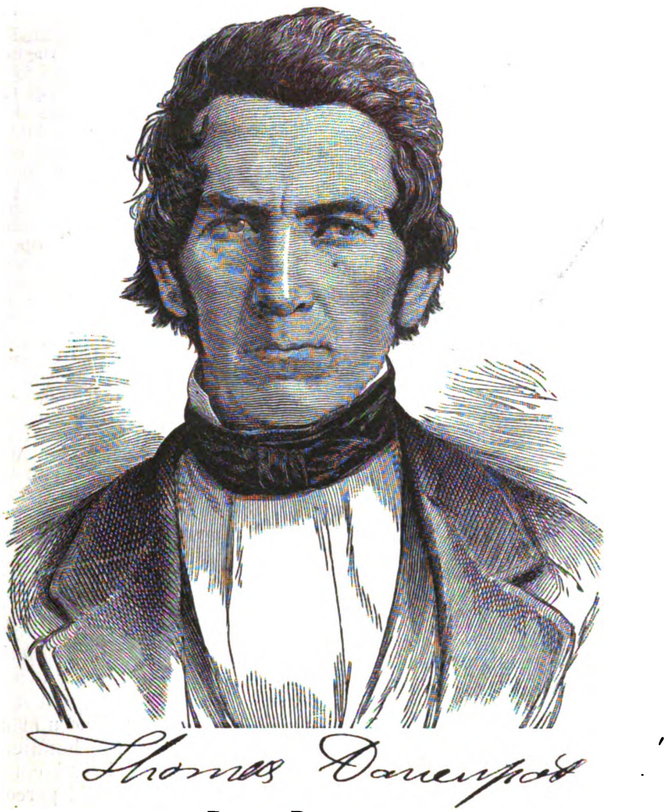
I never myself attempted to reduce these principles to practice, or to apply any of my discoveries to processes in the arts. My whole attention, exclusive of my duties to the college, was devoted to original scientific investigations, and I left to others, what I considered in a scientific view of subordinate importance, the application of my discoveries to useful purposes in the arts. * * * The only reward I ever expected was the consciousness of advancing science, the pleasure of discovering new truths, and the scientific reputation to which these labors would entitle me.—HENRY: Deposition in Telegraph Case, Morse *v.* O'Reilly.

7. I have rather however, been desirous of discovering new facts and new relations dependent upon magneto-induction, than of exalting the force of those already obtained; being assured that the latter would find their full development hereafter.—FARADAY: *Experimental Researches.* § 159.

to leave the practical development of the idea in the hands of those who might feel disposed to pursue it.

The first published description of an apparatus designed to produce a continuous rotary motion by the agency of an electromagnet is due to T. Edmondson, Jr., of Baltimore, and appeared in 1834.[8]

A fac-simile is given of the illustration accompanying Edmondson's account as published. The apparatus will be seen to consist of a number of neutral soft-iron armatures, mounted upon radial arms affixed to a horizontal shaft. These are successively brought within the sphere of attraction of a stationary electro-magnet, while a commutator is provided by which the magnetizing current is interrupted long enough to permit each armature in turn to pass out of the magnetic field. This appears to be the earliest instance on record of the use of the modern commutator; an elastic contact-spring or brush, pressing against metallic segments fixed upon a revolving shaft.



THOMAS DAVENPORT.
[From a daguerreotype made in Salisbury, Vt., about 1850.]

In 1836, Sturgeon, the inventor of the electro-magnet, published a description of a rotary electro-magnetic engine accompanied by an illustrative drawing, in which he stated that the machine described had been constructed and put in operation as early as the fall of 1832, and had been exhibited before a large audience in London in the spring of 1833.[9]

Sturgeon's apparatus, though usually referred to as the earliest example of an electro-magnetic rotative engine, is in fact little else than a re-arrangement of Ritchie's "revolving magnet," which was described in a paper read by him before the Royal Society, March 21, 1833, and published with an illustrative plate in *Philosophical Transactions*, of that year. The device consisted of a straight electro-magnet, mounted so as to revolve freely upon an upright axis, its poles at each half revolution passing close to the poles of two upright permanent bar-magnets. A mercurial commutator reversed the polarity of the electro-magnet twice in each revolution, as it came opposite the poles of the bar-magnets. Dr. Charles G. Page, then of Salem, Mass., improved this apparatus by the substitution of a metallic commutator, and in this form it became one of the stock pieces of electro-magnetic apparatus in the schools and colleges of America.[10]

The engraving on page 1 is a copy of the illustration given by Sturgeon, from which it will be seen that his machine consisted of two permanently magnetized steel bars turning horizontally upon a vertical axis. The poles of these magnets, as they revolve, are successively attracted by the poles of four upright electro-magnets formed of straight rods of soft iron wound with helices of wire. The details of the commutator are omitted in Sturgeon's drawing, but he explains that the reversal of the polarity of the electro-magnets is effected by permitting the ends of the conducting wires to trail in the segmentally divided vessel of mercury which is seen in the centre of the figure. There is in Sturgeon's description no suggestion of the possibility of substituting electro-magnets for the permanent magnets employed by him.[11]

Not long after the publication of the paper of Henry which has been referred to, an attempt was made by parties interested in the Penfield Iron Works at Crown Point, N. Y., to employ magnetism for separating the constituents of pulverized iron ore. A machine was devised, containing a wooden cylinder, the surface of which was armed with a great number of teeth or points of magnetized steel. These were made to revolve continuously through a mass of pulverized ore. The particles of iron were separated from the refuse by adhering to the magnetized teeth, from which they were afterwards brushed off by suitable appliances. In order to charge these magnetic teeth there had been procured, at the suggestion of Professor Amos Eaton, of Troy, from Professor Henry, one of his electro-magnets made of a 1-inch rod, and weighing about 3 pounds. The actuating current for the magnet was supplied by two zinc and copper cells, the plates of which were arranged concentrically upon a plan devised by Dr. Robert Hare. The performances of this electro-magnet, which when excited was capable of sustaining an iron anvil weighing over 100 pounds, were occasionally exhibited for the astonishment of the simple rustics of that somewhat remote region, to whom at that day, the philosophy of electro-magnetism was a thing yet undreamed of. Thus the fame of the Crown Point "galvanic magnet" gradually spread abroad throughout all the surrounding districts.

At the period of which I write, there had grown up in an outlying portion of the township of Brandon, near the foot of the western slope of the Green mountains of Vermont, a scattered village, consisting for the most part of the homes of laborers and other employés of a recently erected blast furnace, which had been christened Forest-

8. Silliman's *Am. Jour. Sci.* xxvi, 205.

9. *Annals of Electricity, Magnetism and Chemistry*. i, 75.

10. DAVIS: *Manual of Magnetism* (Ed. of 1857) p. 212; and SILLIMAN: *Principles of Physics* (Second Ed.) p. 611, give illustrated descriptions of Page's improvement, which was made in February, 1838. SILLIMAN'S *Am. Jour. Sci.* xxxv, 262.

11. Some other early devices for producing mechanical motion by the action of electro-magnets, but which had no direct bearing upon the ultimate solution of the problem of the motor, nevertheless deserve mention as a part of the general state of the art. Descriptive memoirs of these may be consulted, as follows:

DAL NEGRO, SALVATORE.—*Nuova macchina elettro-magnetica, immaginati dall' Ab. Salv. Dal Negro.* (Annali delle Scienze del Regno Lombardo-Veneto, 10 Marzo, 1834, tom. iv, p. 67.) Padova, 1834.

BOTTO, GIUSEPPE DOMENICO.—*Notizia sopra l' applicazione dell' Elettromagnetismo alla mecannica.* Torino, 1834.

SCHULTHESS, RUDOLPH.—*Ueber Elektromagnetismus, etc.* (Lecture delivered to the Philosophical Society, at Zurich, Feb. 18, 1833), Zurich, 1835. A translation of the two papers last referred to may be found in *Taylor's Scientific Memoirs*, vol. i, part iv, p. 552 et seq.

dale. Among the mechanics whom the temporary prosperity of this new settlement had drawn from other places was Thomas Davenport, a man who had for some years lived and pursued his occupation of blacksmith in the village of Brandon, some two or three miles away. Davenport was at this time about 30 years of age; of somewhat slender physique, but of more than ordinary intelligence and acquirements, considering his educational advantages, which had been limited to those afforded during his minority, by an attendance of six weeks per year upon a common district school in a remote mountain town. He had, however, succeeded in getting possession of some fragmentary portions of a scientific book, which he was wont to pore over while laboring at the bellows of his forge, and by this means had learned at least enough to excite his desire to learn more. Shortly after his removal to Forestdale, Davenport formed the acquaintance of another artisan living there named Orange A. Smalley. Smalley was ten years younger than Davenport, bright, enterprising, and with a natural taste for scientific pursuits. Several years before, while at school at Rochester, a town a few miles distant, he had attended a lecture given in the school-house by some itinerant philosopher of that day, which had served to awaken his curiosity and interest, and so it came about that he and Davenport soon became constant and congenial companions during their brief intervals of relaxation from daily toil. Smalley at this time owned a workshop, and had accumulated a few hard-earned dollars in the diligent pursuit of his trade of blacksmithing and wagon-making. In the course of their intimacy these young men conceived the ambitious plan of increasing their scanty incomes by traveling from place to place during the winter, and delivering experimental scientific lectures. While this scheme was under consideration, and the two were endeavoring to hit upon some new feature which might add to the attractions, and consequently to the profits of their projected entertainment, Davenport chanced to hear a wonderful tale of the performances of the "galvanic magnet" at the Penfield Iron Works. His curiosity was especially aroused by the alleged suspension, by mysterious power, of a blacksmith's anvil, and he accordingly made a journey to Crown Point, 20 miles distant, to witness this extraordinary phenomenon. In this he was disappointed, owing to the inopportune absence of the proprietors. He did, however, succeed in learning that the apparatus had been procured in Albany. With the indomitable perseverance which was ever one of his most marked characteristics, Davenport forthwith set out for that city, determined to purchase a "galvanic magnet," presumably with the intention of utilizing it as one of the star attractions of the projected series of lectures. In due time he arrived in Albany, but inasmuch as he had but the most hazy idea of what the thing was that he wished to purchase, and still less of the locality where he might expect to find it, it is perhaps not to be wondered at that his researches were not crowned with success. It is worth while to quote his own naïve story of his adventures on this quest for the electro-magnet :—

As I had been informed that the apparatus was a galvanic battery and possessed powerful magnetic properties, I inquired of my landlord where I should be likely to find a "magnetic battery." He replied that they "made such tubes at the tin-shops for blasting rocks," and directed me there. The tinman sent me to a jeweler's shop where he was sure "they used something of the kind in the manufacture of watches." The jeweler remarked that they had no occasion for such heavy instruments about watches, but advised me to "go to the Eagle furnace where they could cast from any pattern." At this latter place I declined calling and returned home. In December, 1833, I again went to Crown Point with the intention of purchasing some iron, and with high hopes of seeing an anvil suspended between the heavens and the earth by magnetic power. This long-looked-for mystery was finally shown me on my arrival at the Penfield Iron Works; an electro-magnet weighing about three pounds, to which was attached two sets of cups consisting of copper or zinc cylinders to be used in earthen quart mugs. The poles of the magnet were placed upon the face of a common blacksmith's anvil, and as soon as the cups were immersed in the solution of sulphuric acid and water contained in the earthen mugs, the magnet adhered sufficiently to lift the anvil until the battery-cups were removed from the solution. This had to be done by raising the cups out of the mugs, as the conductors were permanently connected together by soldering the battery conductors to those of the magnet. Here was to me one of the wonders of nature and Providence; a new kind of magnetic power! I inquired whether, if the battery cups remained in the solution, and one or both of the conducting wires should be cut in two, on connecting the conductors with the fingers or otherwise, so as to barely bring them in contact, the power would not be suddenly renewed, and as suddenly destroyed by separating them? The reply was that the power of the magnet would be destroyed, for it appeared that they had broken one of the wires which connected the cups with the magnet, and supposing the instrument spoiled, packed it up and sent it to Albany for Professor Henry to repair; whence it had but just returned. I requested the privilege of cutting one of the conductors, and connecting it together for the purpose of ascertaining this fact, but was refused. I demanded the price, and purchased the magnet for the sum of $18, instead of iron which I much needed for my shop. * * * * * As soon as I became the possessor of the magnet, I immersed the cups in the solution and then severed one of the conductors, so as to break the circuit of galvanism. Of course I found the magetism wholly destroyed, but on connecting the wires together with my fingers, the magnet became again fully charged. However rapidly the connection and separation of the conductors were made, I found the charging and discharging of the magnet to correspond, and I observed that the magnet produced a hundred-fold more power than was required to make and break the connection.

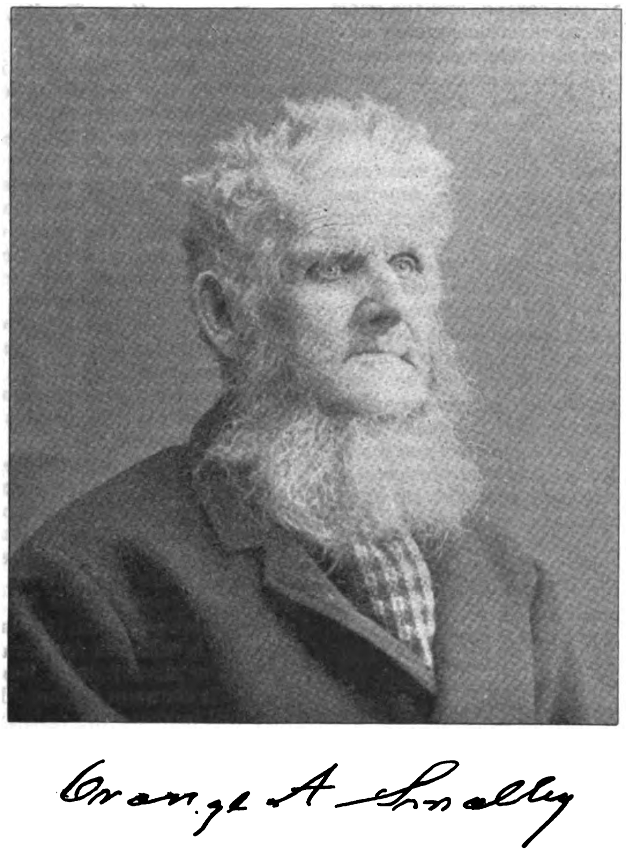
Like a flash of lightning the thought occurred to me, that here was an available power which was within the reach of man. If three pounds of iron and copper wire would suspend in the air 150 pounds, what would 300 pounds suspend? "In a few years," I said to some gentlemen present, "steamboats will be propelled by this power." A bystander replied, "You mean, sir, magnetic boats." "Truly so," I remarked, "and ere long this mysterious and invisible power will supersede steam; for, shall the mighty agent which suspends this ponderous mass of iron between heaven and earth, serve no other purpose than to excite our wonder and admiration? No! The human mind will not rest with so great a prospect before it, of furnishing a valuable substitute for the murderous power of steam; I venture to predict that the time is not far off, when there will be no more need of legislation and committees of inspection on steam boilers; no more aching hearts and desolate homes in consequence of the awful spectacle of human beings hurled into eternity, but the red lightning of heaven will be soon tamed and will become our servant."

Immediately upon the return of Davenport from Crown Point with the coveted apparatus in his possession, with the co-operation of Smalley experiments were commenced, with the object of producing a machine to be continuously moved by electro-magnetism. Davenport, like Fulton, Morse, Bell and many others of those to whom the world is indebted for its great inventions, appears to have been a man possessing in no unusual degree either mechanical ingenuity, or skill in handicraft. He seems rather to have been a man of broad conceptions and of prophetic foresight; one who could perceive what needed to be done, and who could select the men and the instrumentalities to do it. Above all, he was endowed with a more than common share of that indomitable perseverence and inflexible determination in pursuit of a cherished ideal, which cannot be permanently cast down nor turned aside by any obstacle, however great; which in truth can scarcely be conquered by death itself. Smalley, his associate, was a young man of acute perceptions and keen intelligence; not in any sense a trained craftsman, but rather a typical New England backwoods mechanic, "handy with tools" either in wood and in iron; with a brain fertile in expedients and contrivances to overcome unexpected difficulties. During the greater part of the year 1834, these two worked together in the building still standing at Forestdale, which at that time was occupied by Smalley as a shop. Early in the summer of that year, they succeeded for the first time in obtaining rotary motion by electro-magnetism. A permanently magnetized bar was supported at its centre of gravity like a magnetic needle. By placing the pole of an electro-magnet in proximity to the imaginary circle described by the horizontal swing of the bar, and then breaking the circuit by hand at properly timed intervals, it was found that the bar could be kept in continuous rotation. This proved to be the key to the solution of the problem of the electric motor.

After much further experimentation, Davenport and Smalley finally succeeded in completing an organized apparatus which was capable of maintaining continuous rotation by automatic means. Unfortunately, no drawing of this machine has been preserved, but the following brief description of it, written by Davenport in 1851, will serve to sufficiently explain the essential features of its construction :—

In July, 1834, I succeeded in moving a wheel about seven inches in diameter at the rate of thirty revolutions per minute. It had four electro-magnets, two of which were upon the wheel, and two were stationary and placed near the periphery of the revolving wheel. The north poles of the revolving magnets attracted the south poles of the stationary ones with sufficient force to move the wheel upon which the magnets revolved, until the poles of both the stationary and revolving magnets became parallel with each other. At this point, the conducting wires from the battery changed their position by the motion of the shaft; the polarity of the stationary magnets was reversed, and being now north poles, repelled the poles of the revolving magnets that they before attracted, thus producing a constant revolution of the wheel.

The electro-magnets used in this machine were copied, with Chinese fidelity, from the Henry magnet purchased at Crown Point, which had been dissected, and the courses and direction of the convolutions of wire in its helices carefully observed. It almost immediately occurred to the experimenters that the speed and power of the machine would be greatly increased by placing a greater number of magnets upon the revolving shaft. Being unable at the time to procure the necessary copper wire for making any more electro-magnets, they tried the effect of substituting permanent magnets, at the same time increasing the number upon the shaft from 2 to 12. The result exceeded their most sanguine expectations; the wheel now revolved at such a rate that the mechanism of the commutator,—which consisted of bent wires dipping into mercury cups, moved by a cam affixed to the shaft—was utterly unable to keep pace with it.



ORANGE A. SMALLEY.

[From a recent photograph by F. A. Grimes, of Brandon, Vt.]

The machine here referred to unquestionably constitutes a complete embodiment of the principles of the modern electric motor, as we have defined them in a preceding paragraph. The description of Davenport agrees in every essential particular with that recently given to the writer, from his own recollection, by Mr. Smalley, who is still living, and although almost an octogenarian, is in full enjoyment of his memory and faculties. He may be seen standing in the photographic view of his old-time shop, which forms one of our illustrations. It may be of interest to state that he did not hesitate to make a journey of several miles on one of the coldest of winter days, in order that the readers of THE ELECTRICAL ENGINEER might be favored by the presentation of the accompanying admirable and characteristic portrait.

The successful outcome of their first attempt at the construction of an electro-magnetic engine, filled the hearts of the experimenters with pardonable elation. They flattered themselves that at least they would no longer be compelled to endure the sarcastic and derisive comments of the neighbors, few of whom could be persuaded that the scheme upon which they were at work could be anything else than the "perpetual motion," which in those less enlightened days was the *ignis-fatuus* of many an ambitious rural mechanic. They met, however, with scant encouragement. The village pastor, when the mysteriously moving machine was shown to him, and the enthusiastic hopes of its constructors were poured into his ear, made the characteristic observation that "if this wonderful power was good for anything it would have been in use long before this." Nevertheless, regardless alike of ridicule, disparagement and poverty—for both were dependent upon their daily toil for the most ordinary necessities of life—Davenport and Smalley prosecuted their experiments with unwearied diligence. From some of the more intelligent of their townsmen, they received now and then a word of encouragement, and it was largely in the hope of being able to satisfy these friends that their ideas were not wholly chimerical, they determined to take the machine to Middlebury, a town 16 miles north, which boasted of an embryo college, and submit it to the inspection of those more familiar than themselves with scientific pursuits, who were presumably qualified to form a competent judgment of its merits.

ST. PAUL'S ELECTRIC RAILWAY SMOKESTACK.

The smokestack of Mr. Tom Lowry's electric railway power house is just 200 feet high, and has an inside diameter at the base of fifteen feet. It took 875,000 brick and 85,000 fire brick to build it. It weighs 19,500 tons and cost $10,000. The flue, which is eleven feet in diameter for one hundred feet from the base upward, is built of fire brick. The casing of fire brick stands like a cylinder within a cylinder, and from the outside wall. The immense furnaces which are to generate steam in boilers which are to operate engines with 7,000 h. p. capacity, would heat the smokestack up for a distance of nearly 100 feet high to such an extent that it would crack unless there was a fire brick casing inside, and this fire brick casing must have room for expansion. The exterior of the stack is octagonal in shape, faced with beautiful white pressed brick, and decorated with cornice work and figures in colored brick.

BOSTON, MASS.—The West End Railway Co. proposes to increase its capital stock by $4,500,000. Its business is growing rapidly.

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THE INVENTORS OF THE ELECTRIC MOTOR.—II.

WITH SPECIAL REFERENCE TO THE WORK OF THOMAS DAVENPORT.

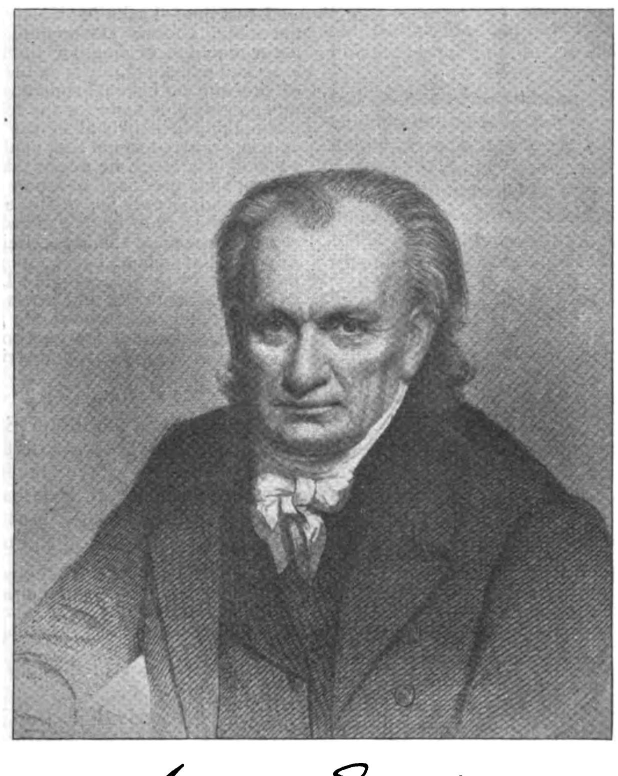
BY

Franklin Leonard Pope

ONE stormy day near the end of December, 1834, Davenport and Smalley drove over to Middlebury, taking with them their best machine, which they set up in a room at the village tavern. Davenport then set out to make the acquaintance of the Professor of Natural Philosophy at the college, and invite him to view the phenomenon. This part of the story shall be told in his own words:

As I had never before seen a college or a professor, I rather dreaded making my acquaintance with those functionaries. I mustered up courage and walked towards the college. As I reached the steps of the building, I saw a fellow with a ragged coat on, an old rusty cap turned over his ears (for it was a cold, stormy day) and a large dirty plank on his shoulder, about entering the college at the same door as myself. I accosted him and inquired if I should be likely to find Prof. Turner about there. He said, "Yes, come in and I will show him to you." I followed him into a lumber room; he threw his plank down, pulled off his leather mittens and said "I am Prof. Turner; perhaps I don't look much like a professor." "As to that, sir," I replied, "I could not say, for you are the only professor I ever saw to my knowledge, but I conclude that your judgment don't lie in your clothes."

Prof. Turner, after having received assurances that whatever the machine might be, it was not claimed to be a "perpetual motion," consented to examine it. The operation of the working model, as exhibited by Smalley, excited his enthusiasm to the highest pitch. He exclaimed :— "Gentlemen, what you have invented is indeed not a perpetual motion; it is nothing less than a *new motive power*, an electro magnetic engine." Prof. Fowler was at once sent for, and upon witnessing the surprising performance of the little machine, became no less enthusiastic than his colleague. In the presence of a dozen or so curious bystanders who had assembled, he made, as Mr. Smalley says, "a regular speech," in which he expressed in emphatic terms the opinion that those present were then witnessing the first exhibition of what would prove to be one of the greatest inventions of the nineteenth century.



Amos Eaton

From a portrait painted by the late Abel B. Moore, circa 1841, and now in the Rensselaer Polytechnic Institute, Troy, N. Y.

Prof. Turner advised Davenport and Smalley to take immediate measures to secure a patent, and with characteristic kindness and generosity undertook to prepare for them a draft specification descriptive of the invention, which he recommended them to place in the hands of a competent attorney at Washington. This interesting document has fortunately been preserved, and the fac-simile of it herewith presented constitutes the best possible evidence of the stage of development which the invention had reached at the beginning of 1835, the date when it was written. This paper, which is in the handwriting of Prof. Turner, is in the following words :—

Davenport and Smalley's Specification of their Invention of an Electro-Magnetic Machine.

Middlebury, Vermont, Jan. 5, 1835.

The following is a description of the electro-magnetic engine invented by Messrs. Davenport & Smalley, of Brandon, Vt., and referred to in the accompanying application of this date. (See drawing below.)

A and B are horseshoe magnets, placed vertically around the axis *ab* to which they are fastened. Of these there may be any number almost; in the model which has been executed there are twelve, although for the sake of simplicity only two are represented in the drawing. It is to be observed that each pair of opposite magnets must have the same poles, as S S, uppermost: but that in case there should be more than one pair, the *adjacent* magnets must have their poles N and S alternately uppermost. C and D are galvanic magnets, or pieces of soft iron having copper wire wound around them, and susceptible of a high degree of magnetism by being connected with either pole of a galvanic arrangement. Q and R are galvanic batteries, consisting each of concentric copper cylinders with zinc between them. 1, 2, 3, 4, 5—16 are cisterns of mercury, of which 1, 6, 11 and 16 are connected with the zinc pole and 2, 5, 12 and 15, with the copper pole by means of wires *z* and *c*. The wires marked *x* connect 3 with 10, 4 with 9, 7 with 14 and 8 with 13. Y T and U V are two levers, turning on pivots at W by the motion of the axis *ab* and carrying with them transverse slips of copper with the extremities bent downwards. When the end Y of the lever Y T is depressed, these slips establish a communication between 9 and 11, 10 and 12, and consequently the wire *m* and the upper branch of C are connected with the copper pole of the battery, and the wire *n* and the ower branch of *c* are connected with the zinc pole. It is evident that, in this case, the upper part of C will be a north pole, and therefore attracted by the pole S of A, while the lower branch of C will be a south pole, and therefore attracted by the pole N of A. In consequence of this attraction the magnet A is brought nearly into contact with C when Y is raised and the end V of the lever V U is depressed; thus establishing a communication between 1 and 3, 2 and 4, or by means of the wires *x*, a communication between 1 and

10, 2 and 9, while the connection between 9 and 11, 10 and 12 is interrupted. Hence the poles of the galvanic magnet C will be reversed, the upper one will be south and the lower north; they will therefore be repelled by the corresponding poles of A. In this manner a rotary motion of the magnets A and B on the axis *ab* is kept up so long as the galvanic action continues in the battery. And in the same manner the influence of the battery on the galvanic magnet D or any others may be illustrated. With twelve magnets on the axis and two at the sides, the axis turns round about sixty times in a minute and consequently the poles of the galvanic magnet are reversed 360 times.

To the axis *ab*, it is evident, that any machinery may be attached for the purposes of manufacture, propelling boats, cars on railroads, etc., etc. In the drawing the machinery is supposed to be applied near *b*. The action of the machine may be continued for any length of time by occasionally renewing the fluid.

And on the other hand, the action may be checked or entirely suspended by raising part or all of the connecting wires *c* and *z* out of the cisterns of mercury.

Instead of the arrangement of magnets above referred to, it is thought that there would be an advantage in employing none but galvanic magnets either on the axis or at the sides.

The significance of the closing paragraph will not escape the attention of the reader. It confirms the written description of Davenport and the independent verbal statement of Smalley, that as early as 1834 the conception of the combination of stationary and rotating *electro-magnets*, with a suitable pole-changing device, had been worked out and tried by them. The suggestion of applying electro-magnetic apparatus to the propulsion of railway cars is also worthy of note, inasmuch as it was not until fourteen years later that the steam locomotive made its advent in the state of Vermont. The Mohawk and Hudson railroad had, however, been in operation between Albany and Schenactady for some years, and it was probably from this circumstance that the suggestion in the specification originated.

The experimenters were greatly encouraged by the cordial reception which the invention had received at the hands of the Middlebury professors, and the warm interest which they had manifested in the further prospects of the undertaking. It is of interest to record that Davenport now for the first time obtained access to scientific books, from which he could gain some further knowledge of the agent which he was using. Among other works he was shown Silliman's Chemistry, containing accounts of some of Prof. Henry's experiments in electro-magnetism, from which, curiously enough, he first learned the proper names of the instruments and materials he had been using. Up to that time, having been ignorantly instructed by the people at Crown Point, he had called the battery the "cups" and the electro-magnet the "battery."

The difficulties which were inseparable from the use of the mercurial commutator when the rapidity of motion was great, have already been alluded to. Immediately after their visit to Middlebury, the experimenters constructed another machine, and correctly reasoning that the circuit might perfectly well be closed by a metallic commutator, as had been proven by touching of the wires together by hand, they substituted for the mercury contacts insulated segments upon the shaft, which were rubbed by contact-springs formed of elastic flattened wires, and were gratified to discover that this serious obstacle to the rapid revolution of the machine was now entirely removed. This improvement was made prior to May 1, 1835. It appears to be the earliest instance of the use of the modern commutator; an elastic contact-spring or brush, pressing against metallic segments, fixed upon a revolving shaft.*

Not long after the completion of this improved machine, a difference of opinion arose between Davenport and Smalley in respect to the most desirable policy to be pursued in disposing of interests and rights in the invention, in order to raise the funds to cover expenditures already incurred, and to provide the means which were urgently needed for the prosecution of further experiments, as well as for the procuring of patents. An amicable settlement was ultimately arrived at, in accordance with which Smalley relinquished his entire interest in the invention for a sum agreed upon, and Davenport was left free to seek for other assistance in the prosecution of his cherished designs.

For some months he continued his experiments, having for the time transferred the scene of his labors to Rochester, a small town a few miles east of Brandon, at which place, with the assistance of a mechanic named Richardson, he constructed no less than ten machines of different designs, some of which were capable of making 50 revolutions per minute.

The invention having now been brought to a tolerable state of efficiency, Davenport was naturally very anxious to lose no further time in securing his patent. In those days it was supposed to be absolutely necessary that the inventor should visit Washington in person in order to properly explain his ideas. At that date, 1835, this was a long, tedious and expensive journey. Being almost entirely destitute of means to carry out his design, Davenport appealed to his friend and neighbors, and succeeded, after many entreaties, in inducing six of them to make up a joint purse to supply him with funds for his intended journey to Washington. In July, 1835, he set out for the capital, carrying with him his latest model, and a letter of introduction from his friend Prof. Turner to Prof. Amos Eaton, who was at that time principal of the Rensselaer Polytechnic Institute at Troy, N. Y., as follows:

MIDDLEBURY COLLEGE, June 4, 1835.

DEAR SIR —I take the liberty of introducing to your acquaintance Mr. Thomas Davenport, the inventor of an electro-magnetic machine of singular interest. Mr. Davenport has labored long and expended much on his invention, but has not the means of prosecuting his experiments farther without the aid of some one possessed of taste for the science, and also of funds requisite for making a *fair* trial of the propelling power of his machine. It has occurred to me that could Mr. Van Rensselaer, of Albany, become interested, he might take pleasure in furthering an enterprise which promises so much; and in patronizing an American artist, who, it may be, will one day compete with Watt and Fulton in the glory of having added another prime mover of machinery to science and the arts. Being personally unacquainted with Mr. Van Rensselaer, I presume you will be so good as to do me the favor of introducing Mr. Davenport (by letter or otherwise) to that distinguished and estimable man. This or any other attention you can conveniently render, will be considered as conferring additional obligations on one who has the honor of being,

Sir, your friend and fellow laborer,

E. TURNER.

Prof. AMOS EATON.

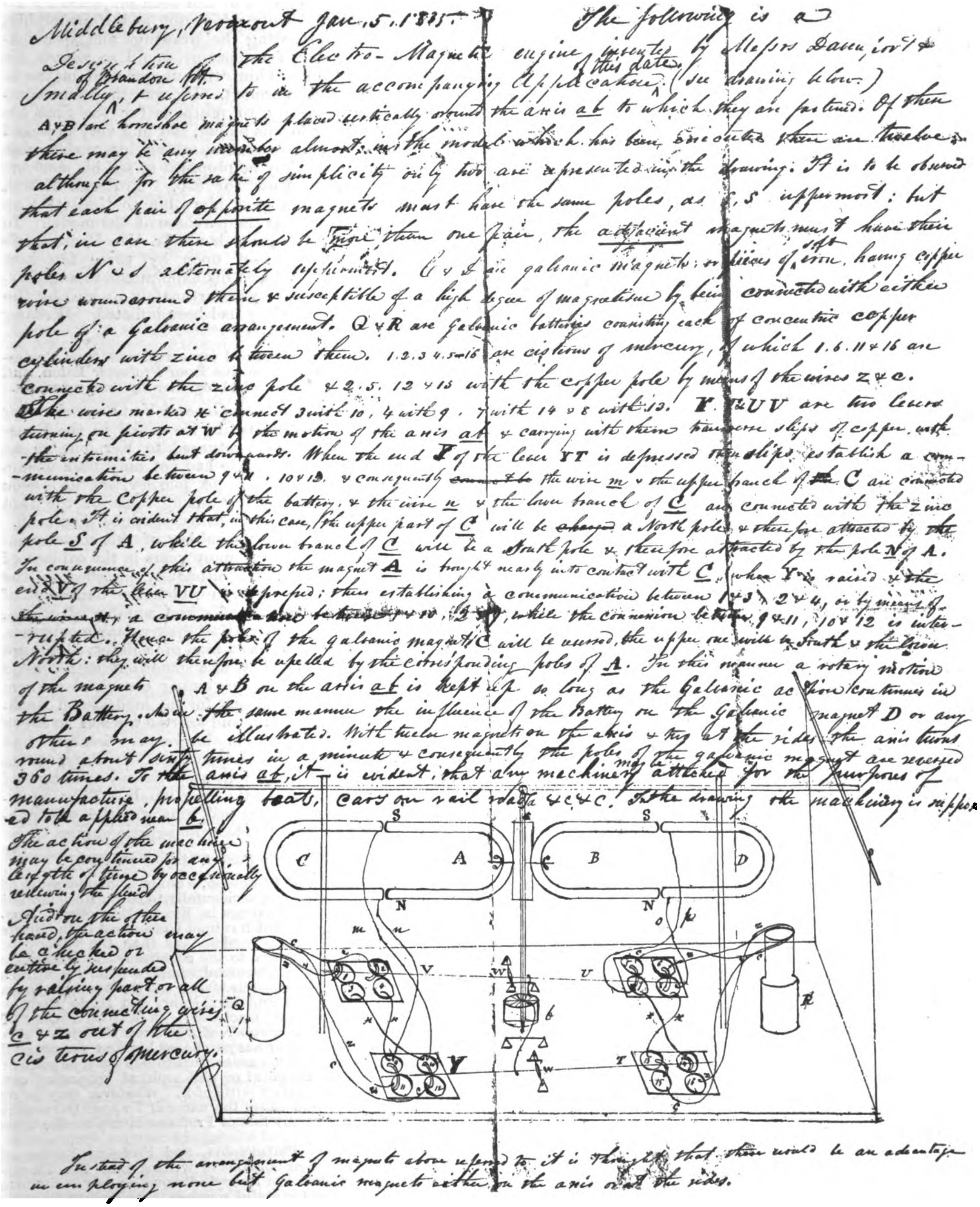
The Honorable William Slade, afterwards Governor of Vermont, who was at that time a member of Congress from the district, gave Davenport a note of introduction to the Commissoner of Patents, Hon. H. W. Ellsworth, from which the following extract is of interest as being indicative of his estimate of the man:

The bearer hereof, Mr. Thomas Davenport, goes to Washington for the purpose of obtaining a patent for the production of motion applicable to machinery by galvanism. His diffidence has induced him to ask a letter to you, which I give with great pleasure. His personal worth is equal to his genius, of which he has given no equivocal evidence in the very ingenious machine for which he asks a patent.

Upon his arrival at the Rensselaer Institute, in Troy, Davenport was most courteously received by Prof. Eaton, who endorsed upon the note of introduction from Prof. Turner, a few lines recommending him to the consideration of General Stephen Van Rensselaer, the eminent founder and patron of the Institute, in which he said:

I have told Mr. Davenport that no one could consistently aid him without Prof. Henry's approval. I have advised him to exhibit his machine to Prof. Henry, after you have seen it. This he will do. Professor Henry has suggested the practicability of applying this great power to machinery, but I did not from him understand that any plan had been fixed on. Mr. Davenport's plan is a simple and efficient one. . . . . It appears to me that Professor Henry would be greatly delighted

* By an error in copying, the foregoing sentence was attached to the description of Edmondson's apparatus, in p. 3 of the last number of THE ELECTRICAL ENGINEER, to which it obviously has no application.



Middlebury, Vermont Jan. 5. 1835. The following is a Description of the Electro-Magnetic engine invented by Messrs Davenport & Smalley, of Brandon Vt. & referred to in the accompanying application of this date (see drawing below.)

A & B are horseshoe magnets placed vertically around the axis ab to which they are fastened. Of these there may be any number almost, in the model which has been executed there are twelve, although for the sake of simplicity only two are represented in the drawing. It is to be observed that each pair of opposite magnets must have the same poles, as S. S. uppermost; but that, in case there should be more than one pair, the adjacent magnets must have their poles N & S alternately uppermost. C & D are galvanic magnets, or pieces of soft iron having copper wire wound around them & susceptible of a high degree of magnetism by being connected with either pole of a Galvanic arrangement. Q & R are Galvanic batteries consisting each of concentric copper cylinders with zinc between them. 1.2.3.4.5–16 are cisterns of mercury, of which 1.6.11 & 16 are connected with the zinc pole & 2.5.12 & 15 with the copper pole by means of the wires z & c. The wires marked x connect 3 with 10, 4 with 9, 7 with 14 & 8 with 13. YT & UV are two levers turning on pivots at W by the motion of the axis ab & carrying with them transverse slips of copper, with the extremities bent downwards. When the end Y of the lever YT is depressed the slips establish a communication between 9 & 11, 10 & 12, & consequently [illegible] the wire m & the upper branch of the C are connected with the copper pole of the battery, & the wire n & the lower branch of C are connected with the zinc pole. It is evident that, in this case, the upper part of C will be ~~changed~~ a North pole, & therefore attracted by the pole S of A, while the lower branch of C will be a South pole & therefore attracted by the pole N of A. In consequence of this attraction the magnet A is brought nearly into contact with C, when Y is raised & the end V of the lever VU is depressed; thus establishing a communication between 1 & 3, 2 & 4, or by means of the wires x, a communication between 1 & 10, 2 & 9, while the connexion between 9 & 11, 10 & 12 is interrupted. Hence the poles of the galvanic magnet C will be reversed, the upper one will be South & the lower North: they will therefore be repelled by the corresponding poles of A. In this manner a rotary motion of the magnets A & B on the axis ab is kept up so long as the Galvanic action continues in the Battery. And in the same manner the influence of the Battery on the Galvanic magnet D or any others may be illustrated. With twelve magnets on the axis & two at the sides the axis turns round about thirty times in a minute & consequently the poles of the galvanic magnet are reversed 360 times. To the axis ab, it is evident, that any machinery attached for the purposes of manufacture, propelling boats, cars on rail roads &c &c. In the drawing the machinery is supposed to be applied near b.

The action of the machine may be continued for any length of time by occasionally renewing the fluid. And on the other hand, the action may be checked or entirely suspended by raising part or all of the connecting wires c & z out of the cisterns of mercury.

Instead of the arrangement of magnets above referred to it is thought that there would be an advantage in employing none but Galvanic magnets either on the axis or at the sides.

Fac Simile of Original Draft of Davenport's Patent Specification of 1835, For His Electric Motor.

with such a satisfactory exemplification of a principle which has extended his name to the ends of the earth.

Acting upon this suggestion of Professor Eaton, General Van Rensselaer gave Davenport a line of introduction to Professor Henry, which he delivered to him in person a few days afterwards at Princeton. Professor Henry was much interested in Davenport's machine, and after witnessing its operation asked how large a power he intended to build, to which Davenport replied "a full one-horse power;" whereupon Professor Henry, with his usual caution, suggested that it would be better if he were to continue his experiments for a time on a smaller scale. He said to him that if it were given out that he was building a one-horse power magnetic machine, and should he fail in his first attempt, which would not improbably be the case, not only would his credit as an inventor suffer, but the electromagnetic engine would be hastily and unjustly stigmatized as a "humbug," a result which could not be but prejudicial to the advancement of science and the arts. Professor Henry, with the courtesy which he invariably exhibited towards deserving inventors, gave Davenport a certificate, in which he spoke highly of the novelty and originality of his invention. At the same time he did not hesitate to express to him the conviction, which he is known to have entertained even at that early day, that the application of galvanic electricity was at best an indirect way of utilizing the energy derived from the combustion of coal, and therefore could not economically compete with that agent as a means of propelling machinery. He nevertheless believed that it might be found useful in many cases in which the actual expense of power was a consideration not to be weighed against other more desirable objects to be attained. In his views in relation to this subject Henry was far in advance of most of his contemporaries, for the grand conception of the conservation of energy had at that day dawned only upon the minds of a few of the most profound thinkers of the period.

Before leaving Princeton, Henry exhibited to Davenport, much to the surprise of the latter, his oscillating electro-magnetic engine, made in 1831, of which an illustration has been given. This was to him the first intimation that any one prior to himself had even conceived the possibility of producing motive power by electromagnetism.

While at Princeton, Davenport made the acquaintance of Professor Henry's life-long and intimate friend, Alexander Dallas Bache, then professor of natural philosophy in the University of Pennsylvania at Philadelphia, and afterwards for many years superintendent of the U. S. Coast Survey. At the cordial invitation of Professor Bache, Davenport accompanied him to Philadelphia, where about the middle of July he exhibited his machine in operation in the library of the Franklin Institute. While in this place it was examined with interest by a large number of scientific men. Prior to his departure for Washington, Professor Bache gave Davenport a letter, the conservative tone of which indicates that he had been led by his association with Henry to entertain similar advanced views in respect to the equivalence of the natural forces. This letter is as follows :—

At the request of Mr. Davenport, I have examined a model of a machine applying the electro-magnetic action as a moving power. At first it appeared to me that an experiment might be made upon this model, from which the useful effects of a machine properly constructed might be inferred. But I am satisfied on examination, that such a result could be had only from a much more complete model than this, or from a working machine of full size. It would be highly interesting in a scientific point of view, and possibly in a practical light, if such an experiment could be made. The power is no doubt adequate to produce any effect which can be required in the arts, but the question of cost can hardly be fairly answered without experimental data.

A. D. Bache,
Prof. Nat. Philosophy,
Pennsylvania University,
Philadelphia.

July 15, 1835.

Upon reaching Washington a few days later, Davenport discovered to his dismay that owing to the unforseen delays and expenses to which he had been subjected by his exhibitions in Troy, Albany, Princeton and Philadelphia, the added cost of preparing the drawings and specifications for his application for a patent would so reduce his available funds as to leave him without sufficient means to return to his home in Vermont. He was therefore compelled by sheer necessity to postpone for the time his intention of applying for his patent, and in a very dejected frame of mind set out for home, taking his model with him. Upon reaching Troy he proposed to sell his machine to the Rensselaer Institute for $30. Professor Eaton, favoring the proposition, gave him a line to General Van Rensselaer, recommending the purchase of the model. In attempting to enter the grounds of Mr. Van Rensselaer's mansion Davenport was set upon by three ferocious watch-dogs, who soon reduced his habiliments to a deplorable condition, although he was fortunately rescued by the servants before serious injury had been inflicted. Writing of this incident, he says :—

Mr. Van Rensselaer examined my certificates from Professors Henry and Bache, and the line from Professor Eaton, and meanwhile the kitchen-maid tacked together my torn garments.

After receiving a check from General Van Rensselaer for the stipulated sum, and depositing his model in the Rensselaer Institute, Davenport returned to Vermont, in no very happy frame of mind. He had not only been unsuccessful in the main object of his journey, but had been brought like many others to a realizing sense of the fact that compliments are far more easily obtained than cash.

The model which formed the subject of this commercial transaction was preserved for many years in the cabinet of the Rensselaer Institute, but ultimately perished in the disastrous fire in Troy in 1862, in which the buildings of the Institute shared the fate of a vast number of others, and were totally consumed with all their valuable contents.

Professor Eaton, who was a man of a deservedly high scientific reputation, as well as of a somewhat enthusiastic temperament, had from the beginning conceived a warm feeling of friendship and respect for the modest and unassuming Vermont blacksmith, and exerted himself in every possible way to advance his interests. Scarcely had Davenport, dispirited and despondent, left Troy, when Professor Eaton penned the following flattering notice of his invention, and procured its insertion in a Troy newspaper. So far as can be learned, this was the first published notice of Davenport's electro-magnetic engine.

[*From the Troy Daily Budget, August* 13, 1835.]

An obscure blacksmith of Brandon, Vermont, 16 miles south of Middlebury College, happened accidentally to become acquainted with Professor Henry's discoveries in Electro-Magnetism. Possessing one of those minds which cannot be confined to the limits of a blacksmith shop—nor any shop less than the canopy of heaven—he applied this power to the astonishment of scientific mechanics. He turns three horizontal wheels around fifty times per second, with this power. The wheels and shaft weigh eleven pounds. He has convinced Professors Henry and Bache that the power is sufficient for strong machinery. A detailed account of it will appear in the next number of *Silliman's Journal*. The Hon. Stephen Van Rensselaer has purchased his first constructed machine (or model) for the Rensselaer Institute in Troy, as piece of school apparatus. No chemical or philosophical apparatus can hereafter be considered perfect without it. Whatever may be its fate in mechanics, it will cause the name of Thomas Davenport (the inventor) to accompany that of Professor Henry to the ends of the earth.

Professor Bache, of Philadelphia, and Professor Turner of Vermont, have given their opinions in writing that Mr. Davenport's application of Professor Henry's discoveries may be made to move heavy machinery for useful purposes. According to their views, another Livingston might make another Fulton of the Brandon blacksmith.

A month later Professor Eaton wrote to Davenport at Brandon, enclosing a copy of the *Troy Budget* containing the article therein referred to. The letter and extract are as follows :—

[*Professor Amos Eaton to Thomas Davenport.*]

TROY, Sept. 9, 1835.

DEAR SIR:—I published a short account of your invention on the 13th day of August. It was copied into all the papers. Last week some mule of a fellow caused the *Daily Advertiser* to publish a statement that your plan "would not work." The New York papers and others copied it. While some gentlemen were trying to raise money to give you a chance for a trial, that rascally article stopped all exertions, and the subscriptions were burned; I felt it my duty to come out boldly for you, for the sake of my own reputation, and of Bache's, Henry's, and Turner's. You will see how I treat the subject in the *Troy Budget* of yesterday. My object in this letter is to tell you that you must be here about the tenth of October, and put your machine in perfect order; also you must exhibit it *yourself* at three o'clock p. m., on Wednesday, 14th of October, before a thousand spectators.

I will deliver a lecture while you are working it, explaining the principles, etc. The judge's seat in the court room is the place to show it. This small damper will, in my opinion, make your fortune. It will give you a chance to exhibit *truth*. I tell you TRUTH, TRUTH is everything! On that day (October 14) your exertion of your skill will make your fortune. Write me *immediately* telling me positively what to depend on. It is advertised in all the papers that your machine will be exhibited at three o'clock p. m., 14th of October next.

Your friend,

AMOS EATON.

[*From the Troy Daily Budget, September 8, 1835.*]

VERMONT ELECTRO-MAGNETIC MACHINE.

To GILES B. KELLOGG, Esq.,

It was through your agency that Thomas Davenport's astonishing application of Professor Henry's discoveries in electro-magnetism was announced to the world, and it is my particular request that you hasten before the public the following communication to the Albany *Daily Advertiser*, without waiting to copy it from that paper:

To the Editors of the Albany Daily Advertiser.

I have just read in the New York *Commercial Advertiser* the following extract from your paper: "We are sorry to inform our contemporaries that, on further examination, the plan of the Brandon blacksmith will not work." Knowing one of the editors of your paper to be a gentleman of true science and liberal feelings, I feel assured that he will contradict the unkind statement upon my assurance that it is totally untrue. Immediately after Professors Bache and Henry had examined this machine in brisk motion, the Hon. Stephen Van Rensselaer purchased it and placed it in my possession and care, but on account of the battery-cups having been injured in Philadelphia, it has not been put in motion since I received it. But I have often seen it in motion, and know it to be all that has been said of it—an astonishing application of electro-magnetism!

I have no interest in the invention; but, as the unaccountable falsehood which originated in your paper is calculated to injure an ingenious mechanic, I request you to publish this article.

On the 14th of October next, the electro-magnetic machine invented by a blacksmith in Brandon, Vt., shall be exhibited gratuitously, in the Court-house in the city of Troy, to all who may please to call, at three o'clock in the afternoon. It shall be in full action and shall be moved solely by electro-magnetism. It shall carry three wheels weighing eleven pounds, and a miniature trip-hammer, as an emblem of the inventor's avocation.

The fourteenth of October being the last day of the examination of students of Rensselaer Institue, many gentlemen of science will probably be present, to all of whom I pledge myself to demonstrate that the "plan of the Brandon blacksmith *does work*," according to the certificates of Professors Bache of Philadelphia, Henry of Princeton, and Turner of Middlebury.

AMOS EATON,
Senior Professor, Rensselaer Institute.

Davenport was at his home in Vermont when this letter reached him. His fortunes were apparently at their very lowest ebb. Day by day, for more than two years, he had labored indefatigably upon his invention, to the utter neglect of his ordinary means of livelihood. The heavy expenditures incurred in his fruitless journey to Washington had brought him to the end, not only of his resources, but of his credit among his townsmen. His father-in-law, a prosperous and well-to-farmer of Brandon; a shrewd and sagacious, though by no means illiberal man—albeit one who is reputed to have appreciated full well the value of a dollar—offered him every inducement he could think of to put aside his visionary schemes, resume his trade, and henceforth support his family in comfort. Other neighbors, who cherished a sincere friendship and respect for Davenport, joined in the appeal. He could not but be strongly impressed with their practical and common-sense view of the situation, and while in a frame of mind to comply with it, replied to Professor Eaton's letter, stating in effect that two years of incessant labor and anxiety had yielded him but scanty reputation and no money; that his credit was utterly exhausted, while his family were almost suffering for the ordinary necessities of life. Professor Eaton immediately replied, under date of September 21, 1835, deprecating in the strongest terms Davenport's resolution, and refusing to listen to his proposal to abandon the undertaking. Among other things he wrote:—

Make my name Thomas Davenport, and I will give you five thousand dollars for your idea—rather, I mean "the bubble, reputation." . . . . It is a thing which will progress slowly; perhaps it may never yield you anything but reputation. But you have involved *friends*; and it is your duty to support their pledges for you. . . . Remember, if you fail to be here on the fourteenth, destruction is your portion!

This was the critical moment, the turning point, in the career of Davenport. Not only was the mere thought of throwing aside the hopes and aspirations which he had so long cherished almost unendurable to him, but his keen sense of honor instinctively revolted from the slightest imputation of bad faith towards the scientific friends who had cordially given him their countenance and support, or of reluctance to make good to the best of his ability, their pledges and expectations. On the other hand, to persevere was to be confronted with poverty, doubt, discouragement and almost with despair. To a man constituted like Davenport, however, a mental conflict waged on these grounds could have but one termination. Paraphrasing the memorable words of the elder Adams, he well might have exclaimed at this juncture in his affairs: "The die is now cast; I have passed the Rubicon. Sink or swim; live or die; survive or perish with my invention, is my unalterable determination." With renewed determination he cast aside all despondency and devoted every energy to his preparations for the demonstration at Troy. It is not easy for us to-day to appreciate the formidable difficulties with which he was obliged to contend. Brandon was at that date but an obscure country town, remote from all main lines of travel and transportation, the nearest city of any importance being Troy, N. Y., 100 miles distant, with which communication was maintained by stage-coach. He now determined to construct an entirely new machine, of a model adapted to railway locomotive purposes, and at once wrote to Professor Eaton to procure for him some necessary materials. In reply Eaton wrote on September 25, sending with the letter by a chance stage-coach passenger two packages of No. 16 copper wire, one of 3 and the other of 2 lbs.:

Luckily I find Mr. Jackson (a neighbor of yours) at the stage-

VILLAGE SCHOOLHOUSE AT BRANDON, IN WHICH DAVENPORT'S ELECTRIC RAILWAY WAS EXHIBITED. NOW PART OF RESIDENCE OF GEO. PARMENTER.

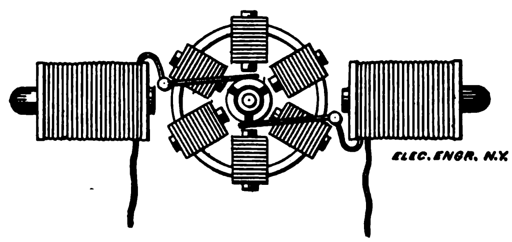
[*From a recent photograph by F. L. Pope.*]

office. He promises to deliver you the wire. *I have broken all the hardware stores, and bought all the wire in the city*, and given it to Mr. Jackson.

Then came the difficulty of insulating the wire. Davenport had been led, from Henry's researches, to suppose that silk was the only material which would answer the purpose. But it was not only difficult, but in fact impossible to obtain this material in that remote region, and he was destitute of means wherewith to procure it from the city. But in this dilemma, the unselfish devotion of the faithful wife, who had loyally stood by him through prosperity and adversity, came to his rescue. Her one silk gown, the wedding dress which was her father's gift; almost her sole remaining relic of more prosperous but of perhaps not happier days, was bravely offered as a sacrifice to the cause of science. Cut into narrow strips, the treasured garment was used to insulate the helices of the new machine. Night and day the work went on with such success that punctually on the tenth of October Davenport presented himself at the Rensselaer Institute with the new motor in readiness for exhibition. On the 14th, pursuant to the pledge of Professor Eaton, it was put in operation on the Judge's bench in the court-room in Troy, in the presence of hundreds of interested and enthusiastic spectators.

Among the audience who attended this exhibition was a young artisan whose home was in Cabotville, a village just north of Springfield, Mass., which then enjoyed a high reputation, as indeed it does to-day, for the skill of its mechanics and the excellence of its products. This young man became greatly interested in the new motive power, and proposed to Davenport that he should immediately accompany him to Cabotville, promising to assist him to the best of his ability in bringing the invention into practical use. The proposal was accepted, and the two worked together at that place for some two months, during which time they completed a model of a circular railway 36 inches in diameter, upon which an electro-magnetic locomotive traveled with amazing rapidity. At the end of this time Davenport was informed by his associate that he was disinclined to go any further with the enterprise, but as Davenport himself says, he had little reason to complain of his conduct, inasmuch as he willingly gave him the benefit of two months' labor and his board during the time, to say nothing of some small expenses which had been incurred. It was now the middle of December and our inventor was again left in a state of destitution at a distance of 150 miles from his home. Hardly knowing which way to turn next, he bethought himself of a letter which he had received just before his visit to Troy from a silk manufacturer in Dedham, Mass., who desired to apply electro-magnetic power to the processes employed in his factory.

Among other acquaintanceships which Davenport had formed while in Cabotville, was that of a Mr. Kimball, himself an intelligent mechanic, who had taken much interest in the project of the electric railway. In his perplexity he consulted Kimball and was advised by him to take his machine to Dedham, and in case he failed to conclude a satisfactory arrangement with the silk manufacturer, to try a public exhibition of his circular railway in Boston, by which means he might perhaps raise sufficient funds to aid him in making further experiments. In addition to his good advice, Kimball very generously handed him $50 for his expenses, and not content with that, told him if his plans all failed to let him know, and he would cheerfully render him further assistance. "Such kindness," writes Davenport, "from a stranger whom I had never seen half-a-dozen times in my life, seemed to be an omen of future prosperity." He proceeded to Dedham, and although "received most politely" by the silk manufacturer, that person did not seem inclined to take any chances in testing the capacity of electro-magnetism for winding silk, nor did he offer to reimbuse Davenport for the expenses he had incurred in bringing his machine a long distance for exhibition. As a last resort the persevering inventor proceeded to Boston, hoping, as he says, "that the thinking portion of that intelligent city would be highly gratified with an exhibition of the wonderful effects of the silent, unseen and irresistible power of electro-magnetism." He accordingly exhibited his locomotive two weeks at the Marlborough hotel, and realized the princely sum of $12, just sufficient to meet the charges of his landlord for the use of the room. Davenport states that notices of this exhibition were published in some of the Boston newspapers of the day, but a diligent search through the columns of such journals as have been preserved has failed to reveal them. The exhibition, however, is well remembered by Thomas Hall, the veteran manufacturer of electrical instruments in Boston, who, although but a boy at the time, was employed in the shop of Daniel Davis, Jr., in which scientific instruments were made and repaired. According to the recollection of Mr. Hall, the machine consisted of a number of small magnets placed upon the rim of a vertical wheel, and constituting a sort of pole-armature, which revolved between the poles of two larger electro-magnets placed in a horizontal position which formed the field. His impression is that the field magnets were connected with the armatures in series. The current was supplied by a large Wollaston battery, and as the zincs became rapidly coated with oxide, necessitating frequent cleaning, two sets of batteries were provided; one of which was used while the other was being cleaned. The motor and battery were mounted upon a truck which traveled at a considerable speed.*



THE DAVENPORT MOTOR EXHIBITED IN BOSTON, AS REMEMBERED BY MR. T. HALL.

At this juncture he received a letter from Kimball, cordially inviting him to stay at his own house for a few weeks and promising to furnish materials for building a larger machine. He accepted the proposal—there was obviously nothing else to be done—until finally, upon his expressing a desire to return to his family in Vermont, the generous Kimball furnished the dejected inventor with a new suit of clothes, and the necessary cash for his journey, and when in parting from him Davenport expressed his doubts as to ever being able to repay him, this good Samaritan cheerily remarked that he "need not trouble himself about that," but whenever he needed further assistance to call upon him.†

Writing of his circumstances at this time, in the early part of 1836, he says:

For several months my prospects of getting assistance for a trial on a large scale, looked very dubious. My friends seemed to be worn out and tired of my talk about electro-magnetism being used as substitute for steam. Many hundreds of ingenious mechanics and wealthy people had seen the power propel machinery of various kinds, and all expressed a strong anxiety, that I should persevere, and apparently wished with all their hearts that I might succeed. The great benefit it would have in saving human life was particularly mentioned by all who seemed to wish the project well, but yet I was totally unable to reach the purse strings of the capitalist. The objection urged by many was that my letters patent had not been taken out, and when I informed them that the patent could be obtained as soon as I could raise the

* The author desires to express his acknowledgments to William Lincoln Smith, S. B., of the Massachusetts Institute of Technology, and W. A. Hovey, of the American Bell Telephone Company, for making an examination of the files of the Boston papers, and to Mr. Smith especially for the information obtained from Mr. Hall.

† The author regrets that he has been unsuccessful in the attempt which has been made by him to identify the Mr. Kimball whose generous conduct towards a needy and struggling inventor, entitles him to the grateful remembrance of all electricians.

means sufficient for that purpose, the reply was that I had delayed so long already that some other person would probably anticipate me.

The necessities of Davenport's family now rendered it imperative that he should at once seek some means of livelihood. With characteristic persistence, he determined to attempt this by giving exhibitions of his circular railway and other electro-magnetic apparatus. His first entertainment of this kind was given in the public school-house in Brandon village. The occasion is well remembered by aged residents of that place who are still living. The building in which the exhibition took place now forms a part of the residence of George Parmenter, Esq., and, it may be remarked in passing, enjoys the further distinction of having been the school attended by Stephen A. Douglas, a native of Brandon, in preparation for college, he supporting himself meantime by working at the trade of a cabinet maker.

During the following summer Davenport exhibited his apparatus two weeks at Saratoga Springs, which even at that early day had come to be somewhat of a resort during the warm season for wealthy people from various parts of the country. While here he formed the acquaintance of a leading citizen of the place, the late Ransom Cook, who was at that time a prosperous manufacturer, and proprietor of an extensive shop driven by steam power and supplied with superior machinery and tools for working both in wood and metal. Cook was profoundly impressed with the apparent value and importance of the invention, and at once tendered to Davenport the technical and financial assistance necessary to bring his enterprise properly before the public.

THE POSTAL TELEGRAPH CO. NOT TO SELL OUT.

A statement has been published that Jay Gould had purchased a controlling interest in the Postal Telegraph Cable Company. This report is so far denied. One of the officials of the company says:

"The report is entirely unfounded. Our stock is not listed on the stock exchange and there is none to be bought. This company was formed for the purpose of carrying on a legitimate business and not for the purpose of compelling the Western Union to buy us out.

"During the past two years we have built more than 4,000 miles of line, and we are now pushing rapidly toward New Orleans. As soon as that link is finished our system will extend from the Atlantic to the Pacific and from the great lakes to the Gulf of Mexico. We have direct connection with the Commercial Cable Company and the Canadian Pacific Telegraph. The gentlemen who own a controlling interest in this company do not wish to sell, nor do the Western Union Company wish to buy our property, for they recognize the fact that should they gain control of our system a new company would be formed within three months."

THE NEW ELECTRIC LIGHT AND POWER STATION AT LOWELL, MASS.

BY

A. C. Shaw.

No better proof of the commercial success of electricity as a producer of light and power can be adduced than the fact that so many cities are at last providing themselves with stations worthy of the name, and that engineers are giving their whole attention to the erection of stations which will not only produce the desired effect of making electric light and power reliable and popular, but which will be able to take care of the rapid increase of business, and at the same time have a chance of creating some dividend for the pocket of the stockholder. As another example of such a station, I take pleasure in presenting in detail the plans of the new electric light and power station at Lowell, Mass., which is now just being put into active service. Like most of the larger cities, Lowell has passed through an interesting history in the development of its electric lighting industry. The Lowell Electric Light Corporation was organized under the laws of Massachusetts, in 1881, with a capital of $10,000, and began business with two Weston arc light machines, leasing power from an accommodating sawmill. Business, however, did not thrive very well, and about a year later the Middlesex Electric Light Company was formed, and a small plant was built on Middle street. This company introduced the Thomson-Houston system, and shortly after effected a combination with the old company, under the same name, and continued to do business till about two years ago. At that time they reorganized under the name of the Lowell Electric Light Corporation, still continuing to use the Middle street station. Without going into details, it may be stated that they started at first with one 50 h. p. Armington and Sims engine, increased to three engines of the same manufacture, and then put in a 250 h. p. Harris-Corliss high pressure engine, remodelling the entire plant. Business continuing to increase, another addition was temporarily made, and then it was decided to build on an adjoining lot, and a 200 h. p. Atlas engine and another 300 h. p. Harris-Corliss engine were put in. In 1889, the alternating incandescent system was introduced, making an enormous increase in the demand for generating capacity, and a contract was entered into to furnish power for the Lowell and Dracut Street Railway Company, and it being at once seen that even the enlarged station was wholly inadequate to meet the requirements, it was decided to build a new first-class station, and accordingly land was bought on Perry street,

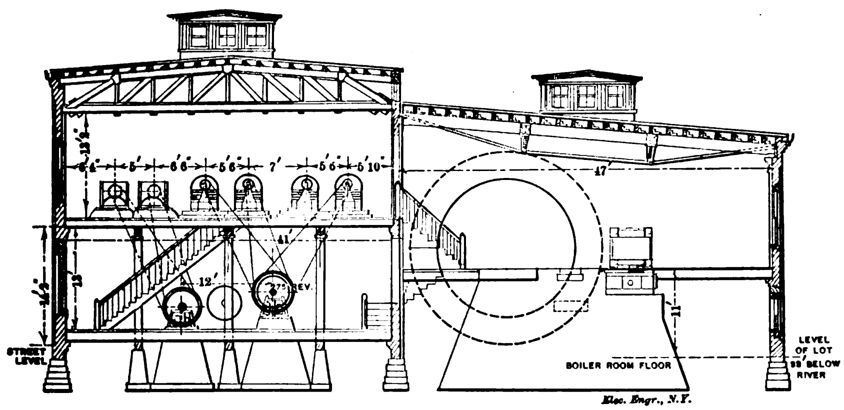


FIG. 1.—THE LOWELL, MASS., ELECTRIC LIGHT STATION.—SECTION OF ENGINE AND DYNAMO ROOM.

THE
Electrical Engineer.

VOL. XI. JANUARY 21, 1891. No. 142.

THE INVENTORS OF THE ELECTRIC MOTOR.—III.

WITH SPECIAL REFERENCE TO THE WORK OF THOMAS DAVENPORT.

BY

Franklin Leonard Pope

RANSOM COOK, the new partner in the enterprise, was in many respects no ordinary man. A native of Connecticut, he had been brought to the state of New York by his parents while yet a child, and had begun life in the then newly settled region of the upper Hudson as a journeyman cabinet-maker. Having by diligence and economy accumulated a small capital, he commenced on his own account in 1822, the manufacture of furniture in Saratoga Springs, and a few years later was able to fit up the large and well equipped shop referred to, which stood on the site of the present Grand Hotel.

Cook was a characteristic type of that self-educated, intelligent, ingenious, and enterprising class of American mechanics, the products of whose industrial skill have become known and esteemed in every country of the civilized world. From his very boyhood, every moment that could be spared from toil was utilized to the utmost in increasing the small store of knowledge with which a common school education had furnished him, and books, not only of the natural sciences, but of history, law and politics, were his unceasing recreation and delight. A man of scrupulous integrity, diligent and successful in business, cordially detesting every form of chicanery and hypocrisy, yet ever ready with hand and purse to aid the needy and deserving; distinguished no less for his sound judgment than for his self-reliance and independence, he was one who could not but occupy a leading position in any community in which his lot was cast. Touched with the narrative of Davenport's struggles and misfortunes, not only did Cook hasten to relieve his immediate pecuniary necessities, but instinctively perceiving the future possibilities of his invention, he suspended the lucrative business which he was carrying on, that he might throw himself heart and hand into the new enterprise. Writing of this period Davenport says:—

Ransom Cook

AGED 83 YEARS AND 7 MONTHS.

[From a Photograph made in 1877, by W. H. Baker, of Saratoga, N. Y.]

My mind was now measurably relieved, and I felt that I could apply myself to the object in view, with renewed diligence. As the patent had not been obtained, we commenced building a model for the Patent Office. Mr. Cook seemed to be more and more enamored with the invention as the work progressed. Several hands were now employed in constructing models, and important alterations in the arrangement of the machine were made by Mr. Cook, which seemed to increase his confidence in the ultimate successful application of the power. As soon as we had completed a model for the Patent Office, I proceeded to Washington and deposited my model and papers. A great variety of experiments were made in Mr. Cook's shop, with regard to the best mode of constructing both steel and electro-magnets, and many models of various sizes were completed.

At least two of the working models constructed by Davenport and Cook during the winter of 1836-7 are fortunately still in existence in an excellent state of preservation. The writer has had an opportunity of making a careful examination of one of these, a small electric locomotive running on a circular railway 24 inches in diameter, an illustration of which is given herewith. The motor proper consists of two straight electro-magnets, one constituting a stationary field, and the other an armature revolving in a horizontal plane parallel to and above the field. The armature is connected with the driving wheels by a speed-reducing bevel-gear. The field and armature magnets are each 5½ in. long, with cores ¾ in. in diameter. They are each wound with two No. 16 copper wires connected in parallel, there being 24 convolutions of each wire on each core. The commutator is constructed with insulated springs rubbing upon insulated metallic segments. The connections with the battery are formed by mercury-cups. Perhaps the most remarkable circumstance about this motor is that the field and armature are connected in parallel, so that in this model we have a veritable example of a *shunt-wound motor*, built in 1836-7. The workmanship of the little machine is of the finest description, and would reflect no discredit upon the shop of any leading manufacturer of to-day. It bears in every feature the impress of the unusual mechanical skill of its designer. This model of the circular railway, together with several stationary motors embodying the same general principles, were intended for exhibition in the city of New York. Near the close of the year 1836, Davenport, who was impatiently awaiting the issue of his patent, received a letter from Congressman Slade, conveying the unwelcome intelligence that his model and all the papers relating to his application had been destroyed in the fire which consumed the contents of the patent office. Not a paper nor a single one of the 7,000 models contained in the hall escaped destruction.

This disaster occurred on the 15th of December, 1836. Another model was immediately constructed and a new set of papers prepared, and about the middle of January, 1837, Davenport, supplied with funds by Cook, set out on his third journey to Washington, and filed an application on January 24, 1837, for his patent, which was issued in due course on the 25th of February following.

The following extract from the columns of a local journal will serve to show the stage which the invention had now reached :

[*From the Saratoga Sentinel, Jan.* 3, 1837.]

DAVENPORT AND COOK'S ELECTRO-MAGNETIC ENGINE.

In company with Dr. Steel and several other gentlemen, we called upon Messrs. Davenport and Cook, of this village, on Saturday, with a view of examining the electro-magnetic engine invented by the senior partner.

The ingenuity, yet simplicity of its construction, the rapidity of its motion, together with the grandeur of the thought that we are witnessing the operation of machinery propelled by that subtle and all pervading principle—electricity, combine to render it the most interesting exhibition we have ever witnessed.

Although we shall say something on the subject, it is perhaps impossible to describe this machine by words alone, so as to give more than a faint idea of it to the reader.

It consists of a stationary magnetic circle, formed of disconnected segments. These segments are permanently charged magnets, the repelling poles of which are placed contiguous to each other. Within the circle stands the motive wheel, having the projecting galvanic magnets, which revolve as near the circle as they can be brought without actual contact. The galvanic magnets are charged by a battery, and when so charged, magnetic attraction and repulsion are brought into requisition in giving motion to the wheel—the poles of the galvanic magnets being charged more than a thousand times per minute. . . .

We were shown a model in which the motive wheel was 5½ inches diameter, which elevated a weight of twelve pounds. And to illustrate the facilities for increasing the power of this engine, another model was exhibited to us with a motive wheel of eleven inches in diameter, which elevated a weight of eighty-eight pounds. Although these models have been for some time in progress, and we have occasionally been permitted to examine them, we have waited till the present period, when the practicability of obtaining a rapid and unlimited increase of power seems to be placed beyond a doubt, before expressing an opinion, or calling the public attention to the subject.

If this engine answers the expectations of the inventor (and we believe no one can assign a reason why it should not), it is destined to produce the greatest revolution in the commercial and mechanical interests which the world has ever witnessed.

While Davenport was in Washington attending to the issue of his patent, Cook formed in New York the acquaintance of a typical representative of a class of people who have become in later years much more widely than favorably known in electrical circles as "promoters." This person, whose prominent position as secretary of one of the leading scientific and technical institutions in New York apparently entitled him to confidence, suggested the advisability of forming a joint-stock association to exploit the patent. To this Cook, and Davenport, after his return from Washington, willingly acceded, the more so, that they had found that the cost of procuring patents in the different countries of Europe, and of building a machine large enough to give the public convincing proof of the value of the discovery, would be likely to be considerably beyond their individual resources. In accordance with this plan, early in March articles of association were drawn up, by the terms of which a portion of the stock was placed in the hands of the promoter to enable him to raise funds "for building models and machinery, and for testing the utility of said invention; for giving to the same its greatest possible value for the benefit of the stockholders (the constructions so made to belong to the association); also for securing the exclusive use of said invention in Europe for the benefit of the association."

A supplementary agreement was executed at the same time, by which the promoter pledged himself to pay Davenport and Cook $12,000 in cash within thirty days. This was a large sum of money in those days, and the struggling inventor at last felt able to congratulate himself that his pecuniary troubles at least were at an end.

Every prospect seemed as favorable as could be desired or hoped for. As a curiosity we give a fac-simile of one the certificates of scrip of this—perhaps the first joint stock company ever organized to exploit an electrical invention.

In March, Davenport received a letter from Professor Benjamin Silliman, of New Haven, requesting information about his machine for publication in the *American Journal of Science* and adding:

I have no doubt you will always receive advantage from the sound and judicious advice of our friend Mr.——— (the promotor) whose experience in business and great zeal and fidelity in this affair will no doubt greatly aid in all the proper business part of your concern.

The publication in Silliman's Journal of April, 1837, of a detailed description from personal examination of two different forms of Davenport's machine, one having revolving electro-magnets in conjunction with fixed permanent field magnets, and the other composed entirely of electro-magnets both in its fixed and revolving members, excited very great interest in scientific circles both in this country and abroad. At the end of the article, which is signed with the initials of Professor Silliman, the author sums up his conclusions in reference to the invention as follows :

1. It appears then, from the facts stated above, that electro-magnetism is quite adequate to the generation of rotary motion.

2. That it is not necessary to employ permanent magnets in any part of the construction, and that electro-magnets are far preferable, not only for the moving, but for the stationary parts of the machine.

3. That the power generated by electro-magnetism may be indefinitely prolonged, since, for exhausted acids and corroded metals, fresh acids and batteries, kept always in readiness, may be substituted, even without stopping the movement.

4. That the power may be increased beyond any limit hitherto attained, and probably beyond any which can be with certainty assigned—since, by increasing all the members of the apparatus, due reference being had to the relative proportionate weight, size, and form of the fixed and movable parts—to the length of the insulated wires and the manner of winding them—and to the proper size and construction of the battery, as well as to the nature and strength of the acid or other exciting agent, and the manner of connecting the battery with the machine, it would appear certain, that the power must be increased in some ratio which experience must ascertain.

5. As electro-magnetism has been experimentally proved to be sufficient to raise and sustain several thousands of pounds, no reason can be discovered why—when the acting surfaces are, by skillful mechanism, brought as near as possible, without contact—the continued exertion of the power should not generate a continued rotary movement, of a degree of energy, inferior indeed to that exerted in actual contact, but still nearly appoximating to it.

6. As the power can be generated cheaply and certainly—as it can be continued indefinitely—as it has been very greatly increased by very simple means—as we have no knowledge of its limit, and may therefore presume on an indefinite augmentation of its energy, it is much to be desired, that the investigation should be prosecuted with zeal, aided by correct scientific knowledge, by mechanical skill, and by ample funds. It may therefore be reasonably hoped, that science and art, the handmaids of discovery, will both receive from this interesting research a liberal reward.

Science has thus, most unexpectedly, placed in our hands a new power of great but unknown energy.

It does not evoke the winds from their caverns; nor give wings to water by the urgency of heat; nor drive to exhaustion muscular power of animals; nor operate by complicated mechanism; nor accumulate hydraulic force by daming the vexed torrents; nor summon any other form of gravitating force; but, by the simplest means—the mere contact of metallic surfaces of small extent, with feeble chemical agents, a power everywhere diffused through nature, but generally concealed from our senses—is mysteriously evolved, and by circulation in insulated wires it is still more mysteriously augmented, a thousand and a thousand fold, until it breaks forth with incredible energy; there is no appreciable interval between its first evolution and its full maturity, and the infant starts up a giant.

Nothing since the discovery of gravitation and of the structure of the celestial systems, is so wonderful as the power evolved by galvanism; whether we contemplate it in the muscular convulsions of animals, the chemical decompositions, the solar brightness of the galvanic light, the dissipating consuming heat, and more than all, in the magnetic energy, which leaves far behind all previous artificial accumulations of this power, and reveals, as there is full reason to believe, the grand secret of terrestrial magnetism itself.

We shall hereafter give an accurate drawing, made to scale, of one of three or four machines, substantially alike, which were constructed in the winter of 1836-37, by Davenport and Cook. The model in the patent office in Washington was one of these, another was sent to Europe to be used in obtaining patents in various countries, and at least one other was kept on exhibition in New York, where it was inspected by crowds of curious spectators.

The workshop and laboratory of Davenport and Cook were in a large building at 42 Stanton street, which has long since disappeared and been replaced by tenement houses. Writing of this period, Davenport says:

During the spring and summer of 1837, our laboratory, which was a spacious one, was crowded to overflowing daily by visitors to examine the variety of machines and apparatus which were on hand, and in progress of construction. Among the distinguished and scientific gentlemen who visited our work, were Professor Samuel F. B. Morse, then of the New York University, and Doctor Charles G. Page, then of Boston. Professor Morse frequently mentioned his intentions of experimenting on the electro-magnet for the purpose of producing signs for signals for telegraphic purposes, and stated that he had long ago conceived the idea of transmitting intelligence by electricity.[1] A gentleman from Germany, Baron D——, purchased secretly from one of our workmen drawings of some of the best models, and in about six months from that time the German papers were teeming with the news that Baron D—— had invented a new motive power, a model of a machine, put in motion by electro-magnetism! The German Diet is said to have voted this *gentleman pirate* 200,000 francs, or $40,000, as a compensation for his wonderful invention.[2] In the course of this summer we constructed a great variety of machines, testing the power of each to ascertain the amount of improvement, and among these was a miniature locomotive engine which moved on a circular railway of 14 feet in diameter, moving a train of half-a-dozen cars. Many of the public prints came out in favor of the invention, recommending that capitalists should examine the operation of the machines, and aid in the enterprise by their assistance in furnishing funds.

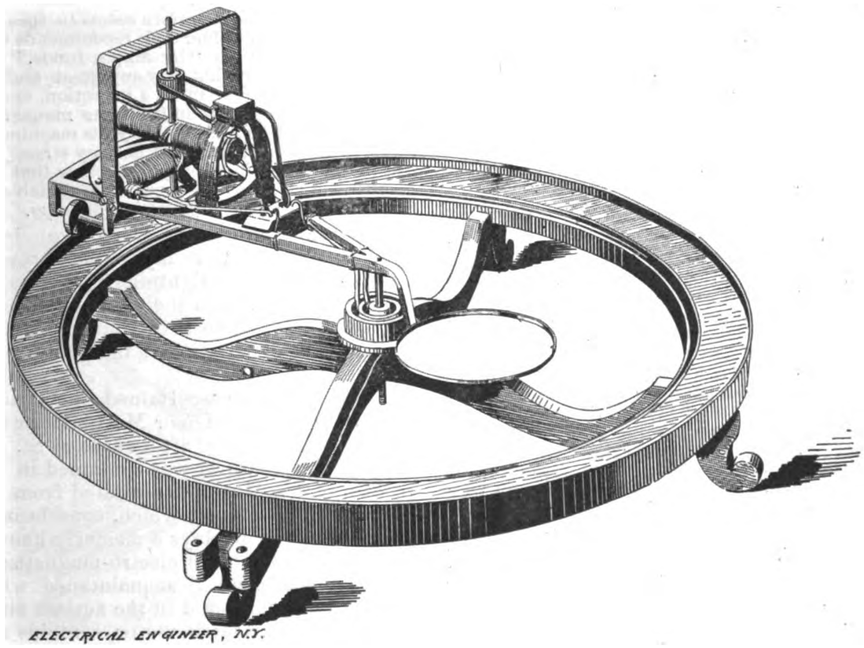
Many of these newspaper notices are so characteristic, that I cannot forbear making a few extracts from them:

(*From the New York Herald, April* 27, 1837.)

A REVOLUTION IN PHILOSOPHY.—DAWN OF A NEW CIVILIZATION.

We mentioned slightly the other day a few particulars descriptive of the electro-magnetic machine now preparing for exhibition in this city. We shall now go a little deeper into this most extraordinary discovery, probably the greatest of ancient and modern times, the greatest the world has ever seen, the greatest the world will ever see. . . . .

We are in the commencement of a revolution in philosophy, science, art, and civilization. The occult and mysterious principle of galvanism is now beginning to be developed in all its magnificence and energy. . . . .



MODEL OF ELECTRIC CIRCULAR RAILWAY MADE BY DAVENPORT AND COOK IN 1836-7.

[*From recent photograph and sketch by F. L. Pope.*]

It is utterly impossible to give vent to all those burning thoughts which crowd upon our mind at the contemplation of this discovery. It surpasses any discovery of ancient or modern times. The generalization of this principle, and its undoubted identification with all the phenomena of nature—with motion—with animal life—with earthquakes—with gravity—with electricity—with the motion of the earth and planets round the sun, must and will create an entire revolution in all science, in all art, in all philosophy, and in all future civilization. Indeed we may go further, and however droll it may appear, we have strong suspicions that the friendship, esteem and the mysterious love between the sexes is founded on the same principle with which Mr. Davenport turns his wheel, and the lightning flashes from heaven—and the aurora borealis spreads out its garments of rosy light in the sky—and the very planets themselves run their races round the sun from eternity to eternity.

Enough for the present. We have long been a student in chemistry, electricity, galvanism, and such like sciences. We shall illustrate our views at our leisure. Meantime we bid all prepare for an organic revolution in science, philosophy, religion, and civilization. We are just entering upon a wonderful age.

(*From the N. Y. Evening Star, August*, 1837.)

In concurrence, unanimously we believe, with all who have

1. From the sworn deposition of Professor Leonard D. Gale, corroborated by others, printed in the record of the Supreme Court in the case of *O'Reilly* v. *Morse*, it appears that the first crude model of Morse's telegraphic recording apparatus was constructed by him in the late fall of 1835, and that Gale became associated with him in 1836. In his deposition Gale says:—"From April to September, 1837, Professor Morse and myself were engaged together in the work of *preparing magnets*, winding wire, constructing batteries, etc., in the University, for an experiment on a larger but still very limited scale, in the little leisure that each had to spare. . . . The latter part of August, 1837, the operation of the instrument was shown to numerous visitors to the University." It must have been while this work was going on, that Morse visited Davenport's laboratory. The marked likeness between the electro-magnet in the original instrument of Morse, preserved in the cabinet of the Western Union Telegraph Company, at 195 Broadway, New York, and the magnets in some of the motors of Davenport and Cook, constructed just before they brought their apparatus to New York, furnishes grounds for the belief that Morse's knowledge of the construction of Henry's magnet may, in part at least, have been derived from observations made during his visit to the laboratory here referred to.

2. The writer, notwithstanding much research, has failed in his attempts to penetrate the incognito of the "gentleman pirate." The statement is given as it is written. Possibly others may be more successful.

witnessed the operations of this extraordinary and simple apparatus, and listened to the lucid and eloquent explanations of Mr. Cook, we confess our utter amazement at the prodigious changes which it manifestly foretells in the application of an entire new and immeasurable agent of mechanical power; and at the same time, while we see and admire, acknowledge ourselves, for want of language to sustain us, utterly incompetent to impart any correct conception of this marvelous invention to our readers. All we say is, "go and be convinced." . . . . . .

It is a sublime but not wild idea of Mr. Cook, that a ship's bottom, covered with suitable plates and the ocean for its bath, may drive herself along with incredible velocity, at the same time generating abundance of hydrogen to light her onward upon the deep. . . . .

But it is in a commercial view that it exhibits, in prospective at least, an importance combined with the finest sublimity. It is well known that sea-water forms an active bath for the galvanic battery when kept up by frequent changes. Is there any insurmountable objection to arranging the sheathing of the vessel so as to form a battery, and with the ocean for its bath and the application of magnetic power, "drive the ship onward in her course and guide her to the point of destination by the same agent?"

When the use of steam is proposed in conducting our distant commerce, we cannot avoid the reflection that on the vast deep the perils of wind and waves are sufficient without adding those of fire and explosion.

(*From the N. Y. Evening Post.*)

We learn that some recent improvements have been made in the application of electricity as a moving power to machinery. A larger apparatus than the one hitherto exhibited has been constructed under the direction of Mr. Cook, now in this city, which is to set in motion a turning lathe, in order that those who take an interest in the invention may see it at work. Nothing but the difficulty of the times now stands in the way of demonstrating the application of this power on a large scale to machinery of the most ponderous description.

(*From American Correspondence of London Morning Herald.*)

I did not write by the packet of the 16th [August, 1837], because I had made an appointment for the next day, to go and see the electric-magnetic machines of Mr. Davenport, and which I considered well worthy to be the subject of a letter, provided there were any grounds for the vast expectations founded upon them, not only by the inventor and his friends, but by every person who had examined them, and heard the explanations of Mr. Davenport. Having seen them, I am free to confess that I cannot discover any good reason why the power may not be obtained and employed in sufficient abundance for any machinery; why it should not supersede steam, to which it is infinitely preferable on the score of expense, safety, and simplicity. I do not very clearly understand the principle (something about changing the poles from positive to negative, or from north to south), and vice-versa, in rapid succession; but this is of little consequence, as I shall be able to send you, probably by the next packet, a pamphlet containing a full exposition, with illustrative engravings. Mr. Cook, who is associated with Mr. Davenport in the patent, is now engaged in preparing this pamphlet, and he has promised me the first copy that is printed. They have patented their invention in France and England. . . . .

The last machine constructed by Mr. Davenport occupies a surface of about 18 inches square, that is, 18 inches on each side, and consists merely of a platform, having upon it an iron circular frame, with an arch extending from side to side above it, a spindle in the centre playing in this arch at top and in a socket below, and on this spindle an incomplete wheel, formed of two cross pieces of iron, with segments of a circle at the four extremities. It is, in fact, a wheel, with four breaks in its periphery. Some hundreds of feet of isolated, or coated, copper wire are wound around the cross pieces, and also around the fixed circular frame; the connection with the galvanic batteries, which are three small cylinders, each consisting of six concentric tubes of zinc and copper, the outer one scarcely larger than a quart pot, is, formed by small rods of copper. The revolving wheel is six inches in diameter, and weighs about six pounds. Attached to the upright spindle is a small cog-wheel, which may be made to work in other wheels, with axles, for the purpose of showing how great a weight can be raised from the ground.

With the three batteries acting on it, the revolution of the wheel was 1,000 times in a minute; and these 1,000 revolutions raised a weight of 200 lbs. one foot. The first machine made by Mr. Davenport, which is much smaller and has but one battery, raised but 24 lbs. He is confident that with a number of batteries, or one very large one, say, as big as a barrel, there would be power enough to drive the largest machinery, while the cost of construction would be reduced to a fifth, or perhaps a tenth, and that of attendance, fuel, etc., now forming so heavy an item in the expenses of steam-power, would be almost done away with. Half a barrel of blue vitriol, and a hogshead or two of water, would send a ship from New York to Liverpool; and no accident could possibly happen, beyond the breaking of some part of the machinery, which is so simple, that any damage could be repaired in half a day. Surely it is a great and vastly important discovery, and the wildest imagination could hardly grasp the wonders in achieving which it may, and doubtless will, become the instrument.

A reference to the preceding description of the machine shown to the correspondent of the London *Herald*, is sufficient to show that it was quite an advanced type of motor, having a horseshoe field, and a four-pole armature fitted with segmental polar surfaces. A model of one of the machines of this type, but having two poles only, is still in existence.

Amid the general chorus of praise, there was, as might have been expected, now and then an inharmonious note, as witness the following communication :—

[*From the Journal of Commerce.*]

Messrs. Editors: I have been much gratified with your exposure of various humbugs of late in science and politics; but if I recollect right, you have not touched upon what I consider as also indubitably a great humbug. I mean Mr. Davenport's machine, so far as it boasts of being of any practical utility. I am aware that Mr. Silliman speaks of Mr. Davenport's invention as "putting into our hands a new power of great but unknown energy," and supposes the power may be increased beyond any limit which can be assigned; he therefore seems to speak of the discovery as of great pecuniary value, and recommends that the investigation should be prosecuted "by ample funds," etc. Mr. S. has not, however, shown in what way any great and useful power is to be attained by Mr. Davenport's invention, and probably he would not again lend his name in the same manner to this affair. I am aware also that Mr. D. is able by his machine to move a couple of tiny cars about a railroad in Barclay street, of a dozen or fifteen feet in diameter; but I propose to show that he cannot, by electro-magnetism, acquire any great and valuable power, and that his machine in its grand promise is a *humbug*.

Annoying caricatures were also circulated, a fashion much in vogue at that day. One of these skits represented a boat propelled by lightning; Davenport and Cook, with despair depicted upon their countenances were tinkering at the machinery, while Prof. Silliman, in an attitude of mock dignity, was expatiating to the public on the merits of the scheme.

So far as can be ascertained, the earliest account of the experiments of Professor Moritz Hermann von Jacobi, of Königsberg, Prussia, afterwards of St. Petersburg, which reached this country, was contained in a paper published in Sturgeon's *Annals*, translated from *Comptes Rendus.*[3] This admirable paper, which, considering the early date of its publication, displays a masterly knowledge of the fundamental principles of electro-magnetism, as well as an intimate experimental acquaintance with its phenomena, especially as exhibited in the actions and reactions of the magnets of an electric motor, contains a full description of Jacobi's machine, illustrated with an isometrical drawing which clearly exhibits the details of its construction. From this drawing, which we reproduce in fac-simile, it clearly appears that not only is its principle the same as that of Davenport and Smalley's motor heretofore described, but that even in the details of construction the differences are comparatively unimportant. In this paper, Jacobi states that he first succeeded in obtaining rotary motion in May, 1834, and incidentally refers to a paper partially describing it, which he read before the Academy of Sciences of Paris, on December 1, of the same year, an abstract of which was published in *l'Institut*, No. 82, on December 3rd. The following is a translation of this note :—

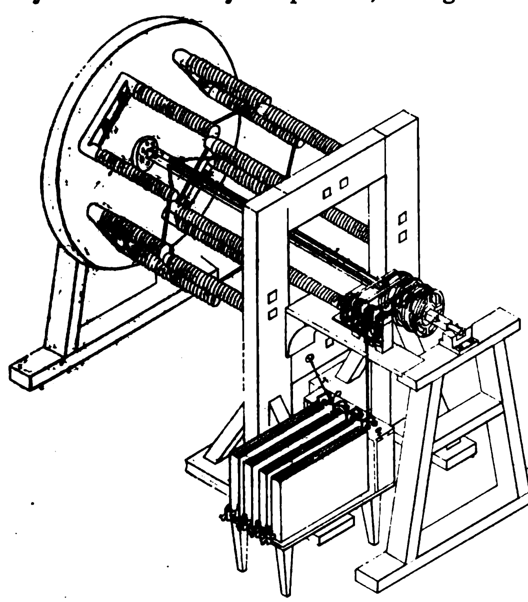
M. Jacobi, of Königsberg, presented to the Academy a paper on a magnetic engine of his invention, in which magnetism is employed as a motive power. The following is the description given of it :—The apparatus consists of two systems comprising eight bars each of soft iron, each 7 in. long and 1 in. in diameter. These two systems of bars are placed at right angles, and so arranged on two discs that the ends or poles of the bars are opposite one another. One disc is fixed while the other revolves on its axis, and the movable bars are thus made to pass as close as possible in front of the fixed ones. The 16 bars are wound with 320 feet of copper wire, 1/8 inch in diameter, the ends of which were connected with a voltaic apparatus. The whole mass, moving at a speed of six feet per second, gives about 50 lbs., being

3. Sturgeon's *Annals of Electricity*, etc., i., 408.

a considerable *vis viva*. The work thus furnished, measured by an apparatus similar to the Prony brake, is equal to a weight of 10 or 12 lbs. lifted one foot per second. This success is principally due to a novel construction of the commutator by which the changes of polarity are worked. These take place eight times in each complete revolution; that is to say, eight times in half or three-quarters of a second, the ordinary speed of the machine, when the water in the cell is so little acidulated that the development of gas is hardly appreciable.

In 1838, under the patronage and at the expense of the Emperor Nicholas, of Russia, Jacobi constructed a much larger motor upon substantially the same principles, with which he succeeded in propelling a boat upon the Neva, at St. Petersburg. As full accounts of this experiment have been many times published, I will not occupy space by repeating them here. The illustration given will suffice to show the general character of the motor used on this occasion.

The question of actual priority, in point of time, as between the invention of Davenport and that of Jacobi is a very close one. If the rotary motion which Jacobi obtained in May, 1834, was effected by the identical apparatus described in his paper read before the Academy in November of that year, then his priority must be conceded, but it does not appear to be certain that such is the case. In any event, the discoveries here and abroad must necessarily have been wholly independent, although nearly coincident in point of time, and it is, to say the least, remarkable, that one who labored under such limitations and disadvantages as Davenport, should by the unaided force of his native genius, have achieved a result which has been universally conceded to reflect the highest credit upon the talents and perseverance of one of the most able and learned experimental philosophers of his day.



Jacobi's Electro-Magnetic Engine of 1834.
[*Reproduced from Sturgeon's Annals.*]

The following letter, written near the close of the year 1837, gives an interesting résumé of the progress of affairs in the laboratory at that date[4]:

[*Thomas Davenport to Professor Benjamin Silliman.*]

Dear Sir:—Having lately made a number of applications of the power of large galvanic magnets in propelling machinery (being independent of the large machine now constructing by the association*), I have thought proper to state to you the results, believing they would not be uninteresting to you.

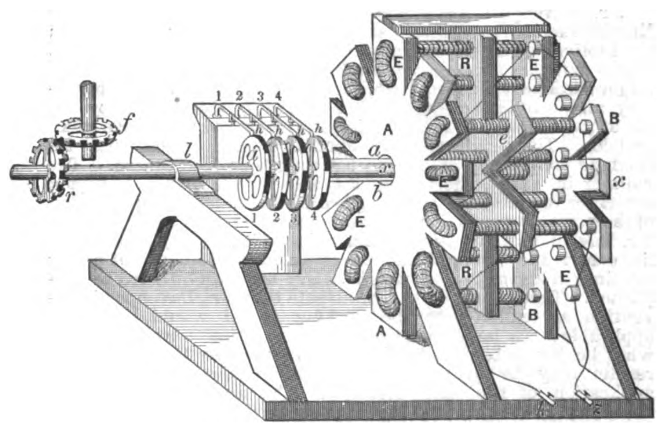
I have constructed a machine with two revolving magnets 2 feet in length, made of iron, 8½ inches in diameter, and weighing, after being wound with 6 coils of No. 10 copper wire, 100 pounds each. Three stationary magnets of 2 feet diameter, were placed around the periphery, making 6 poles and weighing 100 pounds each.

With this machine I have produced 100 revolutions per minute with 6 square feet of sheet zinc exposed to action, surrounded with thin sheet copper.

I then displaced the stationary magnets, and substituted one magnet 3 inches in diameter, forming a semi-circle, with the poles directly opposite each other, and weighing about 100 pounds. With this magnet I produced 150 revolutions per minute, using the same quantity of zinc surface. With one revolving magnet I produced 175 revolutions per minute, with 4 square feet of sheet zinc. I next constructed a hollow magnet 2 feet in length and 4 inches in diameter, made of boiler iron, $\frac{5}{16}$ of an inch in thickness, with 4 coils of copper wire, with which I succeeded in getting 100 revolutions per minute. A hollow magnet was then constructed of thin sheet-iron, of the thickness of common stove-pipe iron, which revolved 150 times per minute. Hollow magnets I think may be used to great advantage where weight is an objection; but in my experiments I generally make use of solid iron.

I also constructed a machine with simply two magnets formed of 2-inch round iron, 15 inches in length, of the stirrup form. The distance between the centres of the poles is 5 inches and the magnet revolves 450 times per minute, with 2 square feet of zinc. The stationary magnets being placed with the poles of the revolving magnet pointing downwards, the shaft to which the revolving magnet is attached passes through its centre and rests on the centre of the stationary magnet. Two of these machines (weighing in all 50 pounds) I have attached to small drilling works, which I find produce sufficient power to do all my drilling of iron and steel, to the size of ¼ of an inch in diameter.

I have adopted this form on the third machine which I have recently put in operation. The magnets are formed of 2¾ inch iron, with the centres of their poles 9 inches apart and weighing 50 pounds each; with this I produced 300 revolutions per minute, and have successfully applied it to turning hard wood of 3 inches diameter. I find the power increases in full proportion to the increase of weight and without increasing in proportion the size of the battery. The wire must be increased in size in proportion to the size of the iron used, and, consequently, the difficulty attending long wires will always be avoided.



Motor used by Jacobi in his Experiment on the Neva in 1838.
[*By permission of D. Van Nostrand Co.*]

I find no difficulty in using my machine 12 hours in succession, without changing batteries or agitating the solution.

I am erecting conveniences to test the powers of each magnet as they are increased in weight and size, and think I shall be able in season for the April number of your journal to give the exact increase of power in proportion to weight, of magnets weighing from 10 pounds to several tons.

I have also made some very satisfactory trials, while making my machines, respecting the expense for the consumption of zinc and acids, and I think I shall soon be able to give nearly the precise cost of making the largest machinery.

Galvanism is, I trust, destined to produce the greatest results in the most simple form, and I hope not to be considered an enthusiast, when I venture to predict, that soon engines capable of propelling the largest machinery will be produced by the simple action of two galvanic magnets, and worked with much less expense than steam. Yours respectfully,

New York, Dec. 26, 1837. Thomas Davenport.

4. Silliman's *Amer. Jour. Sci.*, xxxiii. (appendix).

* The machine alluded to in the above letter, as now being constructed for the Electro-Magnetic Association, by Messrs. Davenport and Cook, is nearly completed, and is expected to be of about two tons' power. It is formed by a combination of small magnets, weighing about four pounds each, and three-and-a-half inches between the poles. These magnets are placed—two hundred and thirty-four in number, on an iron shaft six feet in length, and a corresponding number in a circle as stationary magnets.

In 1838, Frederic Coombs was sent abroad to obtain patents in Great Britain and other countries, and to exhibit the invention with the hope of enlisting foreign capital in aid of the enterprise. The following notice was published in the proceedings of the London Electrical Society, of its meeting of July 17, 1838:[5]

Previous to the chair being taken, Mr. Coombs, of New York, exhibited to the members a locomotive engine propelled by electro-magnetism. This machine, which is at present exhibiting at the Royal Gallery of Practical Science, consist: 1st. Of the carriage containing the apparatus, but which, in consequence of the arrangements necessary to the taking out of a patent in this country not being completed, could not be explained. 2d. Two voltaic batteries; these are made on the principle of Hare's calorimotor, excited with a strong solution of sulphate of copper. 3d. Two carriages attached to the apparatus. The apparatus, batteries, and carriages weigh 60 or 70 lbs., and are placed on a circular railroad. Upon connexion of the apparatus being completed (by means of four cups containing mercury) with the poles of the two batteries, the apparatus is set in motion and revolves for some time with considerable velocity, but which decreases as the action of the battery diminishes.

The exhibition appears to have been favorably received by the members present, but it does not appear that anything further was accomplished. The following is selected from a number of newspaper notices:

[*From the London Morning Herald, August*, 1838.]

DAVENPORT'S ELECTRO-MAGNETIC RAILWAY LOCOMOTIVE.

Mr. Davenport has at length gratified the curiosity of the English skeptics to a certain extent, by sending over a model of a locomotive engine, which is now exhibiting at the Adelaide Gallery, in the Lowther Arcade, worked on the same principle as his larger stationary engines. This carriage runs on a circular railway, and draws after it two other carriages, which move, by the aid of two small galvanic batteries, at the rate of about three miles an hour. The weight thus propelled is nearly 80 lbs., and the carriage containing the apparatus about one foot square. The manner in which the electro-magnets are arranged is kept a secret for the present; but the principle on which the application of the power depends is well known, and the chief superiority in Mr. Davenport's invention consists in his having, by some peculiar contrivance, brought into exercise a greater amount of power within a given space and weight, than has been hitherto accomplished. Though we do not anticipate that Mr. Davenport's invention as exhibited in the working model would be found applicable on a large scale with any practical advantage; yet what he has accomplished is sufficient to show that important results may be expected from future improvements in the application of the same principle. We are informed by an American gentleman who has recently arrived in England that he witnessed a two horse power electro-magnetic engine, of Mr. Davenport's construction, employed in printing a newspaper in New York, and that it performed the work most satisfactorily. Whether or not, however, this was done at a cheaper rate than the same power might be obtained from steam, we are not able to ascertain,

Frederic Coombs, the exhibitor of the Davenport motor in England, in his old age became mentally unbalanced, and from his harmless eccentricities of dress and behavior was, for many years, a well known character in the streets of Washington, San Francisco and New York. His personal appearance was remarkable, combining as it were, the stately dignity of a Washington with the affable and condescending benevolence of a Franklin. The portrait given herewith will be recognized by many of our older readers.

The peculiar business methods pursued by the individual who had been entrusted with the management of the financial interests of the association soon came to be of a character to excite the suspicions both of his associates and of the public. His plan appears to have been a sufficiently simple one, namely, to sell shares to any one who could be induced to purchase, at any price the party could be induced to pay, and to put the proceeds in his own pocket, at the same time persistently refusing to render to his associates any account of his doings, but reluctantly disgorging, from time to time, such sums of money as were absolutely necessary to keep the laboratory going with the smallest possible number of employés. This course of conduct could have but one result. The confidence of the public generally in the integrity of the management of the association became impaired, while those who had purchased shares not unnaturally began to entertain suspicions that they had been duped. Ransom Cook was a man who was not only peculiarly sensitive in matters of honor, but one who was utterly without patience with fraud or chicanery in any form. He did not hesitate to express his disappointment and vexation at the conduct of the business manager, and ultimately, on the 12th of February, 1838, he sold nearly the whole of his interest for a mere pittance, withdrew in disgust from the enterprise, and returned to his home in Saratoga. During the year they had carried on operations in New York, Cook had expended on the work some $3,000, and Davenport more than $2,000 of their own money, while the total amount received from their business manager, instead of the promised $12,000, was only $1,700. After the departure of Cook, Davenport and M. W. Nelson, the party who had purchased Cook's interest, brought a suit in chancery against their unprincipled associate, the result of which was that the court compelled the latter, much against his will, to exhibit his books and render an account of his stewardship. Davenport had meantime sold a part of the patent right for the New England States which he had reserved to himself, and the proceeds furnished him with means to continue his experiments for a time without other aid.

One cannot but deplore the unfortunate occurrences which led to the permanent withdrawal of such a man as Ransom Cook from further association with a department of experimental research, in which his natural tastes, no less than his remarkable talents, so eminently qualified him to achieve distinction. An artificer of surpassing skill; a diligent and observant student of nature's ways and works; an original thinker, and an inventor of a high order; the brief story of a single one of Cook's mechanical conceptions will portray more vividly than volumes of description the rare genius of the man. Ever full of intelligent curiosity regarding the cunning works of nature, he became at one time absorbed in the study of the structure and habits of the so-called "ship-worm" (*teredo navalis*). More than anything else, he was struck with the capacity of this little creature to apply its cutting tool with equal facility and efficacy, at any angle to the grain of the wood, and as a skilled wood-wooker, his mind at once seized upon and sought to apply the hint which nature had thus given. Patiently and skillfully, with his own hands, he forged from steel experimental augers and bits, with cutters modeled from the teredo's mandibles, until at last the result was achieved; the curved tips of the justly celebrated "Cook bit," an implement which by sheer intrinsic merit has made itself indispensable to the "kit" of every woodworker in the civilized world. Of his many other scarcely less ingenious and original conceptions, space forbids even a passing notice here. In the autumn of his days, retiring with a handsome and well-earned competency from the active pursuits of life, he provided himself with a well-stocked library, and a model laboratory equipped with the most improved mechanical appliances and scientific apparatus. Here it was his especial delight to entertain his chosen friends, among whom were numbered many of the most prominent of public men and scientists who were his contemporaries. He died at Saratoga Springs, N. Y., May 26, 1881, at the advanced age of 87. It is impossible to resist the conviction, that had Ransom Cook continued to devote his unusual and peculiar talents to the industrial development of electro-magnetism, many of those knotty problems, which for so many years confronted and obstructed the pathway of the investigator, would have received at his hands an earlier solution.

Thrown once more upon his own resources, Davenport proceeded to build several larger machines, of a type very similar to that of the model locomotive in the illustration

5. Sturgeon's *Annals of Electricity*, etc., iii. 156.

on page 67, referring to which he says:

I increased the size of my magnets to about 50 lbs. each, and with four machines, with two of these magnets in each, I moved a large Napier printing press in the month of April, 1838. There was not, however, sufficient power for printing papers, although the machine would keep the press in motion.

While engaged in these experiments, he received a letter from Dr. Charles G. Page, then of Boston, who had been for some time engaged in exploring the same field. It is of interest as showing the views of Page at that date, and especially in view of the reference to the experiment of arresting the rotation of a magnetic bar by what is obviously an inductive action:

[*Charles G. Page to Thomas Davenport.*]

BOSTON, April 28th, 1838.

THOMAS DAVENPORT, ESQ.,

Sir:—I have for a long time (as is well known to you) been pursuing the same experiment as yourself, but for many months past, I believe I have been on an entirely new and different track. My main object has been to prevent retardation or back action. My plan is to cut off the galvanic current from both systems of magnets instead of changing poles as they arrive at equilibrium. The advantage of this I have fully tested, and my model for a patent went to the office three months ago. I have had notice from the Commissioner that it should be attended to as soon as practicable, but the certificate has not yet arrived. This experiment has been tried on a large scale, and has failed, not because of any fault in the plan, but for the simple reason that the magnets were too much crowded. I made a demand on the company for $500, to alter the machine, but as they have already exceeded their subscription by $500, they thought best to give it up. But

No. ______ ELECTRO-MAGNETIC ASSOCIATION.

. . . . is entitled to . . . . assignable Shares of Stock in the Association formed on Thomas Davenport's Patent for Electro-Magnetic Machinery; the whole number of Shares in said Association being three thousand, and subject to the Articles of Association, dated March 3, 1837.

NEW-YORK, . . . 1837.

For DAVENPORT & COOK, Proprietors,

Shares. Agent.

☞ Shares for sale by the Agent, EDWIN WILLIAMS, No. 76 Cedar-street, New-York. Present price of Shares Dollars, payable in cash.

STOCK CERTIFICATE OF ELECTRO-MAGNETIC ASSOCIATION.

[*Fac-Simile of Original in possession of W. G. Davenport.*]

I have no idea of abandoning the experiment myself, as I have full confidence that a power equivalent to that of one or two men can be obtained with economy. I have a foundation for this calculation, and can prove by some recent discoveries I have made that in the present state of our knowledge, the economy of the power is limited somewhere about the strength of a single man. I have made a still further improvement, which was fairly tested in a machine completed yesterday, by which I can increase the power of a machine to a great extent without increasing the battery. I also made some time since certain important discoveries in magnetic electricity, which throw a vast deal of light on this subject. I showed one of them yesterday to Mr. Horn, in a new machine which works exceedingly well without change of poles. To his great surprise I stopped almost instantly a bar making a thousand revolutions [per minute] by bringing together the two ends of a wire which had no connection with the battery, nor with the wires around the magnet. This is a most singular thing, as the wire is entirely independent, and the machine stops much more suddenly than by reversing poles.

I have still more recently made a more important discovery than this last. It does not relate at all to change of poles or cutting off the current, but is simply a method of increasing the power of the magnet. I will engage to make any machine of yours in five minutes time half as strong again, or forfeit the value of the machine (the battery shall remain the same). I feel very sure the power will be useful to the extent I have above named, but for reasons which I can make conclusive to any one I do not believe in its *indefinite* increase.

FREDERIC COOMBS.

[*From a photograph in the possession of Stephen D. Field.*]

I am now under obligations to no one here, and before I get up another interest I should like to know your views. I believe it would be for your advantage and mine, and contribute much to the success of the experiment, if our interests should be united. If you will make me a reasonable offer, I will take hold with you heart and hand, and there is no question but that in a short time we could make an excellent business of it, as we could cover the whole ground. Please write me immediately.

Respectfully yours,

CHARLES G. PAGE.

Acknowledging the receipt of this letter, Davenport replied briefly on Nov. 2, stating that he was "not in a situation to make or receive propositions relative to a union of interests," inasmuch as the ownership of his invention was largely vested in the corporation which had been organized to exploit it.

HOW TO DISPOSE OF THE INDIANS.

Secretary of War Proctor's mail is burdened with letters from cranks making suggestions as to the conduct of the Indian campaign. One correspondent proposes to exterminate the entire Sioux nation or a large part of it by establishing an electric plant at Pine Ridge and stretching a wire around the hostile camp. Then, turning on the current, the Indians are to be driven down to the wire, which is to be drawn closer and closer until contact with the wire causes wholesale destruction.

THE

Electrical Engineer.

VOL. XI. JANUARY 28, 1891. No. 143.

THE INVENTORS OF THE ELECTRIC MOTOR.—IV

WITH SPECIAL REFERENCE TO THE WORK OF THOMAS DAVENPORT.

BY

Franklin Leonard Pope

EARLY in the spring of 1838, Davenport discovered the principle of the core moving within the magnetic field of a solenoid, which afterwards came to be well known by the name of the "axial magnet." Entertaining the conviction that in this principle lay the germ of an important improvement in electro-magnetic engines, due to the possibility of greatly increasing the effective length of the stroke, he at once prepared and filed in the Patent Office at Washington, a caveat describing his discovery, and giving an outline of the manner in which he proposed to apply it for the movement of machinery. Although this discovery was no doubt original with Davenport, the phenomenon had been observed by Peter Barlow as early as 1822.[1] So far as record evidence goes, however, the caveat of Davenport is believed to be the earliest proposition to apply this principle in any manner for industrial purposes.

As this caveat has never been published, a copy of it is given below, procured by permission of the heirs of the inventor, from the secret archives of the Patent Office at Washington.

The Caveat of THOMAS DAVENPORT, of the City of New York.

The said Thomas Davenport, having invented a new machine of which a description is hereinafter contained, and desiring further time to mature the same, files this his caveat in the patent office of the United States, and prays protection of his right till he shall have matured the same.

The design, purpose, and distinguishing characteristics of his invention are as follows:

Said machine is designed to create or supply a power for any purpose to which animal, mechanical or other physical power can be, or is, applied to move bodies and machinery of every description. It is composed of an instrument denominated in science a helix, which is formed by winding insulated wire proper for the purpose around a hollow cylinder or other shaped tube of thin metal or other suitable substance incapable of being magnetized, in the usual manner and proper quantity in making helices. Galvanism being passed through such wire in proper quantity the helix is complete. The helix should be so formed that the internal hollow will be smooth, firm and uniform throughout, so as to permit a long, straight and uniformly thick piece or bolt of iron of the same shape and nearly exactly filling said hollow cylinder or tube to pass and repass longitudinally through it with as little friction or obstruction as possible. The end of a bolt or piece of iron fitting said tube or hollow cylinder, as before described, is then inserted a short distance into said hollow cylinder or tube, and the helix being galvanized the bolt will be drawn forcibly entirely into said tube and a motion be thus created. It is this machine, composed of the helix and bolt of iron (neither of which do I claim separately), thus producing motion, which I claim as my invention. I have so far improved it as to produce a reciprocating motion by which a crank may be turned in the following manner: I take two of the above machines, and the helices being placed perpendicular, I attach the two bolts at each extremity of a balance or walking beam. I then alternately galvanize each helix, and while one is galvanized, I take off or suspend the galvanism from the other. The consequence is, that the helix which is galvanized draws down its own bolt, and the other, not being galvanized, allows its bolt to ascend. As soon as the latter bolt has nearly reached the top of its helix I remove the galvanism from the former helix and galvanize the latter. The bolt of this is then drawn down and the other bolt ascends, and so on alternately. Intermediate the centre of the balance or walking beam and one of its extremities, at a suitable distance between, is attached a rod which descends to a crank, and as the balance beam moves up and down the crank is turned and turns a wheel band or other instrument to communicate power or produce motion. I put a balance wheel on the axis of the crank, and the axis of the crank forms a convenient means of letting on and suspending the galvanism as before described. In order to do this, separate pieces of silver, copper and other suitable metal are fastened to the axis so as to go about half way around it, forming a semi-circle flat and smooth. The conductors from the battery and the conductors to the helices are placed in contact with those pieces of metal but so as not to communicate galvanism to each other, unless through the medium of those pieces of metal. Then as the axis revolves when the revolution brings the conductors both in contact with their pieces of metal their helix is galvanized, and when, by such revolution the contact ceases, the galvanism of the same helix is suspended, and so of the other helix.

Dated New York, May 5th, 1838.

Attest:

E. PAINE. THOMAS DAVENPORT.

Respecting the work which was carried on during the year 1838, I have been able to obtain but little information. There are indications that matters in New York were practically at a standstill. It was a period of extreme financial depression, in which even well established interests experienced no little difficulty in meeting their liabilities and carrying on their business. In February, 1839, Davenport received a letter from John H. Smith, of Glasgow, a nephew of Junius Smith, who organized the corporation which

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1. This effect was noticed by Barlow in the course of an experiment in magnetizing a steel needle which was placed within a helix wound upon a glass tube. His own account of it is as follows:

"In performing this experiment, I employed a glass tube about 5 inches in length and ¼ inch in diameter; and it was observed, when the needle was placed in it, so that one-half of it projected beyond the end, that the moment the plates reached the acid, the needle was drawn instantly to the middle of the tube, and while the contact was continued it was held suspended in the centre of the tube when the latter was held vertically; the suspending power of the spiral exceeding the power of gravity. (The connection of the spiral with the conducting wires is here supposed to be made before the plates are immersed in the acid.)

"This effect is very curious, because the needle here remains suspended in the open space, directly in the axis of the tube, and not attached to either side as in the usual cases of suspension by attraction." BARLOW: *Essay on Magnetic Attractions*, etc. [2d edition, 1823.] p. 262.

The writer is indebted to Charles L. Clarke for the loan of the exceedingly rare work from which the above extract was taken.

The following editoral note referring to the same phonomenon appears in Sturgeon's *Annals*, vol. ii., p. 80 (Jan. 1838): "In answer to our correspondent, who wants to know if it be possible to suspend a needle in the air by transmitting an electric current through a helix in which the needle or bar is lying, we must say, yes. The fact was first shown at the London Institution, Moorfields. The battery employed was contrived by Mr. Pepys, and consisted of a single pair of plates of copper and zinc, each about 50 feet long and 2 feet broad, formed into a spiral on a cylindrical nucleus of wood, and placed in a barrel or circular wooden trough which held about 50 gallons of acid solution. The experiment may be made, however, with a battery of one square foot of each metal, immersed in a strong solution of nitrous acid. The helix must be of narrow bore, of 6 or 8 layers of spirals, and held vertically. The gravitating propensity of the needle may be much reduced by holding a bar magnet at a small distance above the helix."

In Alfred Vail's *American Electro-Magnetic Telegraph*, p. 59, is an account of "An Interesting Experiment of Supporting a Large Bar of Iron within the Helix. Discovered by Mr. Vail, Jan. 1844," which, so far as the writer is aware, is the earliest *published* account of the suspension of a soft iron bar of any considerable weight. The account is in the following words:—"It has been shown many years since that a magnetic needle would be drawn into and suspended within a helix conveying a galvanic current, and that in the case of using large bar magnets, the coils of helices might be made to move over them as in De la Rive's rings; but in no instance I believe has it been recorded or observed, that a bar of iron weighing a pound or more could be drawn up into the helix and there sustained in the air, as it were, without support. If the helix be connected with from 6 to 12 pairs of Grove's battery, the bar may be drawn up into its centre and there sustained in a vertical position by the action of the helix, forming an exceedingly interesting and paradoxical experiment."

built the celebrated steamship the *British Queen*. It appears that Smith, who had visited America in the preceding summer, had seen a model of Davenport's apparatus in operation at the Mechanics' Fair in Castle Garden, and in his letter he intimated his desire to undertake the introduction of the invention in Great Britain, on Davenport's behalf. Writing from Brandon, in reply to this and other letters from Smith, on August 15, 1839, Davenport says:

> I have experimented these 18 months past with my own limited means, having constructed machines on more than 30 entirely different plans; making great improvements in the power in proportion to the weight, &c. . . . . I have no doubt but that the power is unlimited, which can and ultimately *will be* successfully applied to all purposes for which steam-power is now used. . . . . . An attempt is making in New York by some individuals who have a machine now exhibiting in Gold street, to *monopolize*, as they say, the business of Electro-magnetic speculation. They have obtained a charter, and are offering for sale shares of stock; but their machine, although inferior in principle of application to any ever before exhibited to the public, is precisely on the plan of one constructed by myself in the winter of 1835, a part of which is now at this place [Brandon].

In a subsequent letter to Smith, dated in New York, December 13, 1839, Davenport mentioned that he was driving a rotary printing press with a machine weighing less than 100 pounds.

In January, 1840, Davenport commenced the publication of a journal entitled *The Electro-Magnet and Mechanics' Intelligencer*. This was a small folio sheet 12 by 16 inches, and as its title-page announces, was printed on a press propelled by electro-magnetism. As a matter of curiosity we give a fac-simile of the head of this somewhat unique and not particularly well-printed publication. Copies of the two first numbers issued have been preserved. It is not known how many, if any, subsequent numbers were issued. Among the editorial remarks in the second number I find the following, which are quoted as explanatory of the plan and scope of the undertaking:

> The first number of the *Electro-Magnet* was issued on Saturday, January 18, 1840, which was the first paper ever printed by the power of Electro-Magnetism or Galvanism. The project was proposed and set on foot for the express purpose of bringing before the public some tangible illustration whereby the power might be brought forward upon as cheap and prudent scale as possible. How far we have succeeded, time must show. . . . . . As the second number of our publication is before the public, we would respectfully call the attention of those who wish to advance the cause of philanthropy to come forward and assist us in our experiment. That we may be considered chimerical by many we doubt not; but when all things are fully proved we shall hope for a better fate than many of our predecessors.

On January 28, 1840, only three days later, in a letter to his brother, in Brandon, he feelingly portrays some of the miseries which beset the path of this, the pioneer effort in electrical journalism:

> I have been obliged to bear the whole load in starting the paper and have no writer to aid me yet. I have talked with some, and find that it will cost $10 per week for editorial articles (which accounts for no more original matter), yet I intend to have friends enough soon that will help without expense to me. . . . . . The truth is, I am now in the worst pinch in regard to means for supporting my family that I ever have been, yet my prospects are the most flattering, and I think the most sure to net me something handsome as early as spring. You see I have no way to get a few dollars in a place, except by the prospect of getting subscribers, which I have not yet tried to do. I have only to take time and make my trade in a lump.

A few months later Davenport appears to have made a second essay in the way of a journalistic enterprise, of which, so far as is known, only a single number was issued. The new undertaking was somewhat more ambitious in character, being printed in quarto form upon a sheet 16 by 22 inches. This journal was entitled *The Magnet; Devoted to Arts, Science and Mechanism*, and was "edited by S. J. Burr, secretary, U. S. Society of Science and Mechanism," presumably at the munificent salary of $10 per week, which in fairness it must be stated, was every cent that the work was worth. As a matter of interest, we copy the advertisement which appeared at the top of the first column, together with the prospectus:

LIGHTNING IN HARNESS.

The Printing Press Worked By

LIGHTNING!

EXHIBITION.

The Greatest Discovery of the Age.

The attention of the scientific, mechanical, and curious is respectfully invited to the exhibition of LIGHTNING IN HARNESS, which is this day opened at No. 4 Little Green street. (Little Green street is between Broadway and Nassau street, and runs from Maiden Lane to Liberty street.)

The exhibition of Davenport's electro-magnetic engine will continue open this day, from 9 A. M. to 10 P. M.

The engine is of sufficient power to drive a printing press, and those who witness the exhibition will find it printing the DECLARATION OF INDEPENDENCE.

The proprietor has been induced to exhibit his electro-magnetic engines especially upon this day, for what can be more appropriate than, upon the anniversary of our nation's birth, to print the Declaration of Independence and send it by lightning throughout the whole world.

Admittance free.

July 4, 1840.

PROSPECTUS OF THE MAGNET.

We present our little work to the public with great confidence and for several excellent reasons: First. It is printed upon a new and improved conical rotary press. Secondly. This press is worked by our electro-magnetic engine. Thirdly. Both are wholly American. The first number of the paper is published on the anniversary of our national independence, and offered at a cheap rate to the patronage of the lovers of truth, and those who devote time and labor to mechanical and scientific pursuits.

Though the investigation of electro-magnetism will form the principal feature of our journal, it is not intended to confine its columns to that interesting science; we shall fill our pages with such authentic matter as may come within our reach upon all scientific and mechanical subjects.

With respect to electro-magnetism, it is the intention of the publisher to advance tangible proofs that this power has already triumphed in moving machinery. It is also his design to make known all the experiments made by him since December, 1833, which go to corroborate his views on this subject, with wood cuts, illustrating various models and machines, together with the laws of electro-magnetism, and the great advantage this wonderful power has over steam, in regard to safety, cheapness, and convenience. In the mean time, the experiments of others, more experienced in the science of electricity, galvanism, magnetism and electro-magnetism, will be noticed in order that the reader may get a general idea of the science, and the laws by which they are governed, and by which we are guided in controlling and working the powerful and mysterious agent. It is not our intention to make the subjects tedious, nor the articles too laborious for the ideas of readers in general.

We shall treat upon the different branches of science, and the various inventions and improvements that shall be made known, as also those at present in operation, together with such miscellaneous and interesting matter as shall appear from time to time.

Any objections or difficulties that may be advanced by different individuals, in regard to the application of electro-magnetism as a motive power, we shall be pleased to receive, and shall consider it a favor to communicate with them through the columns of the Magnet.

Several scientific gentlemen of our city, Boston, and Philadelphia, have already engaged to become contributors to make our paper interesting and useful to all classes.

THOMAS DAVENPORT.

NEW YORK, July 4, 1840.

Two or three machines of different design were employed at different times, in driving the printing press. One of them was a helix machine, constructed upon the general plan proposed in the caveat of 1838 which has been given above.

The experiments of Davenport during the season had been so numerous and so costly that he again found himself at the end of his resources, and was reluctantly compelled to suspend operations. Receiving encouraging letters from Great Britain, he finally made arrangements to proceed to that country in order to personally negotiate the sale of his foreign patents, and it was only the lack of promised pecuniary assistance which failed to reach him on the very morning of his intended departure, that prevented him from being one of the unfortunate passengers of the ill-fated steamer President, which foundered at sea, carrying with her every soul on board.

Very little record remains of the labors of Davenport for some time after the occurrences which have just been narrated. It was, however, at some time during this period, that he experienced one of those cruel disappointments by which fortune sometimes seems to delight in making a foot-ball of the struggling inventor. The story of this misfortune is best given in Davenport's own words:

> A gentleman residing in Ohio, finally proposed to assist me to an amount which I considered would enable me to put the electric-motor power on such a footing that it should no longer prove problematical whether electro-magnetism could be used instead of steam. As I had for a long time been completely destitute of means for carrying on my business, and even for comfortably supporting myself and family, I now felt not only relieved as regarded my daily subsistence, but I was much elated at the idea of having sufficient funds to build a proper Electro-magnetic engine.
>
> This gentleman funished me with $3,000 in Ohio bank notes. Of these notes I had used only $10 when I was informed that the bank that had issued the notes had broken, and that my money was good for nothing. This proved to be the fact, I never received $10 in cash for the remaining $2,990. After struggling along for nine months more in trying to convince my friends that the object of which I had so long been in pursuit was still worthy of their attention, I reluctantly gave up all hope of further assistance, and in the fall of 1842 moved my family to Brandon, Vt., where I resumed work at my trade as a blacksmith, which was then my only resource to gain a livelihood.

Early in 1843, the inventor's nervous system, enfeebled by so many years of incessant toil and anxiety, gave way under the strain, and a protracted and dangerous illness ensued, which left him with a constitution permanently impaired. After residing two or three years in Brandon, he retired to a small farm in Salisbury, Vermont, where he passed the few remaining years of his life. He could not, however, wholly withdraw his mind from the fascinating science which had for so many years been a part of his very life, and in the retirement of his quiet home, he continued his studies and experiments in electro-magnetism.

In February, 1849, a memorial of Dr. Charles G. Page was presented in the United States Senate by Senator Benton, asking for the appointment of a committee to examine the merits of an invention for applying electro-magnetism to the purposes of navigation and locomotion, and a committee of seven was appointed for that purpose. In March an appropriation was granted, in pursuance of the recommendation of this committee:

> For testing the capacity and usefulness of the electro-magnetic power, as a mechanical agent for the purposes of navigation and locomotion, and the probable cost of using the same according to the invention of Professor Page, the sum of *twenty-thousand dollars*, to be expended under the direction of the Secretary of the Navy in making a practicable experiment of said invention according to the plans to be proposed and conducted by Professor Page.

From time to time accounts of the experiments of Dr. Page found their way into the journals of the day, and one of these notices, coming into the hands of Davenport, led him to send a communication to a local newspaper, which is not only valuable in itself, as a concise review of the author's own work, but because it was the occasion that led to an interesting correspondence between Davenport and Page, the essential parts of which are printed herewith, and which form a contribution of no inconsiderable importance to the history of the development of electro-magnetism as a motive power:

[*From the Brandon Post, Sept. 26, 1850.*]

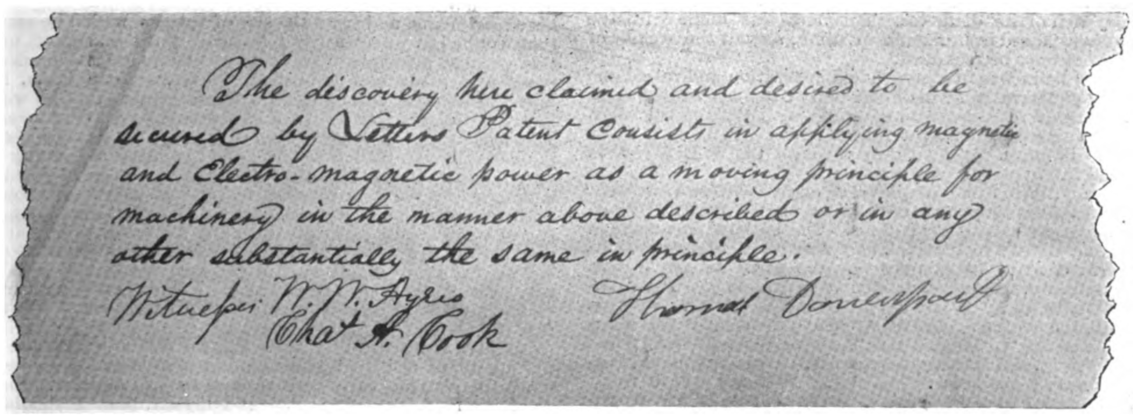
ELECTRO-MAGNETISM TRIUMPHANT OVER STEAM.

Mr. Welch:—Will you allow me a small space in the *Post* for the purpose of making a few remarks respecting Professor Page's successful experiment in applying Electro-Magnetism to propelling machinery, as described in the following article which recently appeared in the *National Intelligencer*:

Electro-Magnetism as a Motive Power.

> Professor Page, in the Lectures which he is now delivering before the Smithsonian Institution, states that there is no longer any doubt of the application of this power as a substitute for steam. He exhibited the most imposing experiments ever witnessed in this branch of the science. An immense bar of iron, weighing 160 pounds, was made to spring up by magnetic action, and to move rapidly up and down, dancing like a feather in the air, without any visible support. The force operating upon this he stated to average *three hundred pounds* through ten inches of its motion. He said he could raise this one hundred feet as readily as through ten inches, and he expected no difficulty in doing the same with a bar weighing one ton or one hundred tons. He could make a pile driver or a forge hammer, with great simplicity, and could make an engine with a stroke of six, twelve, twenty, or any number of feet.
>
> It looked very unlike a magnetic machine. It was a reciprocating engine of two feet stroke, and the whole engine and battery weighed about one ton. When the power was thrown on by a motion of a lever, the engine started off magnificently, making one hundred and fourteen strokes per minute; though when it drove a circular saw ten inches in diamater, sawing up boards an inch and a quarter thick into laths, the engine made but eighty strokes per minute. There was a great anxiety to obtain specimens of the laths sawed in this way to preserve as trophies of this great mechanical triumph. The force operating upon the magnetic cylinder throughout the whole motion of two feet, was stated to be 600 pounds when the engine was moving very slowly, but he had not been able to ascertain what the force was when the engine was running at a working speed, though it was considerably less. The most important and interesting point, however, is the expense of the power. Prof. Page stated that he had reduced the cost so far that it was less than steam under many and most conditions, though not so low as the cheapest steam engines. With all the imperfections of the engine, the consumption of three pounds of zinc per day would produce one horse power. The larger his engines (contrary to what has been known before) the greater the economy. Prof. Page was himself surprised at the result. There were yet practical difficulties to overcome; the battery had yet to be improved; and it remained yet to try the experiment on a grander scale, to make a power of *one hundred horse* or more.

As I am confident that the results of the experiments of this enterprising and scientific gentleman will open the eyes of the people and the purses of capitalists, sufficiently to soon place on our lakes, rivers and railroads, a safer and more convenient power than steam, I hope I may not regret so much in future as I have for ten years past, that the paralyzing hand of *poverty* has for-


The discovery here claimed and desired to be secured by Letters Patent consists in applying magnetic and Electro-magnetic power as a moving principle for machinery in the manner above described or in any other substantially the same in principle.
Witnesses: W. W. Ayres, Chas A. Cook — Thomas Davenport

CLAIM OF DAVENPORT'S PATENT. NO. 132 OF FEBRUARY 25, 1837.
[*Fac-Simile from Original Specification in Archives of Patent Office.*]

bidden any attempt on the part of myself to prove to the world, what as early as 1833, I believed could be done within the space of five years. At that time galvanism appeared to me to have the same relation to the power of an electro-magnet that water does to the power of a steam engine, and I had no doubt but that I could convince the whole sensible world of the fact, by applying the power of a small electro-magnet to moving the lightest machinery. But in this I was disappointed. I found the power more controllable than the minds of men, and compliments more plenty than money.

Having devoted the most part of seventeen years of my life in laboring to apply electro-magnetism to useful purposes (and without receiving any remuneration), it may not be improper for me to state to the public the power and size of some of the electro-magnetic engines which I have invented and applied to the moving of machinery, that they may be compared with the engine lately constructed by Prof. Page. Early in 1838 I ascertained that a bolt of iron could be drawn with great force into a helix whenever the battery current was suffered to pass through the coil. I immediately constructed a small engine on this principle, which, when in motion, very much resembled a little steam engine with two perpendicular cylinders. During the same season I filed a caveat for this improvement in the United States Patent Office, and sent several models to Europe. A patent for this invention was obtained in England and the Provinces, and money paid into several other European Patent Offices where no letters patent have ever been obtained.

In 1839 I experimented on a much larger scale with the magnetic cylinder or helix, and constructed a helix two feet in length with an aperture through the centre two inches in diameter. A bolt of iron 2 feet long and 2½ inches in diameter, weighing about 28 pounds, was forced into the helix when the current of galvanism passed through the wire, with a power equal to 6 pounds to the square inch of its diameter. This test was made with the helix and bolt placed in horizontal position, so that the weight of the iron should not be reckoned.

When the helix was in a perpendicular position and raised one foot from a platform, with the lower end of the bolt resting upon the platform, and the upper end entering one foot into the helix, the battery current would raise this bar of iron with such force that it would often pass entirely through the coil, 2 feet in length, and fall upon the platform.

In January, 1840, I had completed an engine with two magnetic cylinders weighing 50 pounds each. The engine made a 12-inch stroke and weighed about 200 pounds. The battery was made of lead and zinc plates 2 feet long and 5 inches wide, weighing in its most improved state 100 pounds. In the same month I commenced publishing a newspaper, which was printed on a press propelled by this engine. When the press worked off but 10 papers per minute, the engine made 120 strokes in the same time. Many who witnessed the working of this machine, estimated it to be a two horse power, but from my own tests, I could not make it exceed the power of one horse. The cost of zinc and acid in working did not exceed 25 cents per day. In the course of my experiments, up to the time of printing by this power, I had constructed in all more than 100 engines of various dimensions, and all different in point of construction, for the purpose of ascertaining the best proportions and mechanical arrangements for the increase of power. My experiments with helices, using long and short, large and small, hollow and solid bars of iron, were very numerous. My press was first moved by a horizontal helix engine, next by a rotary, and lastly by a perpendicular double helix engine. Now, as Prof. Page's experiment with 160 pounds of iron "dancing like a feather in the air" seems to me to be precisely like the experiment I made in 1839, when the 28 pounds of iron jumped through a helix two feet in length, by magnetic action, and as the Professor's engine is constructed on the same plan and principle as my own above described, I presume the scientific gentleman lays no claim to having presented any *new route* in his application of the power, or to have made any important improvement whatever in my invention. If Prof. Page, by the completion of his engine, has finally come to the point at which I arrived ten years ago in testing electro-magnetism as a prime-mover in the arts, and has expended as much money in the series of experiments which he of course would be obliged to make, I think I could have saved him the needless expenditure of several thousand dollars, by giving him the results of some of my experiments in 1838-9-40, which I should have been happy to do, if I had been consulted in due time.

THOMAS DAVENPORT.

SALISBURY, VT., Sept. 12, 1850.

The publication of this communication drew forth the following letter from Professor Page:

[*Letter of Charles G. Page to Thomas Davenport.*]

WASHINGTON, D. C., Oct. 2, 1850.

Dear Sir:—I have received this day your communication in the *Brandon Post*. I have been aware from the beginning of your experiments with the helix, and although we were operating entirely independent of each other, it will no doubt be gratifying to you to know of a promise of success in the common cause. I believe there is nothing in my improvements that conflict in any way with your inventions, but should it ever prove to be the case, I think we could make an amicable arrangement. I commenced my experiments on the helix primarily in 1830, and made several miniature models, and published accounts of several of them in the early part of 1837. In 1838, in the winter, I think, while I was in Davis' shop in Boston, a gentleman from New York called and said that you thought you could get power in that way, but that you had not yet arranged any machine. My experiments and little models had been successfully tried long before that, and I have always believed and am satisfied that I was the first that ever attempted to get power in that way.

In 1843 I made a great improvement on this principle, and many more since, without which I am satisfied nothing could be done to render the power available.

I have always looked with pleasure upon your zeal and ingenuity in this matter and when speaking in public have always alluded to you in terms of commendation, and although your article was no doubt written with feeling, yet I hope you will not repeat it until we can fully understand each other.

Respectfully, your obedient Servant,

CHA'S. G. PAGE.

THO'S. DAVENPORT, Esq.

[*From the Brandon Post, October* 31, 1850.]

WASHINGTON, D. C., Oct. 24, 1850.

Mr. Editor:—I notice in your paper a communication from Mr. Davenport, in which he gives an interesting historical account of his experiments in electro-magnetism, and concludes that he was in advance of myself in respect to the peculiar plan of operation which he describes. According to his own statements he *was* in advance of me in respect to the scale of magnitude of his experiments, and from the size of battery which he employed that would have necessarily followed. But the attempt to apply this peculiar principle of action to an engine for mechanical purposes was made and published, so far as I can learn, first by myself, and long before Mr. Davenport states that he was first aware of the fact that a bar of iron would be drawn into a helix. This fact has been long known to the world, having been first published by Mr. Barlow in 1823, and I apprehend that the reason why it has been so little thought of as a source of mechanical action, is that the force thus exerted was so very feeble compared with the attraction of the electro-magnet. As to raising a bar, I can of course claim no originality, and the raising of a bar of 600 pounds, which I now do readily, presents a difference only in degree from the experiment of Mr. Barlow in 1823 in raising a small bar, perhaps of only one ounce. But the peculiar improvements by which I raise so great a weight with so *small an expenditure* of galvanic power are novel and original with myself. Mr. Davenport is entitled to great credit for his ingenuity and zeal in the pursuit of electro-magnetism, and I have always viewed with much interest his early perseverance in this matter. But it is due to himself, the community and myself, that I should make this statement, and to add that I do not feel indebted to any one for the peculiar views which I have long entertained in regard to the plan of operation based upon the known fact above mentioned.

CHAS. G. PAGE.

In view of the historical interest attaching to the inquiry, the author has made every effort to verify the statement made by Professor Page in the two preceding letters in respect to his publication in 1837, of accounts of experiments with the helix and core, but without success. From other publications made by Professor Page, it seems impossible to avoid the conclusion that the dates given by him must have been the result of some misapprehension. In an article published in *American Journal of Science* in 1845, vol. xlix, p. 131, he says:

> This new species of electro-motion, which by way of distinction I denominate the axial reciprocating engine, was *unsuccessfully attempted in the year* 1838, and notice made of it *in this* journal (vol. xxxv for 1839, pp. 261 and 262) together with *some other experiments upon the interior of helices*. My failure at that time was for want of suitable batteries, etc. . . . . . .
> To sustain a small needle within the helix is a trite experiment, but by the arrangements which I have adopted, a bar of iron or steel (which becomes instantly and powerfully magnetized) is

2. The improvement here referred to by Professor Page, is probably that embodied in the engine which he exhibited in New York in the fall of 1851, and which is described with illustrations in the *Scientific American* of November 15, of that year (vol. vii., pp. 65, 67). This machine was fitted with a range of hollow helices formed of square wire. A sliding commutator was so arranged as to pass the current through three successive coils of the series at the same time, current being cut off from each rear coil in succession, and thrown on the coil in front of the core in the direction in which the latter is moving. Thus a stroke of any length in either direction could be given to the moving core. The battery used is stated to have been 40 pairs of 10 inch Grove's. This form of motor had been used in Professor Page's well-known experiment in propelling an electro-magnetic locomotive on the Baltimore & Ohio Railroad in April of the same year.

sustained entirely free from any visible support, and this too by the action of only six small Grove's batteries. This is almost a realization of the fable of Mahomet's coffin, or the statue of Theamicles. When the helix is connected with six pairs Grove's in good order, it will draw up within its centre a bar of iron or steel weighing two or three pounds and sustain it with its upper end projected above the helix

He then goes on to give a description of his well known axial reciprocating engine, for which he took a patent January 31, 1854, and which is described in many works on electricity and magnetism.[3]

Referring to the notice in vol. xxxv of *American Journal of Science* of which Page speaks in the above extract, I find that it describes an apparatus consisting of a pair of helices, with U-shaped cores thrust into them at each end, so that the four poles will meet in the centre of the helix. It is distinctly stated that this apparatus was contrived Jan. 11, 1838, but it is not properly an axial magnet, nor is any mode of application to the moving of machinery described. The inference seems unavoidable that Professor Page must have been in error as to his dates, and that Thomas Davenport is really entitled to priority in the application of axial magnetism to the movement of machinery, as set forth in his caveat of May 5, 1838, and as reduced to practice by him in 1838-39-40.

[*Letter of Thomas Davenport to Charles G. Page.*]

SALISBURY, Oct.——, 1850.

Dear Sir:—Yours of the 2d inst. was duly rec'd. When I wrote the article which you noticed in the *Brandon Post*, I had no knowledge of the fact that Congress had appropriated any moneys for testing the availibility of electro-magnetic power. Since then, have received your report to the Secretary of the Navy on the subject of electro-magnetism as a moving power. I am truly gratified to learn that your experiments have resulted so favorably. I believe, however, that if I could have had in 1840, one half the amount of money that you have expended, I should have produced more power and fully as economically. I question whether, in proportion to weight, your machine actually exceeds in power the helix machine with which I printed a newspaper in 1840. But, the improved state of the galvanic apparatus would probably render your power a cheaper one. I perceive that you have made a great many experiments which were precisely like those I had tried, excepting that yours were on a larger scale. The impossibility of my obtaining funds to build larger caused me much regret. In completing my engine for printing, I had used up all the means I possessed, and all that I could get, for I had tired my friends with my solicitations for funds. After trying more than a year without success, I gave up all hopes of enlisting individuals any farther in the enterprise, and I then thought of applying to Congress for an appropriation for the purpose of testing the power on a larger scale. I asked the opinion of many intelligent and influential individuals in regard to my plans, but they invariably gave me unfavorable answers. In 1845-6 I wrote to some gentlemen and members of Congress on the probability of my getting an appropriation from the Government, but their answers were generally discouraging. But I will not tire you at this time with an enumeration of my misfortunes, for it pains me much to call to memory the many distressing circumstances in which I have been placed in consequence of my zeal in the cause. You mention that you believe that you are the first that ever attempted to get power with the helix, and that you had successfully tried a model previous to 1838; also that some of your experiments in the helix were published prior to that date. I find in Davis's "Descriptive Catalogue of Apparatus and Experiments," published in Boston in 1838, the following apparatus described: "Page's revolving helix," "Page's revolving helical ring." These experiments seem to be on the same principle as the "floating helix" and "De la Rive's ring."[4] In your improvements in the "floating helix," it appears that you had no idea of accumulating *power* in that way, for in your letter to me dated Boston, April 28th, 1838,[5] you have said nothing about any experiments with the helix, although you mention a variety of other experiments which you have made in producing rotary motions, without changing poles, and which you considered was an improvement on my system of changing the polarity of the magnet. You also stated in the same sheet, that you could show good reasons why the power would not admit of "indefinite increase," but must be confined to the power of that of one or two men. *Since I first saw the power of an electro-magnet exhibited, any idea that the power could not be indefinitely increased, seemed to affect me with a peculiar disagreeableness.* I write you thus plain, because I have had strong feelings on the subject, and retain them yet. I believe that my zeal and attachment to, and inventions in, electro-magnetism have been of great value to science and the arts, to government and to the whole world, and this I shall endeavor to show in a publication which I hope to have prepared in a few weeks, in which I intend to fully show my position in the matter.

You mention in your letter of the 2nd inst. that if your improvements in any way conflict with my inventions, there could no doubt be an amicable arrangement made between us. It strikes me that if Government has taken the business in hand to perfect the application of this power to moving machinery, that Congress would be the proper body for me to look to for compensation for what I have done in the premises. I should be happy, however, to receive suggestions from you with regard to the best course for me to pursue. In the meantime, I hope that Congress will make still further appropriations, that you may continue on in the noble cause.

For the last four years I have been experimenting in electro-magnetism on a plan for applying the power to new purposes; and have succeeded to my full satisfaction. This invention I consider of very great importance to the public, and I hope to be able in a few months to present you with a model for examination.

Respectfully your friend and fellow-laborer,
THOMAS DAVENPORT.

[*Charles G. Page to Thomas Davenport.*]

WASHINGTON, D. C., October 22, 1850.

Dear Sir: I have this day received your kind letter and although I differ with you in opinion on its most important points, still I believe you to be as sincere as you are zealous. I do not remember the letter of 1838 you refer to, but it has generally been my practice in writing to others upon the subject, to withhold such information as would give them an advantage over myself by giving them the benefit of my own inventions. However in 1838 and after, and in 1836-7, I was fully of the belief that an economical power could not be obtained, unless the difficulties of the time required to charge and discharge magnets and the influence of secondary currents could be overcome. These difficulties always increase with any increase in the size of the engines. I threw out all these objections in *Silliman's Journal* at that time, but I hoped and believed there would be a remedy; I was constantly searching after it, and at last I found it. It was only when I found it, that I thought the way was clear. You must estimate the power of your engine much too high. Your printing press was a very small one, and it would not have required, I think, $\frac{1}{10}$ horse-power to drive it at the rate you mention. I send you a pamphlet containing an account of the performance of my engine

THE ELECTRO-MAGNET,

AND MECHANICS INTELLIGENCER.

PUBLISHED BY THOMAS DAVENPORT, AND PRINTED ON A PRESS PROPELLED BY ELECTRO-MAGNETISM.

OFFICE, 42 STANTON STREET. NEW YORK, SATURDAY, JANUARY 18, 1840. NO. 1.—VOL. I.

FAC-SIMILE, FULL SIZE, OF THE HEADING OF DAVENPORT'S ELECTRICAL JOURNAL, ISSUED IN 1840.

3. See Davis's *Manual of Magnetism* [12th edition] p. 182; U. S. Letters Patent, No. 10,480; Martin and Wetzler, *The Electric Motor*, etc., p. 79.

4. De la Rive's ring is a small helix of thin wire in the form of a vertical annulus which is mounted on a float, having a small plate of copper attached to one end and a corresponding plate of zinc to the other end, which hang below the float. The whole arrangement is then placed upon the surface of a vessel of acidulated water, which causes a current to pass through the ring. If the pole of a bar magnet is presented to the ring, the latter will move towards the centre of the magnet, passing over the bar. It is in fact an inversion of the solenoid and core, and involves precisely the same principle. (See *Davis' Manual of Magnetism* [12 Ed.], p. 115.)

5. See *ante*, p. 71.

which was made about five years since, and which after I got it into the best working order I showed to Congress, working a planing machine (small one) and afterwards carried to Tower's printing office to test it. This engine had by accurate measurement, ¼ of a horse-power and yet you see how large a press it worked at the rate of twelve hundred impressions per hour. There are some other points in your published article which do not seem to me to be correct, as to estimates, etc. But there is no reason why I should raise a discussion now about them. You will notice in the pamphlet that I had given you credit for your labors (see page 6). There seems to be no hope from Congress now. They have taken the ground that it is a matter of individual enterprise, and on that ground they refuse to appropriate further for my experiments. I applied for forty thousand dollars to build a large ship with an engine of one-hundred horse-power, which they refused without a count.

The great feature of my engine is the manner in which I overcome the difficulties I spoke of, and you will I am sure be gratified when you come to know the plan. It has never been made known in public yet, but by next spring my work will be published containing a full description. I shall be always glad to hear from you and render you any aid in my power. Meantime believe me to be,

Your friend and well wisher,

THOMAS DAVENPORT, Esq. CHARLES G. PAGE.

P. S.—I have kept a good account of electro-magnetic engines and I do not think that a horse-power was ever attained before my engine. Jacobi's great engine was about ½ horse-power, and so far as I can learn, was the most powerful ever made.

About the year 1850, Davenport became interested in the development of an idea which he had conceived, of producing music by electro-magnetism. The following notice of this invention appeared in a journal of the time:

[*From the Scientific American, April 3*, 1851.]

The Electric Piano.

Mr. Davenport, of Salisbury, Vt., we learn claims to have made an improvement in pianos, causing the musical chord by means of electric magnets to continue an equable and free vibration for any length of time. The perpetual and hitherto incurable defect of the piano-forte is the impulsive and evanescent nature of its tone, and though great improvements have been made upon it, and various devices have been elaborated to prolong its notes in some degree, yet the want of a sustained vibration is still an inherent defect in that beautiful instrument.

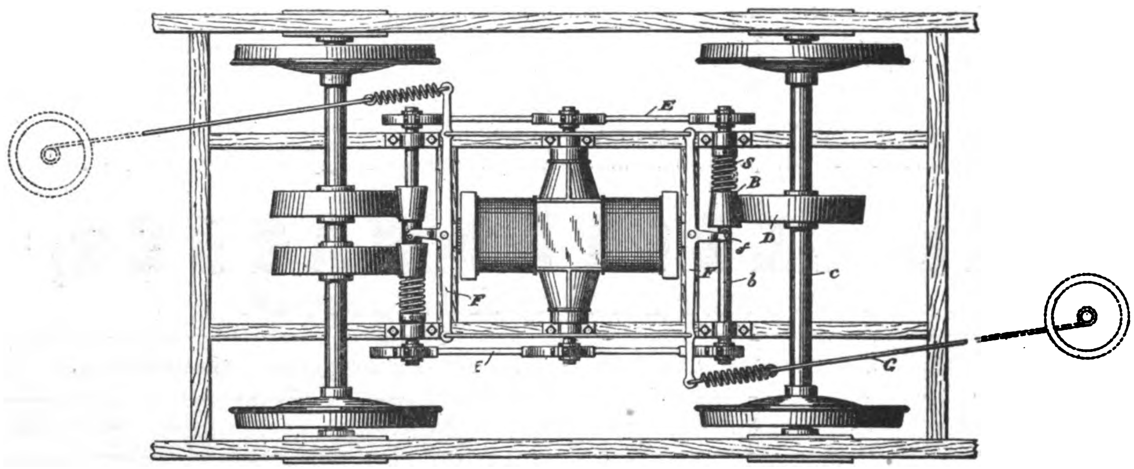
Davenport's work in this direction, which was attended with very satisfactory and successful results, was brought to an untimely end by his illness and death, which took place in the summer of 1851. It is my purpose to enter more at length into the history of his labors in this direction in a subsequent article.

BERLIN, N. H.—The Westinghouse Company is now installing a central station plant at Berlin, N. H., with the Westinghouse alternating current apparatus. The plant will commence operations with 750 sixteen candle power lights capacity.

McCARTHY'S ELECTRIC CAR GEAR.

AMONG the new devices designed to transmit the power developed by the motor to the car axle of an electric car we note that recently patented by Mr. L. A. McCarthy, of Brooklyn, N. Y. In this arrangement the inventor has sought to effect a simple arrangement by which the motor may be kept in constant operation, if desired, and thrown in and out of gear with the axle with the least possible jar, and thus to obtain efficiency with flexibility of connection. As shown in the accompanying engraving, the motion of the armature is transmitted to an intermediate shaft *b* by means of driving rods. Mounted upon this shaft is a movable cone pulley B placed directly opposite a corresponding friction pulley D, mounted on the car axle.

The pulley B is normally held out of contact with the pulley D by the spring S, and under such condition the motor runs free. When it is desired to start the car, the driver, by turning a lever on the platform, draws the rod G taut, which, acting upon the bell crank lever F, moves its short arm *f*, and presses the cone pulley B firmly against



McCARTHY'S ELECTRIC CAR GEAR.

the pulley D. In this manner the motion is transmitted without shock and is under complete control of the driver.

THE PRACTICAL VALUE OF THE PHONOGRAPH.

The greatest feat of reporting that has ever been performed by the official reporters of Congress was that of preparing the Senate report for the *Record* Wednesday night, Jan. 14. The chief reporter is sick, and but two men were available to do the work. The Senate was in session for fourteen hours, all of which time was spent in an active discussion of the silver bill. It was after 12 o'clock at night when they adjourned, and during the session they had talked over 120,000 words. Two stenographers took the report, and, by dictating their notes into phonographs for typewriters to transcribe, they had all the copy ready for the printers by 8 o'clock in the morning, and the *Record* was on the desks of the Senators when Congress convened.

LAWS AGAINST THE EMPLOYMENT OF JUVENILE OPERATORS.

At its last session, the Georgia Legislature passed a law providing that in the future all railway telegraph operators must be not less than eighteen years of age before they can accept such positions, and, furthermore, they must pass an examination as to capability before the chief train despatcher of the road upon which employment is sought. Tennessee operators will push a similar measure before the Legislature of that State. They claim that the passage of these bills means the disappearance of the boy operator and a corresponding decrease in the number of accidents resulting from the employing of inefficient, immature and inexperienced railroad telegraphers. It would be well, perhaps, if every State should adopt such a law.

MR. W. H. McCULLOCH, manager for the Southern Telephone Co., at Greenville, Miss., has been promoted to the position of supervising auditor, with headquarters at Vicksburg. Mr. D. Thomas, of Memphis, succeeds him.

THE
Electrical Engineer.

VOL. XI. FEBRUARY 4, 1891. No. 144.

THE INVENTORS OF THE ELECTRIC MOTOR.—V.

WITH SPECIAL REFERENCE TO THE WORK OF THOMAS DAVENPORT.

BY

Franklin Leonard Pope.

(*Conclusion.*)

THE narrative of the active life and labors of Thomas Davenport in the field of electro-magnetism and its application as a motive power, has now been brought to a close. It only remains for me to sum up, so far as may be, what I conceive to be the true significance of his work as a part of the general history of the industrial application of electro-magnetism, and by way of preface, to say a few words regarding the personal characteristics of the man.

Although forty years have passed since Davenport was borne to his humble grave under the shadow of the stately elms of Brandon, there are still living many old residents, his former friends and neighbors, who well remember him, and who by common consent, speak of him as one who received, and who in the fullest measure deserved, the respect and esteem of the community in which he lived. However visionary his schemes may have appeared to many of his townsmen, there seems to have been but one opinion as to the high character and substantial worth of the man himself.

Thomas Davenport was pre-eminently a student, a thinker and an originator; a strikingly characteristic type of a class of minds to whom the world always has been, and always will be, indebted for its grandest mechanical conceptions. Modest and unassuming in his intercourse with his fellow men, reticent in speech, but cheerful and kindly in manner, and by no means lacking in that dry humor which seems almost inseparable from such a nature, he nevertheless possessed, beneath a peculiarly mild and gentle exterior, a determined and resolute perseverance but little removed from obstinacy, which poverty, adversity and disappointment were utterly powerless to overcome.

From the very moment when he first witnessed the exhibition of the mysterious power of Henry's electro-magnet, the conception of utilizing its invisible force for the propulsion of machinery took possession of his mind and thenceforth occupied it almost to the exclusion of every other consideration. He studied, he pondered, he experimented. Seeking from the beginning to produce continuous rotary motion, with the unerring instinct of the born inventor, in his very first essay he grasped what I have defined as the essential principle of the electric motor, the combination of moving and fixed electro-magnets, one reversible and the other non-reversible; and however extensively and widely he may subsequently have experimented in other directions, he never once loosed his grasp of this fundamental conception.

It may be asked whether it is certain that this conception is due to Davenport alone. It is true that in an absolute sense, this question at this late day can only be answered by the light of internal evidence. Every one who has much intercourse with inventors must have observed that when two minds have wrought upon a mechanical problem until success has crowned their efforts, it is ordinarily quite impossible even for the parties immediately concerned to dissever and distinguish their respective contributions to the general result. Yet the experienced observer, familiar with the mental characteristics of the varying types of the creative mind, usually finds little difficulty in reaching a conclusion which is at least satisfactory to himself. He only needs to know the two men to know in what manner and by what mental processes the ultimate result must have been reached.

From the moment that Davenport declared, in the presence of the little assemblage at Crown Point, his intention of producing rotary motion by means of electro-magnetism, it is certain that he never for one moment permitted himself to doubt that he would ultimately accomplish that result. He was fortunate in having a coadjutor like Smalley, young, enthusiastic, a natural mechanic and a willing worker; and it is altogether probable that to the latter is largely due the embodied form and structure of the machine, particularly the contrivance of the mechanism employed for effecting the reversal of the current which is shown in the sketch accompanying the specification of 1835. It is not unlikely that the design of the first metallic commutator may also have been due to him; but the fact remains, that the master mind, wholly absorbed in the subject, and possessing the determination and the capacity to succeed in spite of every obstacle was that of Davenport. Had Smalley not been at hand to assist him, some other person would have been found. Had it been necessary for him to carry on his work alone, he would have done it. When a mind possessing the indomitable perseverance of that of Davenport, is once in possession of an original idea—the conception of something to be done—its ultimate accomplishment, whether with or without the assistance of others, is as certain as fate. It is the story of every great invention; poverty, ridicule, discouragement, may defer, but are powerless to prevent, the development of an idea.

In the argument before the Supreme Court of the United States in the Telephone case, the learned counsel for the complainant remarked:—

> It is of common experience that the maker of a great invention which originates a new art, seldom has the technical skill and turn of mind which produces the best apparatus. . . . It is an interesting fact that the particular forms Watt thought of when he took out his patent, were practically so ineffective that it required ten years' unremitting work of himself and Boulton, the best machinist in England, before an engine was produced which was commercially satisfactory. But since he took his patent, no engine has ever been constructed which condensed the steam in the working cylinder.

Many instances might be cited as evidence as the truth of this statement. Not only Watt, but Fulton, Morse, Bessemer, Bell, and to mention a very recent instance, Rogers, the inventor of the wonderful typograph machine, were men of only ordinary mechanical skill, and were almost wholly indebted to others for devising and working out the mechanical contrivances in which their conceptions were embodied, and by which only their work could be rendered useful to mankind. Yet this fact does not in the least detract from their individual merit as inventors of the highest type, and as benefactors of the human race. I have seldom seen this idea more forcibly expressed than in a decision of Judge Kane, rendered many years ago in an important patent case, in which he said;

All machines may be regarded as merely devices, by the instrumentality of which the laws of nature are made applicable and operative to the production of a particular result. He who first discovers that a law of nature can be so applied, and having devised machinery to make it operative, introduces it in a practical form to the knowledge of his fellow men, is a discoverer and inventor of the highest grade—not merely of the mechanism, the combination of iron, brass and wood, in the form of levers, screws and pulleys, but the force which operates through the mechanical medium—the principle—or to use the synonym given for this term in the act of 1793, the *character* of the machine, ... the essential principle which his machine was the first to embody, to exemplify, to illustrate, to make operative, and to announce to mankind.

I have expressed the opinion that the combination of the moving and fixed electro-magnets, one reversible and the other non-reversible, must be regarded, in the light of our present knowledge, as the essential principle of the electric motor. The experience of the past few years has demonstrated beyond question, that the largest motors yet made, show as high, if not a higher, net efficiency than the smaller sizes, and in fact it has not as yet been found practicable to construct an efficient motor of any considerable power upon any other principle. A moment's reflection serves to show the impracticability of organizing a large motor, either with permanent magnets as in Sturgeon's plan, or with non-reversible electro-magnets and neutral armatures as in Edmondson's plan, while on the other hand, by employing the principle introduced by Davenport in his pioneer machine of 1834, no apparent limit to the dimensions or power of the motors which it is possible to construct has yet become manifest.

In our own time, when the doctrine of the conservation of energy is so inseparably interwoven with every conception of the mechanical and chemical interactions of the natural forces, it is wellnigh impossible for us to realize that in Davenport's day, this fundamental law was wholly unknown, or at most had been only dimly perceived by one or two of the most profound philosophers of the day. Davenport himself lived and died in the full conviction that the day which should witness the triumph of electro-magnetism over steam was close at hand. There is much reason to hope that ere many years have passed, his cherished belief and expectation will prove to have been not wholly without foundation. Undoubtedly he also believed that voltaic energy was in like manner destined to take the place of coal energy. In his time science had not sufficiently advanced to enable the latent fallacy of this idea to be detected and demonstrated. It is not to have been expected that a humble village artisan, knowing literally nothing of science beyond that which his own discoveries had taught him,[1] should have mistrusted the existence of a law of equivalence between the forces of nature, which was as yet undiscovered and even unsuspected by the most learned philosophers of the day. The following extracts, selected at random from many which might be cited, give ample evidence of the views which generally prevailed among scientific men in relation to this subject, prior to the year 1840. In his treatise on the steam engine, then recently published, and considered a work of high authority, Dr. Lardner had said :—

Philosophy already directs her finger at sources of inexhaustible power in the phenomena of electricity and magnetism, and many causes to combine to justify the expectation that we are on the eve of mechanical discoveries still greater than any which have yet appeared ; and that the steam-engine itself, with the gigantic powers conferred upon it by the immortal Watt, will dwindle into insignificance in comparison with the hidden powers of nature still to be revealed, and that the day will come when that machine, which is now extending the blessing of civilization to the most remote skirts of the globe, will cease to have existence except in the page of history.

At the meeting of the British Association in 1840, Prof. Jacobi presented to that body a very carefully prepared paper "On the Principles of Electro-Magnetical Machines," in the concluding portion of which he said :—

I consider that there will not be much difficulty in determining with sufficient precision the duty of one pound of zinc, by its transformation into the sulphate, in the same manner that in the steam engine, the duty of one bushel of coal serves as a measure to estimate the effect of different combinations. The future use and application of electro-magnetic machines appears to me quite certain, especially as the mere trials and vague ideas which have hitherto prevailed in the construction of these machines have now at length yielded to the precise and definite laws which are conformable to the general laws which nature is accustomed to observe with strictness, whenever the question of effects and their causes arises.[2]

The eminent English philosopher, James P. Joule, of Manchester, in a communication containing an account of some of his quantitative experiments and investigations in electro-magnetism, expressed himself as follows :—

I can scarcely doubt that electro-magnetism will eventually be substituted for steam in propelling machinery. If the power of the engine is in proportion to the attractive force of its magnets, and if the attractive force is as the squares of the electric force, the economic effect will be in the direct ratio of the quantity of electricity, and the cost of working the engine may be reduced *ad infinitum*. It is to be determined, however, how far the effects of magnetic electricity may disappoint these expectations.[3]

So late as 1851, Professor Page, in discussing the question of the relative cost of steam and electric power, as affected by the then recent investigations of Joule, remarked :—

We have no proof of any such relation of electricity to heat as to make the mechanical power of one the measure of the mechanical power of the other. Whatever may be the connection and analogy between heat and electricity, we must consider them as distinct forces in their mechanical relations.[4]

The subsequent researches of Grove, Mayer, Liebig, and more particularly of Joule himself, ultimately established the law of the equivalence of forces upon the firm and enduring foundation of experimental demonstration, and confirmed the opinion long before expressed by Henry, that the endeavor to find in voltaic electricity a substitute or a rival to coal-power, must, from the nature of things, be an utterly hopeless one.

The publications made by Professor Page at various dates between 1837 and 1855, and the interesting correspondence between Page and Davenport which has already been given, show that the conceptions of the two men, both in respect to the most desirable principle of construction of the electro-magnetic motor, and as to the possible limits of its power, were widely at variance ; but time, which proves all things, has shown conclusively, that of the two, the views of Davenport were the more correct. The opinions of Page are indicated in the extracts which follow, taken from articles written by him at various times :

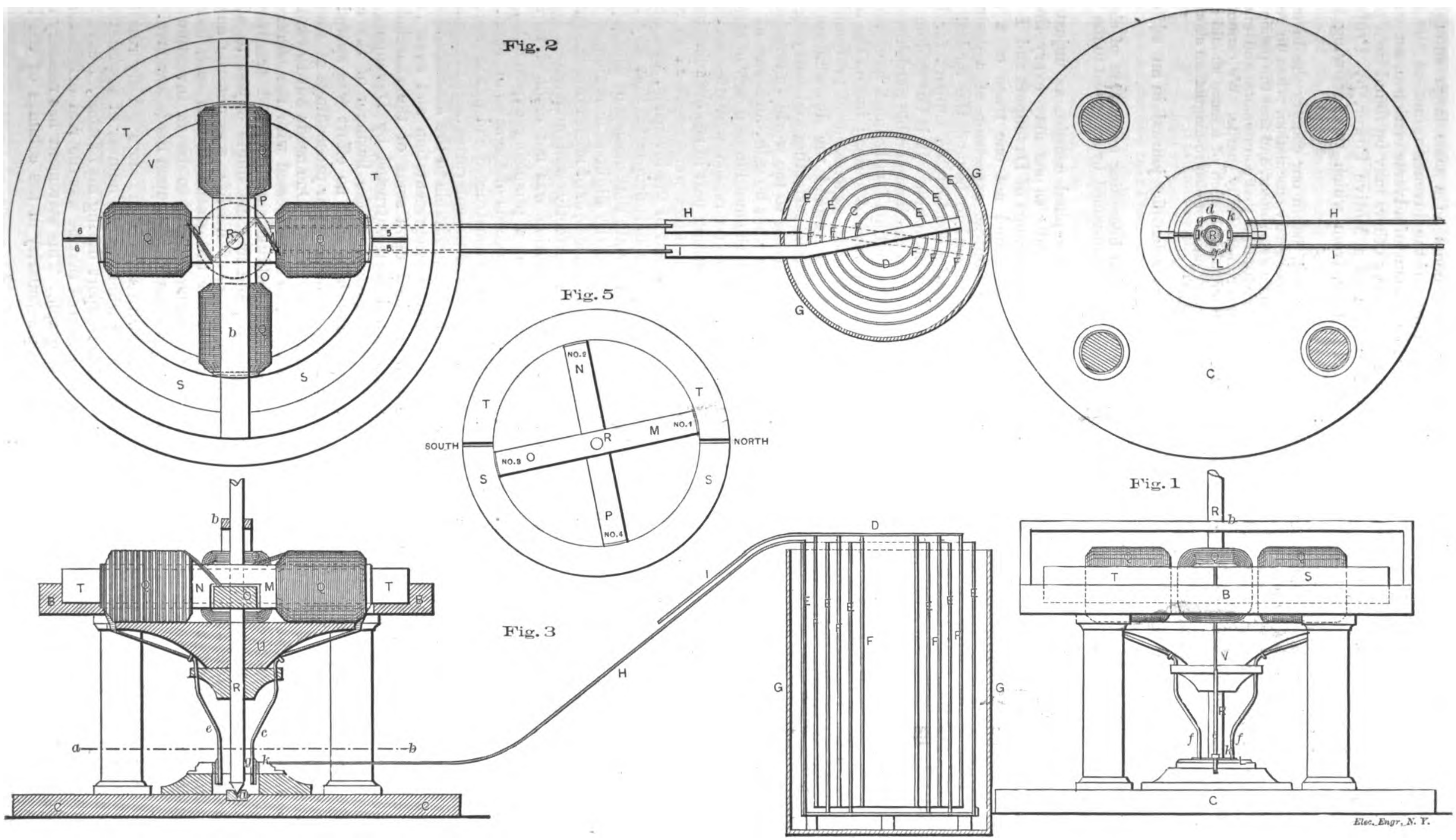
Since the announcement of Mr. Davenport's invention, the innumerable experiments which have been performed in this country, in England, on the continent of Europe, and even in the East Indies, have all contributed to prove that the smallest engines which have been made, have had by far the greatest proportionate power. Since I first gave the subject any attention, I have had sixteen different models constructed, each involving distinct principles. From all these experiments the inference is still the same, viz., the fewer the magnets and the smaller their size (within certain limits), the greater the ratio of mechanical power obtained.[5]

Practically we have already been taught, that (unlike other powers, where the largest engines are the most simple and least expensive) electro-magnetic engines, above a certain limit, increase in complication and expense and in a much greater ratio than the power obtained. *To ascertain this limit, the precise point where economy ceases, is now the great, and ought to be the only, object of research.*[6]

I must premise here (as I have heretofore expressed myself) that I *do not suppose this power capable of indefinite increase*, and in giving this description to the public, I am only selecting from the multitude of machines I have constructed, such forms as obviously economize a given galvanic power. A number of ma-

1. "This he effected in a country village, unaided by scientific knowledge, by books, or by the encouragement of men of superior attainments, or with kindred spirits. Whatever may be the result of his labors, his merits are of a high order, and he has proved himself well worthy of the most splendid success. Should his machine finally accomplish that which he and many of his friends anticipate, its value will be incalculable." THOMAS P. JONES: *Journal of Franklin Institute.* [2d ser.] xxiv, 342.

2. Sturgeon's *Annals of Electricity*, etc., vi, 159.
3. *Ibid*, iv, 135.
4. *Scientific American*, (1st series) vi, 315.
5. *Amer. Jour. Science*, xxxv, 106.
6. Ibid, xxxv, 108.



DRAWING ACCOMPANYING DAVENPORT'S BRITISH PATENT.

[Made to scale from actual Working Machine.]

Fig. 1, elevation.—Fig. 2, plan.—Fig. 3, vertical tranverse section.—Fig. 4, horizontal transverse section in plane of *a b.* of Fig. 3.—Fig. 5, plan of arrangement of magnets.

B platform; C base; D battery, consisting of concentric cylinders of copper E and zinc F, immersed in vessel G containing sulphate of copper solution; H I, positive and negative conductors; K L insulated commutator segments fixed upon vertical shaft R. M N O P cores of electro-magnets; Q Q Q Q helices of insulated copper wire; *a b* bearings of shaft R. *c d e f* commutator springs; V support for electro-magnet; S T semi-circular permanent steel magnets; 5 5 north poles and 6 6 south poles of permanent magnets.

chines wherein *the poles of the magnets were changed*, and others wherein the poles of the magnets were not changed, but both systems, the stationary and the revolving, were rendered magnetic and non-magnetic at intervals, *have been laid aside as not worth describing.*[7]

So also in his letter to Davenport of April 28, 1838, he says :—

I feel very sure the power will be useful to the extent I have above named (a power equivalent to one or two men), but for reasons which I can make conclusive to any on e, *I do not believe in its indefinite increase.*[8]

The subsequent comment of Davenport upon this opinion, is a peculiarly significant one. In his letter to Page of October, 1850, he says :—

Since I first saw the power of the electro-magnet exhibited, any idea that the power could not be indefinitely increased, seemed to affect me with a peculiar disagreeableness.

So also in his letter to Smith in 1839, he had said:—

I have no doubt but that *the power is unlimited*, which can, and ultimately will, be successfully applied to all purposes for which steam power is now used.[9]

This difference of opinion was radical, and it extended to the details of the method of applying the electro-magnetic power. In his letter of April 28, 1838, Page says: "My main object has been to prevent retardation or back action. My plan is to cut off the galvanic current from both systems of magnets instead of changing poles as they arrive at equilibrium. The advantage of this I have fully tested."[8]

In an article written a year later, he remarks :—

Change of poles cannot be introduced in a machine, for the following reasons :—1. It requires time; and during this time, the magnets which change poles are attracted and retained (retarded?) somewhat by those which do not change. 2. Similar poles will attract and produce back action ; for unless the magnets which change poles be favored by excess of battery or superior conductors, they cannot receive near the same charge as those which do not change : for first, there is magnetism of an opposite character to be overcome ; and secondly, two breaks in the galvanic circuit are necessary to produce change of poles. 3. Two magnets which have a statical repelling power, that is, a power which will merely keep them asunder when the machine is at rest, will attract each other when the machine is in motion. This singular fact is a consequence of secondary currents.[10]

So far as I have been able to ascertain, the views of Professor Page in this particular, remained unchanged throughout the whole course of his subsequent experimental labors. In every attempt made by him to produce electro-magnetic power on anything like a large scale, as, for example, in his locomotive, and in the other experiments made under the Congressional appropriation, he appears to have consistently adhered to the theory that the best results were to be attained by simply cutting off the current from the magnets, without reversing polarity. Davenport, on the other hand, with equal persistency, adhered to the plan of reversing the polarity of one set of magnets twice in each revolution, and out of the very large number of machines constructed at different times by him or under his direction, the only instance I can find in which this principle was departed from, is in the case of the two or three helix machines which were built in New York between 1838 and 1840.[10a] The results of modern research and experience, have abundantly verified the correctness of Davenport's ideas, and have shown that the "peculiar disagreeableness" with which the notion of an assignable limit to the power of electro-magnetism affected him, was but a prophetic manifestation of the instinct and inspiration of the true inventor.

The course of Davenport and Cook in transferring their invention to an incorporated company, for the avowed purpose of raising money by the sale of shares to reimburse them for their expenditures, and to provide means for conducting further experiments on a scale large enough to demonstrate the utility of the invention, met at the time with a considerable amount of adverse criticism, an example of which among many others may be found in a paper on Electro-Magnetism as a Motive Power, by Professor Page, published in 1839, from which the following is an extract :

It is much to be regretted, that in our country the invention should be a subject of mercenary speculation, when in reality it has no value except as an experiment, and that the public have been so far misled, as to withdraw that countenance and encouragement which the experiment really merits. We cannot but deplore, that such an interesting branch of science should be so traduced, and that the very name of electro-magnetism should be coupled with empiricism.[11]

So also, a prominent scientific journal in an editorial paragraph, observed:—

We rather regret that this interesting application of electro-magnetism is attempted to be sustained by an appeal to the hope of immediate profit.[12]

I cannot but regard this implied censure as unjust and unmerited. Examine critically as one may every line of the correspondence and writings of Davenport and I venture to say there can be found not one trace of a self-seeking spirit, not the faintest expression of a desire to make money from his invention, beyond the modest and reasonable expectation of a comfortable support for himself and those dependent upon him. It is but seldom that he refers, even casually, to the innumerable hardships and inconveniences which he and his family must have not infrequently suffered from want of means ; but on the other hand, we find more than once, expressions of profound regret at being unable to command the financial support which was essential to him in perfecting and carrying out his self-imposed task of giving to the world an economical and efficient substitute for what he calls, and was at that time justified in calling, "the murderous power of steam." For my own part, I can see no reason why the action of Davenport and Cook, in taking part in the organization of a stock-company whose earnings were expected to come from the future development of the invention, was not in every respect as legitimate and proper at that day as it would be at this. It is certain that neither of the principals could have entertained the slightest intention of misrepresenting the circumstances, or of misleading the public. It appears to have been perfectly well understood by all concerned, that the invention was not claimed to have passed beyond the stage of a promising experiment, but nevertheless, that if the proceeds of the sales of stock enabled a large engine to be constructed and put in successful operation, the future of the enterprise might reasonably be expected to be highly profitable to the shareholders. It is not impossible that misrepresentation and even fraud may have been practiced upon some of the shareholders by the agent who had been entrusted by Davenport and Cook with the management of the business of the company, but the records show that no effort was spared by them to put a stop to his irregular proceedings as soon as they became aware of them. One needs but to read the letters of Davenport, to be impressed with the conviction that he was a man of childlike simplicity and transparent integrity of purpose, and that the single object to which he devoted every energy of his life, was not the accumulation of money nor the gratification of self, but the development of what he believed to be an invention destined to confer priceless benefits upon his fellow men.

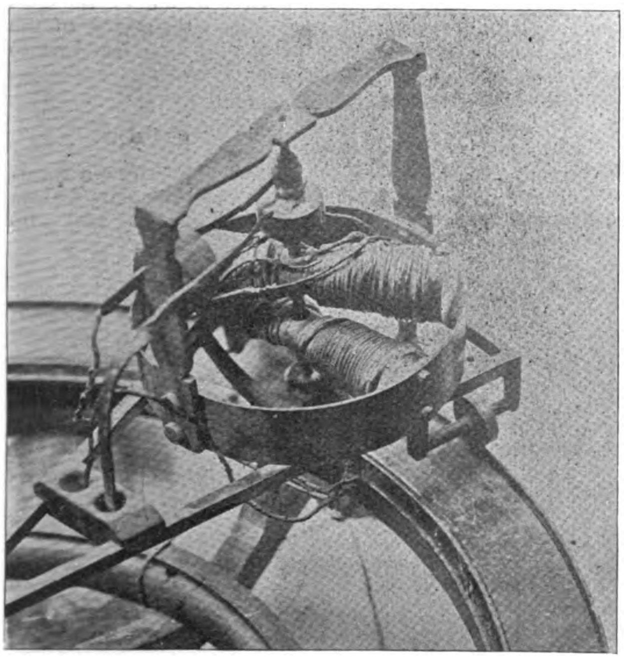
In conversation with some of the more elderly residents of Brandon, among whom were a number of acquaintances and friends of Davenport during his lifetime, I have been more than once assured that he was the real originator of the electric telegraph. This statement has recently been made with some particularity in the columns of the local press :

7. *Amer. Jour. Science*, xxxvi., 350 (1839).
8. *Ante*, p. 71.
9. *Ante*, p. 94.
10. *Amer. Jour. Science*, xxxv, 109 (1839).
10a. It does not appear that Davenport ever took out a patent in this country on the helix machine. It was, however, patented in Great Britain, as a communication from abroad, on July 11, 1838, by Lewis C. Callet.

11. *Amer. Jour. Science*, xxxv., 107.
12. *Ibid.*, xxxiii, 194.

[*From the Brandon (Vt.) Union, December* 19, 1890.]

There are but very few outside this immediate vicinity that are aware of the fact that the first telegraph line in the world for transmitting signals over a wire by electricity was erected in Brandon, and by a Brandon man. Yet such was the case, and this town has the honor of being the first spot where this mighty invention of modern times was put to practical use. . . . Mr. Davenport, then living in Brandon, in connection with Mr. Smalley, now living at Forestdale, experimented considerable in electric appliances. Long before Prof. Morse had projected anything of the kind, these gentlemen had a wire that connected their two residences, on which were transmitted dispatches by means of electricity, using a battery, and which gave by machinery the sound as now heard from machines in ordinary use. After this wire had been in operation for some length of time, Mr. Davenport moved to New York and began the publishing of the *Electro-Magnet*, being printed by a machine propelled by electro-magnetic force, as the paper claims upon its title-page. While in New York we are informed that Prof. Morse called upon Mr. Davenport, and was struck with his discovery, and then began to make improvements thereon, inventing the Morse alphabet. He then applied it to Mr. Davenport's discovery which has proven to be such a magnificent success. To Prof. Morse belongs a great deal of honor for bringing before the public the wonderful merits and advantages of telegraphy, but the discovery and origin of this great invention justly belongs to Thomas Davenport of Brandon.



WORKING MODEL OF DAVENPORT'S ELECTRIC LOCOMOTIVE.

[*Photograph from the Original in the Cabinet of the Troy Female Seminary. Supposed to have been constructed circa 1837.*]

No claim of this kind is asserted or even remotely hinted at in any of the letters or papers of Davenport which I have examined. On the other hand, in response to a specific inquiry as to the telegraph line which Davenport and himself are reputed to have constructed and used, Mr. Smalley has stated that in the course of their experiments in 1834, they discovered that physical effects could be produced by the electro-magnet through a considerable length of wire, and that any length at their command seemed to make no difference in the *time* required to effect the result, but that no attempt was made by them to transmit intelligible signals, or to construct apparatus for that purpose. The fact first mentioned by Mr. Smalley, was, however, well known at the date mentioned (1834), having been fully demonstrated in the experiments made by Henry in Albany in 1830–31.

The source of this telegraphic legend may undoubtedly be traced to a conviction which Davenport is known to have entertained, and honestly so, that Morse's telegraphic apparatus was an infringement upon his own patent of 1837. In a letter written from Brandon, under date of April 18, 1846, to Dr. Thomas P. Jones, of Washington, he writes :—

> I learn from Mr. ——— who has recently been in Washington, that it is your opinion that Prof. Morse's application of electro-magnetism to propelling his machinery for the telegraph is an infringement on my patent. I have long thought so myself, but not knowing how to proceed in consequence of my poverty-stricken situation, I have taken no steps in the case. . . . As the claim granted me is for "applying magnetic and electro-magnetic power as a moving principle for machinery," it is as clear as the solar light that Morse must be using what of right belongs to me.

In explanation of this erroneous opinion on the part of Davenport, it must be borne in mind that at the date when the above letter was written, the history and chronology of the invention of the telegraph had never been made public; it was first brought out in the course of the exhaustive legal investigations consequent upon the interference proceedings between Morse and Bain, and the suits against O'Reilly and others by the Morse patentees at a still later date. The very earliest published notice of Morse's invention appeared in the New York *Journal of Commerce;* a communication over Morse's own signature, accompanied by a sample of the writing of the apparatus then used, which was dated September 4, 1837. As this was some two or three months after his visit to Davenport's laboratory, the latter, by a very natural process of reasoning, assumed that Morse had merely applied his (Davenport's) idea to the movement of another kind of machinery for a different purpose. But at a later date it was established, upon evidence which cannot be gainsaid, that Morse had actually constructed and operated his electro-magnetic recording apparatus in a short circuit in his rooms in the New York University building, as early as November, 1835, more than a year before Davenport and Cook came to New York with their machinery for exhibition.[13]

It is not improbable that Morse was indebted to Davenport for a more effective construction of the electro-magnet than he had hitherto employed, but even granting this, the electro-magnet was a feature which Davenport himself had borrowed from Henry, and which formed no part, *per se*, of his own discoveries.

The patent of Davenport was granted February 25, 1837, under the title of "An Application of Electro-Magnetism to Propelling Machinery." The claiming clause of this patent has been criticised by unfavorable implication, as "a remarkable instance of the granting of a broad claim by the Patent Office to an inventor." It may not be out of place to consider for a moment whether such a criticism is well-founded. The statement is in the following words :

> The discovery here claimed and desired to be secured by Letters Patent, consists in applying magnetic and electro-magnetic power, as a moving principle for machinery, *in the manner above described*, or in any other substantially the same in principle.

Within a few months after the issue of the patent, Davenport, referring to his invention, wrote :

> No departure from the principle of the orginal invention has been or can be made. That principle was *the production of rotary motion by repeated changes of magnetic poles;* this it is which is secured by patent; and no peculiarity of arrangement or modification of the magnets can be made to move without adopting the essence of the first invention.

This assertion, although in a strictly literal sense inaccurate,[14] is nevertheless substantially true, inasmuch as every practical motor in use at the present day involves the prin-

13. In the case of Morse *v.* O'Reilly in the United States Supreme Court, the following witnesses testified to having seen the operation of Morse's electro-magnetic recording telegraph in his rooms in the New York University in 1835 and 1836: Leonard D. Gale, Daniel Huntington, Osbert B. Loomis, and Robert Rankin.

14. Neither the prior machine of Edmondson already described (ante, p. 1) nor the helix and core machines, subsequently constructed by Davenport himself and by Prof. Page, make use of the principle of "repeated change of poles." But none of these types of machines have achieved permanent industrial success, in comparison with the pole-changing type, for reasons which are now well understood.

ciple of the "production of rotary motion by repeated changes of magnetic poles." If, therefore, we read into the claim of the patent the mode of operation original with Davenport, viz., the combination of reversible and non-reversible "galvanic magnets" which is described in the specification, as being the organization referred to in the words "in the manner above described," we find that its manner is not only not unwarrantably broad, but that it defines with accuracy and clearness the precise invention which Davenport made ; no more ; no less.

Justice Curtis, in his decision in a leading patent case before the Supreme Court of the United States, has remarked :

> It is this *new mode of operation* which gives it the character of an invention and entitles the inventor to a patent ; and this new mode of operation is, in view of the patent law, the thing entitled to protection. . . . . . . Specifications are to be construed liberally, in accordance with the Constitution and the patent laws of the United States, to promote the progress of the useful arts, and allow inventors to retain to their own use, not anything which is a matter of common right, but what they themselves have created.[15]

"In that case," says James J. Storrow, confessedly one of the most learned and able advocates of our own day, "the maturest judgment of the Court was announced by a jurist whose peculiar faculty it was to perceive both the groundwork of a legal rule, its limits, and the limits of its application, and to formulate the whole in language which defined as well as stated." And in a more recent case decided in the same court the venerable Justice Bradley has remarked :

> The whole subject-matter of a patent is an embodied conception, outside of the patent itself, which to the mind of those expert in the art, stands out in clear and distinct relief, whilst it is often unperceived, or but dimly perceived, by the uninitiated. *This outward embodiment of the terms contained in the patent is the thing invented*, and is to be properly sought, like the explanation of all latent ambiguities arising from the description of external things, by evidence *in pais*.[16]

If, therefore, we interpret the claim of Davenport's patent, not only in its relation to the state of the art at the date of its invention, but in the light of the well-considered utterances of the highest tribunal of the land, and compare it thus understood with the definition of the fundamental principle of the modern electric motor which was formulated at the beginning of this series of papers, we shall find that they are substantially identical. The conclusion necessarily follows, that the invention thus identified was conceived and embodied in concrete operative form by Thomas Davenport at least as early as July, 1834, was exhibited and described to others prior to January 5, 1835, and was covered by his Letters Patent of February 25, 1837. If, therefore, this patent, which expired in February 1851, were in force to-day, it is not too much to say, that upon a fair judicial construction of its claim, every successful electric motor now running would be embraced within its scope.

Thomas Davenport was born in Williamstown, Orange County, Vermont, on July 9, 1802. He was descended from the family of the same name prominent in the early annals of the New Haven colony, and was the eighth in a family of eleven children of Daniel and Hannah (Rice) Davenport. His father, who was a farmer, died when he was but ten years of age, leaving the family in indigent circumstances. At the age of 14 he was apprenticed to Samuel Abbott, of Williamstown, with whom he learned the blacksmith's trade. Upon the expiration of his apprenticeship, about 1823, he removed to Brandon, Vt., where he set up business for himself. He married, February 14, 1827, Emily, daughter of Capt. Rufus and Anna Goss, of Brandon, born March 29, 1810. The mother of Rufus Goss was a daughter of the celebrated American traveler, Jonathan Carver. Davenport was prosperous in his business, and shortly after his marriage, built a commodious brick house in Brandon village, and was in a fair way to accumulate a comfortable property, when his attention was directed by the circumstances already related, to the study of electro-magnetism. From that time forward, the history of his labors and the history of the man are inseparable.

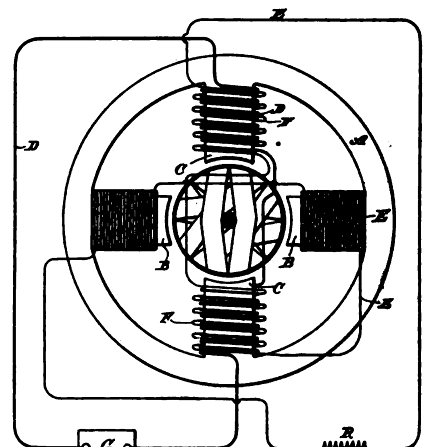
Two sons were born to Davenport, both of whom subsequently enlisted and became officers in the war of the rebellion. The elder, George D., a captain in the 5th Vermont Regiment, fell in the battle of the Wilderness ; and the younger, Willard G., who is still living, became a clergyman in the Protestant Episcopal Church. The story of the active life of the inventor has been fully told in connection with the history of his work. He died on a small farm in Salisbury, Vt., July 6, 1851, at the comparatively early age of 49, and was buried in Brandon. The immediate cause of his death appears to have been a species of nervous prostration, superinduced by excessive study ; and no doubt aggravated by the effects of so many years of toil, privation and disappointment.

If the publication of these papers shall in any measure serve to render tardy justice to the memory of one of the most meritorious of inventors, as well as one of the most amiable and deserving of men, then the story of the "Brandon blacksmith," the writing of which has been to me a labor of love, will not have been in vain.

15. Winans *v.* Denmead, 15 Howard, 330 (1853).
16. Bischoff *v.* Wethered, 9 Wallace, 812 (1869).

NEW TESLA ALTERNATING MOTOR.

We have already described a number of different forms of alternating current motors designed by Mr. Nikola Tesla, depending upon a variety of phenomena met with



Tesla Alternating Motor.

in the employment of alternating currents. One general type of these consists of a machine with, say, four poles, between which is mounted an armature, generally wound with closed coils. On two opposite poles of the field are primary coils connected up in the main circuit. On the same cores are also wound secondary coils which are closed through coils on the other pair of poles. When an alternating current is caused to pass through the primary coils, it energizes directly one set of poles, and induces currents in the secondary coils, which in turn energize the other poles ; but the phases of the current in the secondary coils may differ in time from those of the primary current, and hence a shifting of the poles is effected, that imparts a rotation to the motor.

In the new motor designed by Mr. Tesla, however, two energizing circuits are brought into inductive relation in the motor itself, and the employment of an external in-