Origin of the Electric Motor

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Had it not been for the efforts of men like Davenport, De Jacobi, and Page, the benefits of the electric motor would not be enjoyed today. It is the purpose of this article to trace briefly the early history of the science of electromotion and, in particular, to bring to light and to honor the inventor of the electric motor.

THE DAY that man molded the first wheel from the sledlike skids of his primitive wagon should be one of great commemoration, had not its identity been lost in the passing of time. Not unlike the wheel and probably second only to the wheel, the electric motor has been a great benefactor to man and its history, too, slowly is being forgotten.

Today, we hear very little, if anything, about Thomas Davenport, the blacksmith who invented the electric motor; or about De Jacobi, who propelled the first boat by means of an electric motor; or of Charles Page who successfully carried passengers on the first practical electric railway. Had it not been for the efforts of these men and others like them, the benefits of the electric motor probably would not be enjoyed today. It is the purpose of this article, in general, to trace briefly the early history of the science of electromotion and, in particular, to bring to light and to honor the inventor of the electric motor.

EARLY HISTORY

The development and rapid growth of our electrical science and the electrical industry can be followed very easily through the growth of the basic principles. The basic principle governing the operation of the electric motor is, of course, that of the production of motion by the use of magnetic fields. Legend tells us that the first exercise of this knowledge probably is accredited to Hoang Ti, the mythical founder of the Chinese empire, who was the first to construct a magnetic compass in 2634 B.C. Factually, the citation delivered by Andre-Marie Ampere in 1820 A.D. of the nature of the electric current and its relation to magnetism was the classic truth that was necessary for the development of the practical motor. Not quite a year later, Michael Faraday, using this information, produced rotation of a wire carrying electric current, around a magnetic pole. But it was not either of these two illustrious men who deserve credit for the development of the practical electric motor. There were others, some talented, some not, some prophetic, some curious, who, through discouragements and failures, were directly responsible for giving us the modern electric motor. Briefly, these early achievements, up to the year 1850, may be listed as shown in the following.

1821—Michael Faraday demonstrated for the first time the possibility of motion by electromagnetic means with the movement of a magnetic needle in a field of force.

1829—Joseph Henry, a teacher of physics at the Albany Academy in New York, constructed an electromagnetic oscillating motor but considered it only a "philosophical toy."

1833—Joseph Saxton, an American inventor, exhibited a magneto-electric machine before the British Association for the Advancement of Science.

Figure 1. Thomas Davenport, inventor of the electric motor

Courtesy Smithsonian Institution

1837—Thomas Davenport, an American inventor, obtained the first patent on an electric motor.

1838—Solomon Stimpson, an American, built an electric motor having 12 poles and a segmental commutator.

1839—Moritz-Hermann De Jacobi, a Russian scientist, demonstrated the use of the electric motor to propel boats.

1840—Truman Cook, an American, built an electric motor having a permanent magnet armature.

1840—Robert Davidson, a Scot, built a lathe and a small locomotive powered by electric motors.

1845—M. Froment, a Frenchman, built an electric motor similar to a "breast wheel, whose paddles were acted upon by magnetism instead of water."

1847—Moses G. Farmer, an American, constructed and exhibited a 2-passenger car and locomotive driven by an electric motor.

1850—John Lillie, an American, constructed an electric motor having radially arranged permanent horseshoe magnets.

1850—Charles G. Page, an American, developed a solenoid-type electric motor.

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Although these accomplishments and the many others that took place in the years following 1850, helped considerably in the design of our present electric motor, the most outstanding efforts were those of Davenport, De Jacobi, and Page. These are significant because Davenport's machine was, without a doubt, the first practical electric motor; De Jacobi's apparatus demonstrated the first practical application; and the device of Page showed the possibilities of a different motor design.

THE DAVENPORT MOTOR

Thomas Davenport, the rightful inventor of the electric motor, spent a life that seems more fictional than factual. His rigid understanding of the motor's principles, his clear vision of the possibilities of such a device, and his driving persistence to establish a foundation for a discovery too early for its time, easily should qualify him as a member in the society of Ampere, Faraday, Morse, Bell, and other immortals of the electrical science. To understand the trials of this early American inventor, it would be unwise not to present at least a slight glimpse into his early life.

That Thomas Davenport came from true American stock, there can be no doubt. His ancestors came to Dorchester, Mass., prior to 1640, a short time after the landing of the Pilgrims. His grandfather was a soldier in the American Revolution and he had two brothers in the War of 1812.

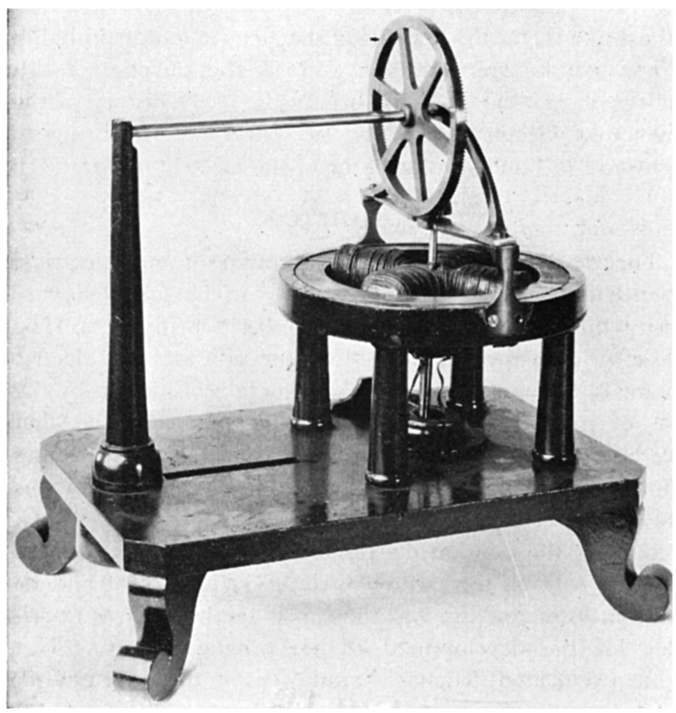
The inventor, one of 12 children, was born in Williamstown, Vt., on July 9, 1802, of poor, though patriotic and religious parents. His early boyhood consisted mainly of working the soil and tending the farm, but he did not neglect to obtain the little education that was available in those days. He took advantage of every possible moment in the classroom, even engaging in reading during the recess periods.

At 14 years of age, he became a blacksmith's apprentice. In this trade he was "bound out" for seven long years, with no compensation other than a knowledge of smithing and a 6-week term a year at school. Here again, he occupied his leisure time in reading books that he obtained from "auction" libraries.

At the end of his apprenticeship, though penniless, he started his own blacksmith's shop in the town of Brandon, Vt. He continued his trade for ten years until the year 1833 when his curiosity was aroused by a report that "a galvanic battery" which would "lift a common blacksmith's anvil" was on exhibition at Crown Point, N. Y. He instantly made the trip to Crown Point but was unable to view the device. Later reports informed him that this newly found wonder contained a horseshoe-shaped magnet. These accidental references of "anvil" and "horseshoe" had excited him so thoroughly, that he made plans for a second trip to Crown Point. Not having the funds with which to finance this second journey, he persuaded his brother Oliver, a "tin peddler," to take him in his peddler's cart.

Arriving at Crown Point, Davenport succeeded in viewing the "galvanic battery" which would "suspend an anvil between heaven and earth." It was an electromagnet invented a few years previously by Professor Joseph Henry of Princeton University. It consisted of a suspended horseshoe magnet about a foot long, wound with silk-insulated copper wire connected to a galvanic cell. It had been purchased by the proprietor of the Penfield Iron Works to separate the iron from the waste in the local low-grade ore. Davenport marvelled at the ability of this 3-pound magnet to raise an anvil weighing 150 pounds and, imagining that this power could be put to more useful work, asked its purchase price. The price was $75. Again brother Oliver was called upon. Reluctantly, Oliver traded his wares, his cart, and his horse for the necessary $75 plus a worthless nag, and the magnet was purchased.

Having brought the magnet home, Davenport discovered that he could make the magnet lose its power by disconnecting one of the wires to the battery and could restore it again by holding the severed ends together. This simple electrical fact immediately convinced him that the power bestowed upon the magnet was controllable. The starting and stopping of an electric current by the making and breaking of an electric circuit revealed a most important fact, the discovery of which, simple though it may seem today, well could be accredited to Davenport, for there is no record to show that anyone else, even Joseph Henry, had performed such an experiment.



Courtesy Smithsonian Institution

Figure 2. Patent Office model of the Davenport motor

Overwhelmed by curiosity, Davenport began to dismantle the magnet—but not without care; for he summoned his wife, Emily, to take exacting notes of its construction. From these notes, he constructed a larger magnet, using the silk from his wife's wedding dress as an insulator between the conductors. The home-made replica was a success. He built more and larger ones and predicted that "steamboats would be propelled by this power" and that "it would replace the murderous power of steam."

Davenport's next objective was to convert the linear motion of the electromagnet into rotational motion and thereby make the flow of energy continuous. After much experimentation, he finally obtained rotational motion early in 1834. He accomplished this by mounting a magnetized iron bar horizontally on a bearing and held the electromagnet in such a position that its repulsion set the iron bar in motion. Then, by breaking the circuit by hand at properly timed intervals, he found that the iron bar could be kept in continuous motion.

Later, he built a better and larger motor, about which Davenport writes in his own memoirs:

> In July 1834, I succeeded in moving a wheel about seven inches in diameter at the rate of about 30 revolutions a minute. It had four electromagnets, two of which were on 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 had before attracted, thus producing a constant revolution of the wheel.

How Davenport actually reversed the flow of current through the electromagnets, his memoirs fail to state, but it probably consisted of some sort of a cam mechanism that did not operate very satisfactorily. But the satisfactory operation of his creation was of lesser importance than his successful attempts to convince others of the possibilities of this newly found aid to man. He had more followers who believed that he was developing a perpetual motion machine rather than a form of magnetic power. As the power developed by this early motor was only about 1/50th of a horsepower, those who viewed it, called it "mosquito power" and could see no practical value for such a device. His strong desire to establish his electric motor resulted in a neglect of his trade, a loss of customers, and near financial ruin. He sought encouragement from his village pastor who rebuked him with the statement, "If this wonderful power was good for anything, it would have been in use long ago." But undaunted by these setbacks, he took his motor to Middlebury College, there to seek the advice of the possessors of higher learning.

Professors Turner and Fowler of the Middlebury faculty watched a demonstration of the motor, recognized its potentialities, and advised Davenport to apply for a patent immediately. Elated, Davenport returned home and set about developing a new mechanism for reversing the flow of current through the electromagnets. In April 1835 he constructed a reversing mechanism that consisted of insulated segments rubbed by elastic flattened wires connected to the rotating armature. It was the inception of the modern commutator and it greatly improved the operation of Davenport's early motor. So enthusiastic was the press with this improvement that the August 13, 1835, issue of the Troy *Daily Budget* praised the accomplishments of Davenport and predicted that his name "would follow that of Henry's to the ends of the earth."

UNITED STATES PATENT OFFICE.

THOS. DAVENPORT, OF BRANDON, VERMONT.

IMPROVEMENT IN PFOPELLING MACHINERY BY MAGNETISM AND ELECTRO-MAGNETISM.

Specification forming part of Letters Patent No. 132, dated February 2?, 1?37

To all whom it may concern:

Be it known that I, THOMAS DAVENPORT, of the town of Brandon, in the county of Rutland, State of Vermont, have made a discovery, being an Application of Magnetism and Electro-Magnetism to Propelling Machinery, which is described as follows, reference being had to the annexed drawings of the same, making part of this specification.

The machine for applying the power of magnetism and electro-magnetism is described as follows:

The frame A may be made of a circular or any other figure, divided into two or more platforms, B and C, upon which the apparatus rests, of a size and strength adapted for the purpose intended.

The galvanic battery D is constructed by placing plates of copper and zinc E and F, alternately of any figure, in a vessel of diluted acid, G. From each vessel are two conductors, H and I, one from the copper and one from the zinc, leading to and in contact with copper plates K and L placed upon the lower platform. These plates or conductors are made in the form of a segment of a circle corresponding in number with the artificial magnets hereinafter described, placed around the shaft detached from one another and from the shaft, having a conductor leading from the copper plate of the battery to one of said plates on the lower platform, and another conductor leading from the zinc plate of the battery to the next plate on said lower platform, and so on alternately (if there be more than two plates on said lower platform) around the circle

The galvanic magnets M N O P are constructed of arms or pieces of soft iron in the shape of a straight bar, horseshoe, or any other figure, wound with copper wire Q first insulated with silk between the coils. These arms project on lines from the center of a vertical shaft, R, turning on a pivot or point in the lower platform, said copper wires Q extending from the arms parallel, or nearly so, with the shaft, down to the copper plates K and L and in contact with them. The galvanic magnets are fixed on a horizontal wheel of wood, V, attached to the shaft.

The artificial magnets S T are made of steel and in the usual manner. They may be of any number and degree of strength and fixed on the upper platform, being segments of nearly the same circle as this platform; or, if galvanic magnets are used, (which may be done,) they may be made in the form of a crescent or horseshoe, with their poles pointing to the shaft. Having arranged these artificial magnets on the top of the upper circular platform, there will be a corresponding number of magnetic poles, the north marked 5 and the south pole 6. Now, we will suppose the machine to be in a quiescent state. The galvanic magnet No. 1 being opposite the north pole of the artificial magnets, the galvanic magnet No. 3 will, of course, be opposite the south pole No. 6, and the galvanic magnets Nos. 2 and 4 will be opposite each other, between the poles just mentioned. There being a corresponding number of copper plates or conductors placed below the artificial magnets around the shaft, but detached from it as well as from each other, with wires leading from the galvanic magnets to these plates and in contact with them, as before described, these wires will stand in the same position in relation to the copper plates that the galvanic magnets stand to the artificial magnets, but in contact with the plates.

Now, in order to put the machine in motion, the galvanic magnet No. 2, being changed by the galvanic current passing from the copper plate of the battery along the conductors and wires, becomes a north pole, while at the same time the magnet No. 4 is changed by the galvanic current passing from the zinc plate of the battery, and becomes a south pole. Of course the south pole of the artificial magnet No. 6 will attract the north pole of the galvanic magnet No. 2 and will move it a quarter of a circle. The south pole of the galvanic magnet No. 4, being at the same time attracted by the north pole No. 5, causes the said magnet No. 4 also to perform a quarter of a circle. The momentum of the galvanic arms will carry them past the centers of the poles Nos. 5 and 6, at which time the several wires from the galvanic magnets will have changed their positions in relation to the copper plates or conductors. For instance, the north pole No. 2 having now become a south pole by reason of its wire being brought in contact with the conductors of the zinc plate, and No. 4 having in like manner become a north pole, its wire having changed its position from the zinc plate to the copper plate, the poles of the galvanic magnets are, of course, now repelled by the poles

that before attracted them, and in this manner the operation is continued, producing a rotary motion in the shaft, which motion is conveyed to machinery for the purpose of propelling the same.

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.

THOMAS DAVENPORT

Witnesses:
W. W. AYRES,
CHAS. A. COOK

FACSIMILE OF THE ORIGINAL PATENT

Figure 3. Facsimile of Davenport's patent on the electric motor

With continued encouragement from Professor Turner of Middlebury College, Professor Amos Eaton of Rensselaer Institute, Professor Joseph Henry of Princeton University, Professor Silliman of Yale University, and Professor Alexander Bache of Pennsylvania University, Davenport finally prepared a patent model and papers and presented them to the Patent Office. But misfortune followed him to Washington too, for the Patent Office burned and his model together with the papers was destroyed. However, with the aid of Ransom Cook, a prosperous manufacturer, another model was built and the papers rewritten. A photograph of this model, now on display at the Smithsonian Institution in Washington, D. C., is shown in Figure 2. He filed his claim again on January 24, 1837, and only 30 days later, on February 25, 1837, received United States Patent number 132, a reproduction of which is shown in Figure 3. Here, without question, is evidence that Thomas

Davenport is the inventor of the electric motor, about which the New York *Herald*, on April 27, 1837, so pompously stated:

A Revolution in Philosophy—Dawn of a New Civilization . . . 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.

The electric motor was not the only "first" for Thomas Davenport, for he built a model of the first electric railway, and, on the first electrically-driven printing press, which he built in 1839, he printed his own publication, *The Electro-Magnet and Mechanics' Intelligencer*, the first American periodical on electricity. But, like the electric motor, they offered him no reward, and, in 1851, Thomas Davenport died penniless, with a broken heart, the patent on his electric motor having expired a few months prior to his death.

THE DE JACOBI MOTOR

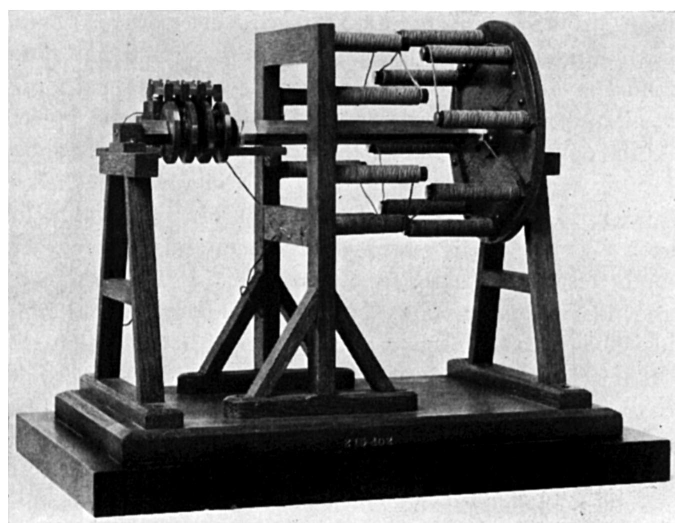
On December 1, 1834, a Russian scientist, Moritz-Hermann De Jacobi presented a paper before the Academy of Sciences in Paris in which he stated that he had obtained rotation by electromagnetic methods in May 1834. Since Davenport wrote in his memoirs that he first succeeded in producing motion electrically in July 1834, the question of actual priority in the point of time, is a close one. If the results obtained by De Jacobi in May 1834 were effected by the same apparatus that he described in his paper before the Academy in December 1834, then the priority must be conceded to him, but there is no proof available to show that such is the case. However, there is no doubt that the discoveries made by the two men were wholly independent.

In the year 1839, the Emperor Nicholas of Russia granted a sum of $12,000 to De Jacobi to enable him to prove that his electric motor had practical application. De Jacobi had a boat constructed, 28 feet long and 7 feet wide, which was propelled by means of paddles connected to an electric motor of his design. Figure 4 shows a model of the motor used on this craft. It consisted of two sets of electromagnets, eight in each set, one set being stationary and the other fastened to a rotatable wheel. Current from a bank of batteries was delivered to the rotating "star" through a commutator which reversed the polarity of the magnets eight times each revolution. The commutator used by De Jacobi appeared to be of better design than that used by Davenport and is very similar to the ones used today.

The De Jacobi boat, the first practical application of an electric motor, carried about 14 passengers and was powered by 320 Daniell cells, which is equivalent to about 100 of our present-day 6-volt storage batteries. In its trip up the Neva River it never achieved a speed greater than three miles an hour and consequently offered very little competition to man-propelled craft. The weight of the many batteries made the accomplishment impractical and it shortly was declared a failure. The cause of the failure was obvious, but the value of the electric motor as a new form of marine power was not forgotten.

THE PAGE MOTOR

Charles Grafton Page, a physician from Salem, Mass., performed many electromagnetic experiments during the middle of the 19th century, the accounts of which may be found in Silliman's *American Journal of Science and Art*, the outstanding science publication of that time. In 1841 he became one of the two principle examiners in the United States Patent Office, and from 1844 to 1849 held the chair of chemistry at Columbian College, now George Washington University. In 1846 he built a small reciprocating electromagnetic engine which operated in an entirely different manner from that of Davenport's and De Jacobi's machines and, though the principle was sound, it never gained much popularity. Its motion resembled very much that of a steam engine's piston and in appearance was quite similar. It consisted of a hollow electromagnetic coil and an iron bar which was free to move within the coil. Both the coil and the bar were held vertically so that the bar was in a position of rest outside the coil when the coil was de-energized. Once current was allowed to flow through the coil, the bar would be attracted upward. Then when the current in the coil was interrupted, the bar would fall downward. This vertical motion was transferred to a flywheel by means of a crankshaft. A commutating device, fastened to the crankshaft, automatically interrupted the flow of current to the coil at the proper time. In 1850, Page improved upon this single-acting motor by adding another solenoid which would pull the rod in the



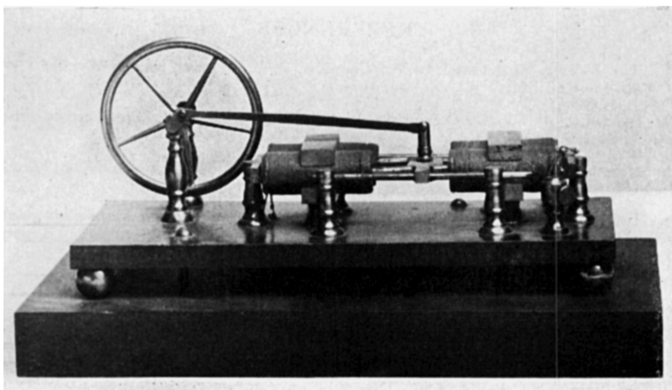
Courtesy Smithsonian Institution

Figure 4. The De Jacobi electric motor

other direction and thus not depend upon the force of gravity for assistance. This improved model, for which Page was issued United States Patent number 10,480 dated January 31, 1854, is shown in Figure 5.

Although Page's motor did not receive public acclamation, it is worthy to note, as in the case of De Jacobi, that he made an outstanding contribution in publicizing the feasibility of such a device. In 1851, the Congress voted $50,000 to allow Page to construct an electric locomotive. A very interesting account of this early experiment may be found in the first American textbook on electric motors entitled "The Electric Motor and Its Applications," by Thomas C. Martin and Joseph Wetzler. Portions of this account as found on page 20 of this book are given here.

Professor Page made a trial trip with his electromagnetic locomotive on Tuesday April 20, 1851, starting from Washington, along the tracks of the Washington and Baltimore Railroad. His locomotive was of 16 horsepower, employing 100 cells of Grove nitric acid battery, each having platinum plates 11 inches square. The progress of the locomotive was at first so slow that a boy was enabled to keep pace with it for several hundred feet. But the pace soon increased, and Bladensburg, a distance of about five miles and a quarter, was reached, it is said, in 39 minutes. When within two miles of that place, the locomotive began to run at a rate of 19 miles an hour, or seven miles faster than the greatest speed theretofore attained. This velocity was continued for a mile, when one of the cells cracked entirely open, and, as a consequence, the propelling power was partially weakened. Two of the other cells subsequently met with a similar disaster. It was found that the least jolt, such as caused by the end of a rail a little above the level, threw the batteries out of working order, and the result was a halt. This defect could not be overcome and Professor Page reluctantly abandoned his experiments in this special direction.



Courtesy Smithsonian Institution

Figure 5. The Page electric motor

Page knew of Davenport's accomplishments in the field of electromagnetism and much correspondence passed between the two in which the merits of their individual devices were discussed. There were two major points of disagreement between them which time has shown that Davenport held the sounder theory. Page consistently adhered to the theory that the best results would be attained by simply discontinuing the flow of current to the electromagnets, without reversing the polarity. Davenport strongly persisted that the reversal should be performed. On the other point of argument, Page claimed that the size of the electric motor was definitely limited, since his experiments showed that the smaller machines were more efficient. Davenport could not see any sound foundation for such a claim and stated that such an idea affected him with "peculiar disagreeableness."

CONCLUSIONS

The efforts of these early pioneers, although seemingly failures, laid the necessary foundation for the development of the modern electric motor. Their accomplishments proved disappointing not because the soundness of the electric motor as a means of converting energy was in doubt, but rather because the device was born too soon. Since most crafts and skills were performed satisfactorily by hand at that time, the need of such labor-saving devices for mass production was not in demand. Also, the expense of the batteries to drive these primitive motors made its use prohibitive. Around the year 1850, Robert Hunt, an English natural philosopher, analyzed the relative cost of power obtained from a steam engine and from an electric motor using a battery and found that the electric power was 25 times more expensive than steam power. It did not occur to these early experimenters that the reverse process of electromagnetism was possible—that of the d-c generator. It was not until 1860 that Antonio Pacinotti, an Italian scientist, showed conclusively that by reversing the operation of the electric motor, "motion would produce electricity." Even after that discovery, industry was slow to make use of this knowledge. It was not until 1886 that the electric motor found its place in the American home when the Curtis, Crocker, Wheeler Company began manufacturing battery-operated motors for sewing machines. It was not until 1887 that the City of New York decided to lay the first tracks for its famous "elevated." It was not until 1897 that the first electric automobile made its appearance. It was not until 1910 that the first electrically-driven washing machine was introduced to the American housewife. And it was not until 1915 that the *U.S.S. Mexico* the first electrically-propelled battleship, was launched.

Nevertheless, much credit should be given to those men who had the vision to foresee the marvels of their bundles of copper and steel. First to Thomas Davenport, the inventor of the electric motor; second, to Moritz-Hermann De Jacobi, who was the first to apply the electric motor practically to marine propulsion; and finally, to Charles Grafton Page, who was probably the first to apply the electric motor successfully to rail locomotion. Without a doubt, the most outstanding of these men is the Brandon blacksmith. In spite of the paucity of both his educational and financial advantages, he achieved a goal which others, far more fortunate than he, never had gained. His education could not have exceeded any more than three years of study based on today's standards and he was not gifted by any grant of money for the continuation of his experimental studies. Both De Jacobi and Page were learned men, fully equipped to battle the problems of their newly found science—electromotion. Moreover, their struggles were cushioned heavily by large governmental grants. It required supreme effort for a man, completely lacking such aids, to follow through to the time of his death an ambition that sprang from mere curiosity and resulted in one of man's most useful devices. It is hardly necessary to point out what fortunes would have been his had he renewed his patent rights and had he lived a few decades longer. The claims of his patent were extremely broad:

Applying magnetic and electromagnetic power as a moving principle for machinery in the manner above described, or in any other substantially the same in principle.

What with an estimated 50 million motors manufactured in the United States during the year 1947, a possessor of such a claim easily could mass a fortune far exceeding that of Rockefeller and Carnegie combined. But neither fame nor fortune was the lot of Thomas Davenport, a man who rightly deserved both.

In 1891 Franklin Leonard Pope, a charter member of the AIEE who became its president in 1884, wrote a series of five articles for *The Electrical Engineer* entitled: "Inventors of the Electric Motor." Although the title carried the word "inventor" in the plural, he proved conclusively that Thomas Davenport alone was the inventor of the electric motor. His evidence can be considered to be most trustworthy since he had opportunity to converse with living witnesses and examine original documents. On February 24, 1891, exactly 54 years, less a day, after Davenport had received his patent on the electric motor, Pope read a paper before a meeting of the AIEE in which he sought "to rescue from impending oblivion the true story of the invention of the electric motor." But now, more than 110 years since United States Patent number 132 was issued, the darkness of that oblivion seems to have engulfed the accomplishments of this early American inventor. It would seem fitting that, at this time, some lasting tribute be made to perpetuate the memory of Thomas Davenport. Throughout the history of our electrical science fitting honor has been bestowed upon such men as Alessandro Volta, Andre-Marie Ampere, Georg Simon Ohm, James Watt, Joseph Henry, Michael Faraday—such that their names are of common usage in the classroom and in industry. Would it not seem appropriate that Thomas Davenport be honored in a similar manner? Could not the unit of performance of rotating engines, the horsepower, which is used so much in connection with electric motors, be changed to "davens," in honor of the inventor? What procedure must be followed to effect such a change, I do not know, but an expression of our tribute to this almost forgotten American seems to be wanting, and the opportunity to change this archaic term may present the occasion to bestow this belated honor.

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New Shunt and Inductor Designs

The satisfactory measurement of surge currents presents peculiar difficulties because of the high values of impulse current obtained in millionths of a second, and because of the high-frequency components of the surge current. Important advances are being made in the design of shunts and mutual inductors for measuring magnitude and rate of change of surge currents by the National Bureau of Standards.

After a rather complete theoretical comparison of the various types of shunts which might fulfill necessary predetermined requirements, it was concluded that a shunt consisting of two coaxial tubes, with the potential-measuring circuit brought out as a coaxial cable from the smaller tube, would be most satisfactory. Advantages of the coaxial-tubular design include a more nearly constant impedance over a wide frequency range, minimum inductive pick-up for current-carrying parts of the surge generator, and freedom in location of ground connections at the surge generator. Two workable models already have been designed at the bureau.

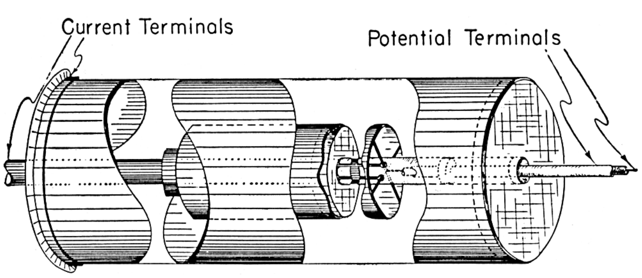

Figure 1. Cut-away drawing of the mutual inductor used in determining the rate of change of current with time during a high-current surge discharge. The innermost tube is the primary of the inductor, while the secondary consists of the shorter middle tube, the portion of the inner tube within the middle tube, and a ring connecting the two tubes. The large outermost tube provides a return lead for the primary current. Thus, the least possible inductance is added to the discharge circuit. The outer current return tube also serves as an electrostatic shield for the secondary circuit. The voltage induced in the secondary —a measure of the rate of change of current in the primary—is determined from the record of a cathode-ray oscillograph connected across the secondary by potential leads which form a coaxial cable at right

For other experiments involving high-current surges, the rate of change of current with time was obtained by use of a mutual inductor. The primary of the mutual inductor is connected in the heavy-current discharge circuit, and its secondary is connected to the oscilloscope. The voltage record obtained on the oscilloscope is then a function of the rate at which the current is changing and of the known mutual inductance of the inductor. To be suitable for this purpose a mutual inductor must have a low mutual inductance (about 0.05 microhenry) computable from its dimensions, and its effective inductance should be constant for frequencies up to 50 megacycles per second or higher.

As no previously known design of mutual inductor would fulfill these requirements, a coaxial-tubular mutual inductor was designed and a 0.05-microhenry inductor was constructed (see Figure 1). As in the case of the shunt, the coaxial-tubular construction tends to minimize inductive pick-up from any magnetic fields that may be present. It is expected that this type of inductor may prove useful in other applications requiring measurements at high frequency.