

THE ELECTRIC MOTOR AND ITS APPLICATIONS.

By Franklin Leonard Pope.



ON the morning of December 25, 1821, the young wife of an assistant in the laboratory of the Royal Institution of London, was called by her husband to share his delight at the success of an interesting experiment, the possibility of accomplishing which had occupied his thoughts for many weeks. What the young woman saw, upon entering the laboratory, was this: Upon a table stood a small vessel filled nearly to the brim with mercury; a copper wire was supported in a vertical position, so as to dip into the mercury, while a little bar-magnet floated in the liquid metal as a spar-buoy floats in a tideway, having been anchored by a bit of thread to the bottom of the vessel. The mass of mercury having been connected by a wire to one pole of a voltaic battery, the experimentalist had found that whenever the electric circuit was completed by touching the other battery conductor to the vertical wire, the floating bar would revolve around the latter as a centre. In this simple manner a continuous mechanical motion was, for the first time, produced by the action of an electric current.

The world is even now but just awakening to a conception of the magnificent possibilities of the humble gift which was slipped into its stocking on that Christmas morning by the since world-famous man, who not long before had jocosely described himself as "Michael Faraday, late book-binder's apprentice, now turned philosopher."

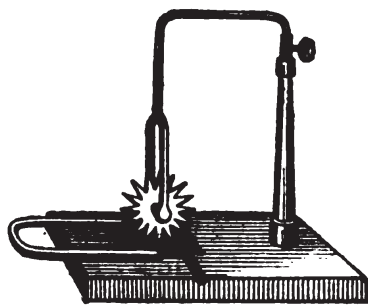
In the winter of 1819-20, the Danish philosopher Ørsted had observed that if an electric current was made to traverse a wire in proximity and parallel to a magnetic compass-needle, the needle was deflected, and instead of pointing to the north, tended to place itself at right angles to the wire. The consequences of this discovery, which

in truth was nothing less than that of the possibility of converting the energy of an electric current into mechanical power, proved to be far reaching and important. It was at once seized upon by the brilliant and fertile mind of the French academician Ampère, who by a series of masterly analyses, showed that all the observed phenomena were referable to the mutual attractions and repulsions of parallel electric currents, while his *confrère* Arago succeeded in permanently magnetizing a common sewing-needle by surrounding it with a helically coiled wire through which an electric current was made to pass.

These brilliant discoveries inaugurated an era of active research. Faraday, as we have seen, was successful in producing continuous mechanical motion. Barlow, of Woolwich, elaborating Faraday's discovery, made in 1826 his electric spur-wheel, a most ingenious philosophical toy, and, in point of fact, the first organized electric motor. In 1826 Sturgeon devised the electro-magnet. He bent a soft iron rod into a horseshoe form, coated it with varnish and wrapped it with a single helix of bare copper bell-wire. A current passed through the wire rendered the rod magnetic, and caused it to sustain by attraction a soft iron armature of nine pounds weight.

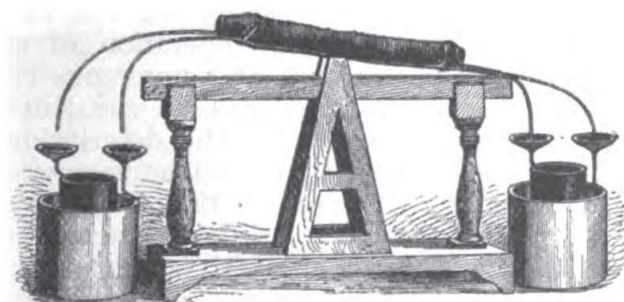
In this country, Professor Dana, of Yale, in his lectures on Natural Philosophy, exhibited Sturgeon's electro-magnet. Among his listeners was Morse, in whose mind was thus early planted the germ which ultimately developed into the electric telegraph. Professor Joseph Henry, then a teacher in the Albany Academy, starting with the feeble electro-magnet of Sturgeon, reconstructed and improved it, and then, by a series of brilliant original discoveries and experimental researches, developed it into an instrumentality of enormous mechanical power, capable of exhibiting a sustaining force of 2,300 pounds, which nevertheless vanished in the twinkling of an eye upon the breaking of the electric current.

With characteristic sagacity Henry at once foresaw the more important uses to which his improvements were applic-



Barlow's Spur-wheel Motor.

able. He constructed, in 1831, a telegraph in which strokes upon a bell were produced at a distance by the attractive force of the electro-magnet, embodying all the fundamental and necessary mechanism of the electric telegraph of to-day. He also devised and constructed the first electro-magnetic motor. In a letter to Professor Silliman, in 1831, he says: "I have lately succeeded in producing motion by a little machine which I believe has never before been applied in mechanics—by magnetic attraction and repulsion." It was a crude affair and served merely to illustrate the essential principle of such an apparatus. A vibrating or reciprocating electro-magnet was provided with an attachment for controlling the current of the battery by interrupting and reversing it at the proper time. This machine, which is of much historical interest, together with some



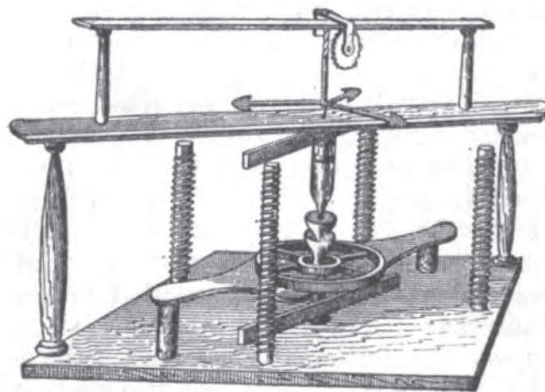
Professor Joseph Henry's Electro-magnetic Motor. (From a photograph of the original.)

of Henry's large electro-magnets, is preserved in the cabinet of Princeton College.

After having thus demonstrated the possibility of constructing an opera-

tive electro-magnetic engine, so far from giving way to the natural enthusiasm of the successful inventor, Henry proceeded, with the sobriety of judgment which was perhaps his most prominent characteristic, to forecast the future possibilities of the new motor. He was soon led to see that the power must be derived solely from the oxidation or combustion of zinc in the battery, and hence that the heat-energy required for the original deoxidation of the metal must represent at least an equal amount of power, the inevitable corollary of which was that the fuel required for this purpose might with much more economy be employed directly in performing the required work.

Although thus well assured that elec-



Sturgeon's Electro-magnetic Engine.

tro-magnetism could never hope to compete with, much less supersede steam as a prime motor, he predicted that the electric motor was destined to occupy an extensive field of usefulness, particularly in minor applications where economy of operation was subordinate to other considerations.

This fundamental, and as time has shown, prophetic conception of the legitimate field of the electric motor, failed to impress itself upon the minds of Henry's contemporaries. The problem of the application of electricity as a universal motive power was taken up

with great zeal by a host of sanguine inventors. In 1832, Sturgeon constructed a rotary electro-magnetic engine, of which we give an illustration above, a fac-simile of his own drawing, which he

exhibited before a large audience in London in the spring of 1833. In our own country, perhaps the earliest electric motor was the production of Thomas Davenport, an ingenious Vermont blacksmith, who, having seen a magnet used at the Crown Point mines in 1833 for extracting iron from pulverized ore, was seized with the idea of applying magnetism to the propulsion of machinery. In 1834 he produced a rotary electro-magnetic engine, and in the autumn of 1835 he exhibited in Springfield, Mass., a model of a circular railway and an electro-magnetic locomotive.

Many citizens of New York will recall the erect and handsome figure of a venerable gentleman, dressed with scrupulous neatness in the Continental costume and cocked hat of the period of the revolution, who fifteen years ago was to be seen on Broadway every pleasant day, and whose resemblance to the accepted portraits of Washington was so striking as to at once arrest the attention of the observer. This was Frederick Coombs, who, as the agent of Davenport, visited London in 1838, where he exhibited a locomotive weighing 60 or 70 pounds, propelled around a circular railway track by electric power, which excited the greatest interest in the scientific circles of the metropolis.

In 1840, Davenport printed by an electric motor a sheet entitled the "Electro-Magnet and Machinist's Intelligencer." Meantime others had occupied themselves with similar undertakings. Professor Jacobi, of St. Petersburg, invented a rotary electro-magnetic motor in 1834, and with the financial assistance of the Emperor Nicholas constructed, in 1839, a boat 28 feet long, carrying 14 passengers, which was propelled by an electric motor with a large number of battery cells, at a speed of 3 miles per hour. In 1838-39, Robert Davidson, a Scotchman, experimented with an electric railway car 16 feet long and weighing, including the batteries, 6 tons, which attained a speed of 4 miles per hour.

The limits of this article preclude even the briefest notice of the labors of many ingenious experimenters who occupied themselves in this line of research, but

no historical sketch of the electric motor would be complete without some reference to the work of Dr. Charles Grafton Page, for many years occupying an official position in the Patent Office at Washington.

Page, while a medical student in Salem, Mass., entered upon an experimental investigation of the relations between electricity and magnetism, which he continued to prosecute with extraordinary diligence and success during the greater portion of his active life. He particularly distinguished himself by his researches in electrical induction, notably by his invention of the electrostatic coil and circuit-breaker, which has been persistently, but wrongfully, credited to Ruhmkorff. His work in connection with the electric motor, although not so well known, is certainly no less important. Many middle-aged men of to-day will recall the interesting and curious array of apparatus for illustrating electro-magnetic rotation which formed such an important part of the philosophical cabinets of the academies and colleges of the preceding generation, almost every one of which owes its origin to the fertile and ingenious brain of Page. As early as 1845 it had been observed by Alfred Vail, the coadjutor of Professor Morse in the construction of the electric telegraph, that a hollow coil of insulated wire, traversed by an electric current, possessed the curious property of sucking an iron core into itself with considerable force. Upon this phenomenon being shown to Dr. Page, he at once conceived the idea of utilizing it in the operation of an electric motor, and after numerous experiments he succeeded in constructing, in 1850, a motor of this description, which developed over 10 horse-power. Aided by an appropriation from Congress he subsequently constructed an electric locomotive, with which an experimental trip was made from Washington to Bladensburg, on the Washington branch of the Baltimore and Ohio Railroad, on April 29, 1851, on which occasion a rate of speed was attained, on a nearly level plane, of 19 miles per hour. Of course in this, as in other experiments which have been detailed, the great cost of producing elec-



Faraday Announcing His Discovery to His Wife on Christmas Morning, 1821.

tricity by the consumption of zinc in a battery precluded the possibility of any commercial advantage from the scheme,



Charles Grafton Page.

but the achievement was nevertheless a notable one. Not far from the same time Mr. T. Hall of Boston, who had constructed much of Page's apparatus, made a small model of an electric locomotive and car, which is of interest, as establishing the practicability of conveying the electric current to a car by employing the rails and wheels as conductors, thus dispensing with the necessity of transporting the battery.

One of the most enthusiastic experimentalists with electro-magnetic machinery was Dr. James P. Joule, of Manchester, England, who in a letter written in 1839, said: "I can scarcely doubt that electro-magnetism will eventually be substituted for steam in propelling machinery." Professor Jacobi, too, one of the most eminent philosophers of that day, wrote: "I think I may assert that the superiority of this new mover is placed beyond a doubt as regards the absence of all danger, the simplicity of action, and the expense attending it."

Some years afterward, when Dr. Joule had become older and possibly wiser, he made a series of investigations on the mechanical equivalent of heat and other motors. The results led him to estimate

that the consumption of one grain of zinc produced only about one-eighth of the mechanical equivalent of a grain of coal, while its cost is more than twenty times as much. This conclusion, being generally accepted by the scientific world as authoritative, ultimately tended to discourage further efforts to apply electro-magnetism as a prime motor. The question was well summed up by Professor Henry, in these words: "All attempts to substitute electricity or magnetism for coal-power must be unsuccessful, since these powers tend to an equilibrium from which they can only be disturbed by the application of another power, which is the equivalent of that which they can subsequently exhibit. They are, however, with chemical attraction, etc., of great importance as intermediate agents in the application of the power of heat as derived from combustion. Science does not indicate in the slightest degree the possibility of the discovery of a new primary power comparable with that of combustion as



Professor Joseph Henry.

exhibited in the burning of coal. . . . We therefore do not hesitate to say that all declarations of the discovery of a new power which is to supersede the use of coal as a motive power have their origin

in ignorance or deception, and frequently in both."

In the words which have been italicized, Henry accurately foretold the true place, in the domain of industry, of the electric motor. Much confusion of thought exists in the popular mind at the present time in reference to this very point. We continually hear electricity spoken of as a motive power, and the prediction is freely made that it will soon take the place of the steam engine; that it will be employed to propel vessels across the Atlantic, and the like. But such a view of the matter is wholly without scientific basis. Electricity, in its important applications to machinery, is never in itself a source of power. It is merely a convenient and easily manageable form of energy, by which mechanical power is transferable from an ordinary prime motor, as a steam engine or a water-wheel, to a secondary motor which is employed to do the work. It performs an office precisely analogous to that of a belt or line of shafting, which, however useful in conveying power from one point to another, can, under no conceivable circumstances, be capable of originating it.

To properly understand and appreciate this new and important aspect of the mechanical application of electricity, it is necessary to return to the experiments of Faraday. In 1831, after he had become the director of the laboratory of the Royal Institution, he turned his attention to what he called the "evolution of electricity from magnetism." The brilliant generalizations of Ampère, followed by the experimental demonstrations of Arago, Sturgeon, and Henry, to the penetrating mind of Faraday necessarily implied reciprocal action, and he accordingly sought diligently to obtain the electric current from the magnet.

On the second day of his experiments he wrote to a friend: "I think I have got hold of a good thing, but cannot say; it may be a weed instead of a fish, which after all my labor I may pull up." On the tenth day, he became fully satisfied that he had hooked a fish. A crucial experiment showed that he had made a grand discovery which may,



André Marie Ampère. (After a steel engraving, by Tardieu, in 1825.)

without injustice, fairly be compared, in point of practical importance, with Newton's immortal discovery of gravitation. The principle upon which this discovery hinges may be explained in a few words. Every magnet is surrounded by a sphere of attraction which gradually diminishes in intensity as the distance from the pole of the magnet increases, and which has received the technical name of the "magnetic field." If an electric conductor be moved through this magnetic field the influence of the field tends to retard or oppose the movement of the conductor;

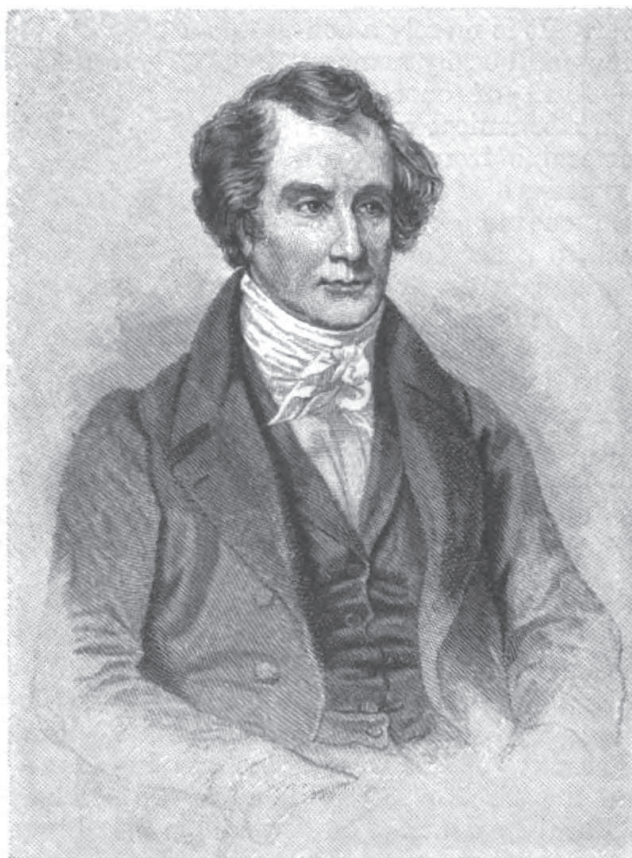
the mechanical force exerted in overcoming this resistance is converted into electrical energy, and appears in the conductor in the form of an electric current. If instead of the magnet we substitute another wire conveying an electric current, this last is surrounded by a magnetic field and similar results are experienced when another wire is made to move within it. The same phenomena occur if the conductor remains stationary and the magnetic field is moved, or its strength increased or diminished. This effect is known by the general name of induction, and the law which governs it was formulated by the Russian philosopher Lenz as long ago as 1833. It may be stated as follows: The currents induced by the relative movements either of two circuits, or of a circuit and a magnet, are always in such directions as to produce mechanical forces tending to stop the motion which produces them.

To Faraday also is due the first experimental machine for the mechanical production of electric currents. But he went no further. He possessed pre-eminently the scientific mind. His pleasure in the pursuit of natural truths was so absorbing that he could never turn away from them for the mere purpose of following up their practical applications. "I have rather been desirous," he writes, "of discovering new facts and new relations dependent on magneto-induction, than of exalting the force of those already obtained, being sure that the latter would find their full development hereafter." In the words of Professor Sylvanus Thompson, "Can any passage be found in the whole range of science, more profoundly prophetic or more characteristically philosophic, than these words with which Faraday closed this section of his *Experimental Researches*?"

Within a year after the publication of Faraday's experiment, Pixii, a philosophical instrument maker of Paris, constructed an apparatus in which a permanent magnet was made to induce currents in the wire surrounding an

electro-magnet; this was called a magneto-electric machine, and was doubtless the first organized appliance for producing an electric current by mechanical power. In 1838 it was materially improved by Saxton, of Philadelphia, whose apparatus will be recognized as the well-known "shocking machine" in which electric currents are produced by turning a crank. A similar device is used for ringing telephone call-bells. For many years the practical applications of the magneto-electric machine were comparatively unimportant, and were principally confined to its employment for actuating certain forms of telegraph apparatus, thereby dispensing with the voltaic battery.

In 1850 Professor Nollet, of Brussels, essayed to make a powerful magneto-



Arago.

electric machine for decomposing water into its constituent elements, oxygen and hydrogen, which were to be used in producing the lime-light. In 1853 a company was organized in Paris, and experiments were made with a large

machine constructed by Nollet. So far as the lime-light scheme was concerned the experiments were unsuccessful, but subsequently Mr. F. H. Holmes made some alterations in Nollet's machine, and applied it directly to the production of the electric light between carbon points. These experiments induced others to take up the subject both in France and England, which ultimately resulted in the production of the brilliant and beautiful electric arc-light, by which the streets of our principal towns are now nightly illuminated. It has been used in some of the French lighthouses since 1863.

The substitution of the electro for the permanent magnet, first suggested by Wheatstone in 1845, was applied in the construction of large machines by Wilde, of Manchester, who worked at the subject continuously from 1863 to 1867, with results incomparably in advance of all previous attempts to obtain electricity by mechanical power. In 1867 he exhibited a machine which produced the electric arc-light in its utmost magnificence, and was capable of instantly fusing iron rods fifteen inches long and one-fourth of an inch in diameter by the flow of the electric current.

The final step in the development of the magneto-electric generator was an almost simultaneous, although independent discovery by Moses G. Farmer, of Salem, Mass., Alfred Varley and Professor Charles Wheatstone, of England, and Dr. Werner Siemens, of Berlin. This was the idea of employing the current from an electro-magnetic machine to excite its own electro-magnet. The invention of this improved form of apparatus, which received the name of the dynamo-electric machine, gave an extraordinary impetus to the investigation of all branches of electric science. The subject was once more taken up by scores of enthusiastic workers in Eu-

rope and America, and innumerable minor improvements were made which have resulted in the exquisitely organized dynamo machine of to-day, a machine which has confessedly reached a state of perfection, leaving but the nar-



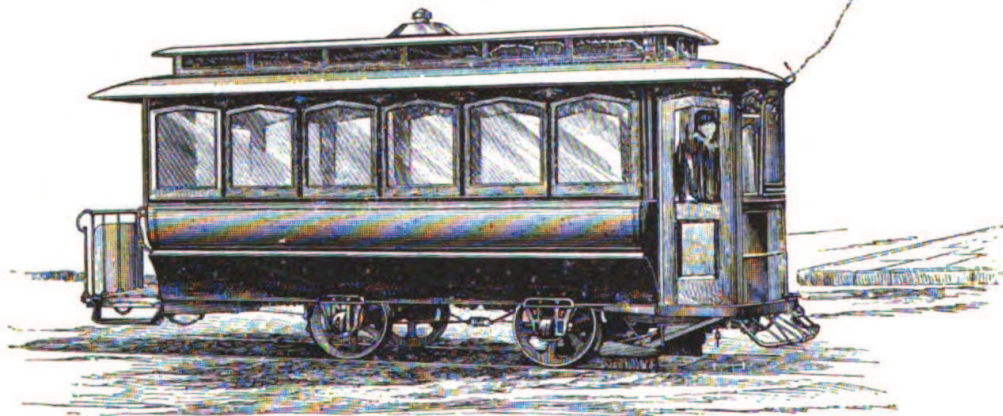
Dr. Werner Siemens.

rowest margin for any future improvement in its efficiency.

As we have seen, the earliest field of usefulness for the dynamo-machine was found in electric arc-lighting, which has now become, in the United States at least, an enormous industry. One of the most useful and convenient of these machines was designed by Gramme, of Paris, in 1872, which was capable of giving a constant current resembling in its characteristics that from a battery. At an industrial exhibition in Vienna, in 1873, a number of Gramme machines were being placed in position, in order to exemplify its various uses as an electric generator, on which occasion occurred one of those singularly fortunate accidents which have again and again played so prominent a part in the history of industrial progress. In mak-

ing the electrical connections to one of these machines which had not as yet been belted to the engine-shaft, a careless workman attached to it a pair of wires which were already connected with another dynamo-machine, which was in rapid motion. To his amazement, the second machine commenced to revolve with great rapidity in a reverse direction. Upon the attention of M. Gramme being directed to this phenomenon, he at once perceived that the second machine was performing the function of a motor, and that what was taking place was an actual transport of power through the medium of electricity. This singularly opportune occurrence led to the instant recognition of the true place of the electric motor

verting mechanical energy into electric currents and again reconverting these by means of a reversed dynamo-machine into mechanical power, naturally suggested the practicability of transmitting power through electric conductors to any required distance. One of the earliest applications of this character was the revival of the electrically operated railway. This, as we have seen, was by no means a novel idea, but its commercial development for obvious reasons



A Street-car Propelled by an Electric Motor.

in the domain of mechanics. From the date of Page's experiments almost the only practical use to which the electric motor was applied is in the operation of dental apparatus, to which it has been adapted with great ingenuity and success.

The late Professor James Clerk Maxwell, one of the master minds among the electricians of the new era, expressed the opinion that the reversibility of the Gramme machine was one of the most important discoveries of modern times. While it is true that the circumstance attracted general attention in scientific circles, its application to useful purposes was no doubt deferred for many years by the counter-attraction of electric lighting, which promised to inventors and capitalists larger and more immediate profits. The principle of con-

remained in abeyance until generating machinery was available to furnish large quantities of electricity at moderate cost.

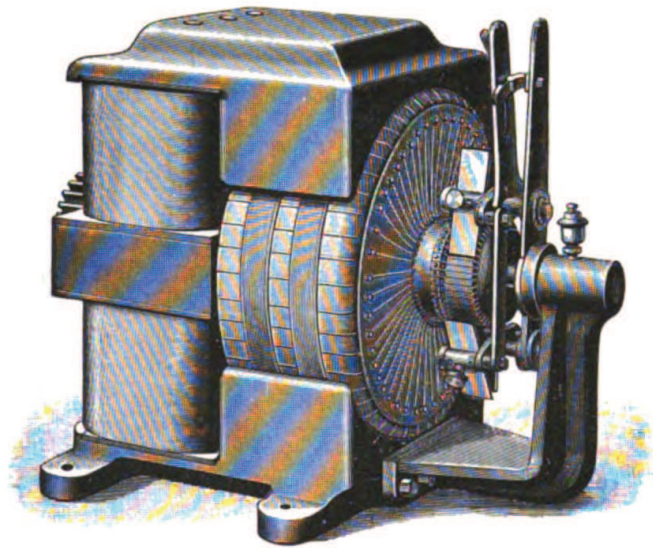
One fact of controlling importance in this connection is that electricity is capable of being supplied to a moving motor through frictional or rolling contact, a method of communicating energy impossible of realization by other known means; hence the energy could be supplied by machinery situated at any required distance from the moving train by extending the conductor along the railway, for which, as we have seen, the rails themselves might serve when properly insulated. It is probable that the earliest detailed conception of the modern electric railway was due to Jean Henry Cazal, a French engineer, who proposed, as early as 1864, to utilize the natural powers, such as water and wind, for op-

erating railways, by the electrical transmission of power. But this was in the day of small things in electric generators, and hence the practical realization of the ideas of Cazal was only rendered possible by the subsequent development of the dynamo-machine, as heretofore related.

A request by the proprietors of a German colliery to be supplied with an electric locomotive for hauling coal cars in the levels led Dr. Werner Siemens to devise and construct an electric railway, which was exhibited at the Industrial Exhibition in Berlin, in the summer of 1879. This railway was circular, about 1,000 feet in length and of one metre gauge. A dynamo-electric machine driven by a steam engine supplied the current, the expenditure of energy being about five horse-power. One hundred thousand persons were transported over this line, during the period of the exhibition.

Meantime several American inventors were independently at work upon this problem, among them Stephen D. Field, of San Francisco, Dr. Joseph R. Finney,

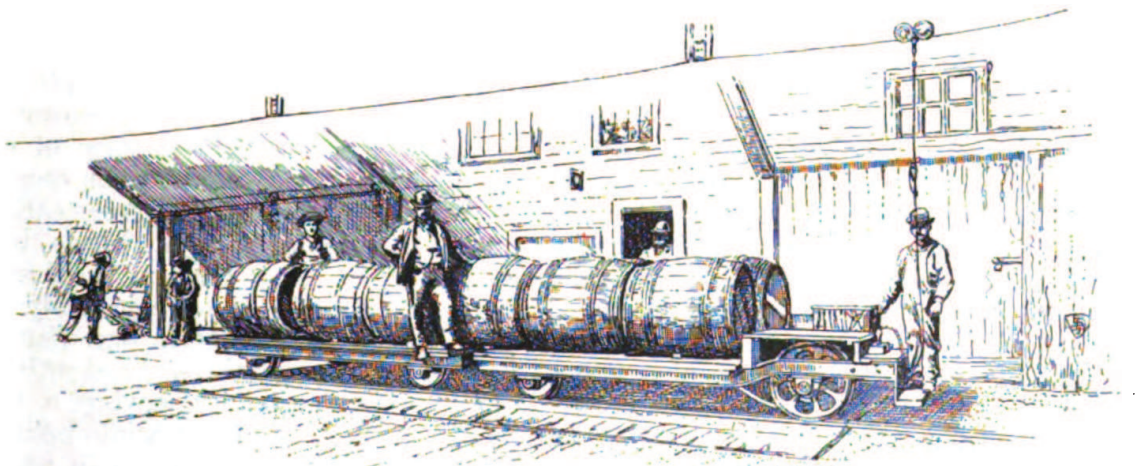
80 or 90 rods in length. Field's electric locomotive was first exhibited at the Exposition of Railway Appliances in Chicago,



The Van Depoele Electric Motor.

go, in June, 1883, during the continuance of which nearly 27,000 passengers were transported. Both Field and Edison utilized the rails of the track to convey the current to the motor.

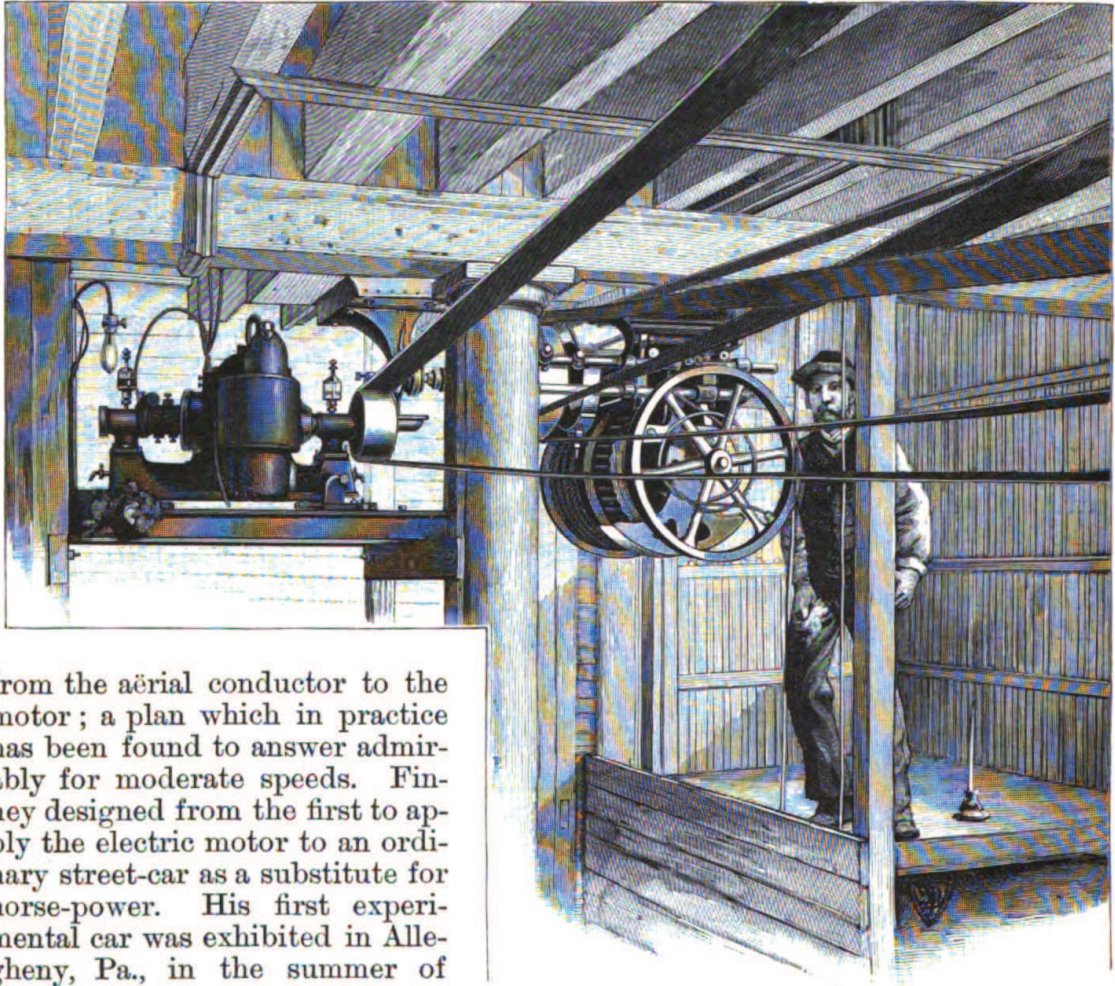
Finney's plan was somewhat different. He suspended an insulated copper wire, about the thickness of a lead pencil, 15



Electric Tramway for Hauling Freight, used in a Sugar Refinery.

of Pittsburgh, and Thomas A. Edison, of New York. Edison was the first to construct a dynamo-electric railway in America. This was in the spring of 1880, at Menlo Park, N. J., the track being some

or 20 feet above the line of the railway. A small wheeled trolley, running on this wire as on a track, and connected with the car by a flexible conducting cord, served to convey the electric current



from the aerial conductor to the motor; a plan which in practice has been found to answer admirably for moderate speeds. Finney designed from the first to apply the electric motor to an ordinary street-car as a substitute for horse-power. His first experimental car was exhibited in Allegheny, Pa., in the summer of 1882.

The first electric street railway established in America for actual service was on a suburban line two miles in length extending from Baltimore to Hampden, Md. It had previously been operated by animal power, and was cheaply and roughly constructed, having sharp curves, and grades as high as 330 feet per mile. This line has been continuously operated by electricity since September 1, 1885. The electric current is conveyed by an insulated rail fixed to the ties midway between the traffic rails. The electrical machinery was designed and constructed by Leo Daft, of Jersey City, N. J. The results of the change of motive power were highly gratifying to the management, inasmuch as the receipts of the line were largely increased during the first year, while on the other hand, the expense of operation was diminished, and this in spite of the fact that the application was made under exceptionally unfavorable circumstances. The success of this undertaking went far

The Sprague Motor Running an Elevator.

to demonstrate the advantages of electricity as a street-car motor.

Every consideration of humanity, no less than of convenience and economy, unites to urge the substitution of mechanical for animal power upon our numerous street railway lines at the earliest practicable moment,* and hence it is gratifying to know that on the first of January, 1888, there were in daily service, in the United States and Canada, no less than twenty-three street railways operated by electricity, having a total length of about 100 miles, while between twenty and thirty others are in an advanced stage of construction.

One of the most successful examples of an electric street railway is that at

* In the street railway service in large cities, the distance traveled each day by a two-horse team averages about ten miles, so that each animal works only about two hours out of the twenty-four. The cost of stabling, feeding, and replacing horses is \$200 per year, each. The active life of a car-horse is only from two to four years.

Scranton, Pa., designed by Charles J. Van Depoele, of Chicago, which has been in daily operation since December, 1886. It is four and one-half miles in length, of standard gauge, laid with steel rails, and its passenger equipment consists of seven handsomely finished Pullman cars, each propelled by a 15 horse-power electric motor, which stands on the glass-enclosed front platform and is geared to the forward axle by the familiar mechanical device of sprocket-wheels and steel chains. The external appearance of the motor is shown in the illustration on page 315. It stands about two feet high and occupies a space perhaps eighteen inches square. The car, of which an illustration is given on page 314, can be run at a speed of fifteen miles per hour, if required, and in its regular work ascends grades of nearly 350 feet per mile with great facility. The machinery is nearly noiseless and quite unobjectionable in every respect. It is stated that the cost of running at Scranton, using for fuel the waste coal-dust or "culm" from the anthracite mines, which can be had in almost inexhaustible quantity at the nominal price of 10 cents per ton, is about one dollar per car per day, or a trifle over one cent per car mile. The economy over animal power, the cost of which in New York and Boston is reckoned at something over ten cents per car mile, is very apparent.

Similar electric railways are in operation at Appleton, Wis., and St. Catharine, Ontario, which are driven by water power at an almost nominal cost. In many instances natural power may be thus used with the utmost advantage, as it is by no means necessary that the power should be in the vicinity of the line of the railway.

Several of the inventors whose names have been already mentioned in connection with electric railway work have paid much attention to the problem of city and suburban rapid transit, and there is every reason to hope that an early day will witness the successful introduction of electric power upon the elevated railway system in New York, for which it would seem on every account to be peculiarly well adapted.

The pioneer electric street railway in

Europe was the Lichterfelde line, in the suburbs of Berlin, constructed under the superintendence of Dr. Siemens, which has been running since the spring of 1881. Several other electric lines have been constructed in Great Britain, Ireland, and on the Continent, but as usual with inventions of this class, our own country quickly placed itself in advance of all others in the extent to which the new system found a practical application.

A considerable number of street-cars have been constructed, both in Europe and America, with the design of deriving the electric energy for propelling each individual car from storage batteries or accumulators carried upon it. An accumulator may be described, in a general way, as a vessel containing acidulated water in which is immersed a pair of leaden plates. The passage of a strong electric current from a dynamo, through the liquid from one plate to the other, produces a chemical action which has the effect of oxidizing one of the plates. After this process has gone on for some hours, the dynamo may be detached, and the two plates joined by a wire. An electric current will now pass through the wire from one plate to the other, as in an ordinary voltaic battery, the effect of which is to undo the work which has been done in charging the battery. Strictly speaking, in a battery of this kind, no electricity is stored; its energy is in fact converted into chemical energy, and this may be reconverted into electric energy at will. Many quite successful experiments have been made with self-propelling motor cars operated by these batteries, and there is little reason to doubt that they will ultimately find an extensive use and application in large cities and other localities where the employment of an overhead conductor for electrical distribution is from any cause objectionable. The most serious objection to their use is the expense of operation, which has thus far proved to be much greater than in the case of direct supply from the dynamo.

Many inventors are endeavoring to find a thoroughly practicable plan of insulating the electric conductor beneath the roadway; and while the problem is unquestionably a far more diffi-

cult one than would be supposed by a person unfamiliar with the subject, yet there is probably no good reason to doubt that it will in due time receive a practical solution.

The commencement of the general introduction of electric lighting by incandescent lamps supplied from central stations, which may be fairly considered to date from about 1883, had the almost immediate effect of creating a demand for small electric motors. It was at once perceived that the electric lighting conductors, if introduced into every building in a town and supplying a constant electric current, at an expense ordinarily not exceeding 8 or 10 cents per horse-power per hour, could be utilized with great advantage in driving sewing machines, lathes, ventilating apparatus, and innumerable other sorts of machinery for domestic purposes, or for the lighter class of mechanical industries. Quite an assortment of neat little motors of this character, of different patterns, and of capacities ranging from one-tenth to one-half a horse power, were exhibited at the Industrial Electrical Exhibition at Philadelphia, in 1884, for operating sewing machines, and other light work, where they attracted much attention.

One of the most interesting exhibits of this character was made by Lieut. F. J. Sprague, formerly an officer in the U. S. Navy, who showed two or three motors of his own design having a capacity of perhaps five horse-power, which were employed to drive looms and other textile machinery requiring considerable power. Another motor of about two horse-power, built by Mr. Daft, was at work for several weeks during the exhibition, printing the regular weekly issue of an electrical journal, on a power press with a bed 31 by 46 inches. The successful and satisfactory operation of these motors led almost immediately to the establishment of an extensive business, and there are now in New York, Boston, and other cities, systems of electric power-distribution from central stations of considerable importance, employing machines of the types first exhibited at Philadelphia on the occasion just referred to.

It is a very difficult matter to ascertain

even approximately the extent to which this business of electric power-distribution has already attained in this country, but a somewhat cursory investigation has shown that it is greatly in excess of what might have been anticipated. One central power station in Boston operates nearly one hundred motors of a capacity ranging from 15 down to one-half a horse-power, the greater number used being from 5 to 10 horse-power. The supply conductors are carried underneath the pavement of the streets. A single corporation of the dozen or more actively engaged in this manufacture has sold within three years over 1,000 motors aggregating more than 5,000 horse-power, and the demand is increasing daily. It would be almost impossible to catalogue the number and variety of purposes for which the electric motor is now in daily use. Some of the most usual applications are for printing presses, sewing machines, elevators, ventilating fans, and machinist's lathes. At the present time every indication unmistakably points to the probability that within a very few years nearly all mechanical work in large cities, especially in cases in which the power required does not exceed say 50 horse-power, will be performed by the agency of the electric motor. It is an ideal motor, absolutely free from vibration or noise, perfectly manageable, entirely safe, and with the most ordinary care seldom if ever gets out of order. Indeed there is no reason to suppose that the limit of 50 horse-power will not be very largely exceeded within a comparatively short period, when it is remembered that scarcely five years ago the production of a successful 10 horse-power motor was considered quite a noteworthy achievement.

An extremely useful application of the electric motor, which is likely to be widely extended, is in connection with large manufacturing establishments, already supplied with incandescent electric lighting apparatus. It is a very simple matter, by means of a current derived from the same dynamo, to operate elevators, hoists, presses, pumps, trucks, tramway-cars, and many similar appliances, which are now worked at greater expense, and with far less convenience, by hand, animal, or indepen-

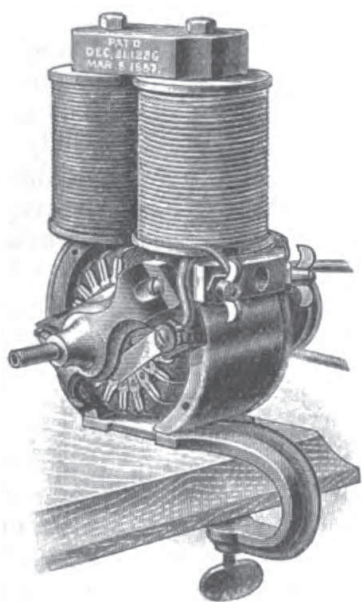
dent steam power. We give an illustration of this description of tramway work at a sugar refinery in East Boston, Mass. [p. 315]. The electric motor is geared to the axle of a low platform car, and serves to propel it, together with a second car, along the track, the whole being operated by a current from the incandescent dynamo used for lighting the premises. This little freight train makes a round trip every five minutes under the management of an ordinary laborer, hauling an average load of ten tons of raw sugar from the wharf to the refinery at each trip, at an inconsiderable expense.

Another very important service to which the electric motor is especially well adapted is that of a substitute for belts, shafting, and gearing, in the transmission of power from the prime motor in large manufacturing establishments. A New England cotton-mill engineer of high repute has ascertained, from actual measurement of a number of modern mills fitted with first-class shafting, that over thirty per cent. of the gross power of the engines is absorbed in driving the various lines of shafting alone, before the delivery of any power whatever for actual work. Numerous tests demonstrate that it is entirely within the truth to estimate the loss of conversion, transmission, and reconversion in well-designed electrical machinery, under like conditions, at less than thirty per cent., so that in the use of the electric motor for this class of work, we have at once an actual saving over the loss experienced in the direct mechanical transmission of power, with the further and in most cases controlling consideration, that in the case of the electrical system this loss affects only such portions of the machinery as are actually at work, while under the ordinary conditions, the entire system of belting and shafting must be kept in continuous operation, entailing a constant loss, irrespective of the number of machines which may be actually in use at any given time. The advantages of having every individual machine driven by its own independently controlled power, and at any required speed, are so obvious that it is scarcely necessary to mention them.

The conditions of electrical power transmission have been thoroughly studied, by competent engineers, and are now so well understood, that those conversant with the practical aspects of the subject are well assured that within a few years even the smallest towns and villages will supply themselves with electric light and power plants. In such places a plant of 50 horse-power, or even less, will be quite sufficient to furnish a good profit on the moderate investment of capital required. The establishment of a power centre, even in a rural village, cannot fail to attract a greater or less number of small though by no means unprofitable industrial enterprises, and the mere fact that such power can be had will in itself tend to rapidly increase the demand. The management of an electric power plant requires no unusual scientific knowledge. Once the station has been established it can be carried on by the ordinarily intelligent class of mechanics and workmen who are to be found in every village. It is computed by statisticians, that the average price at which power is sold in the United States, approximates \$110 per horse-power per annum. A 50-horse-power electrical plant, including the station building, engines, boilers, dynamos, distributing wires, and fixtures, can be erected, at present prices, at an expense not much exceeding \$150 per horse-power, and the gross cost of operating such a plant may be fairly estimated at about \$4,000 per year. Experience has shown, that in consequence of the intermittent demand for power by a group of miscellaneous consumers, it is entirely safe to contract to supply a quantity considerably in excess of the actual capacity of the station, so that indeed as much as 70 horse-power might be sold from a 50 horse-power plant, thus bringing in a yearly gross revenue of \$7,000 or more and leaving a net profit of some \$3,000. Where a good water-power is available at a moderate outlay, the profits might be even more than we have estimated, while it will be readily understood that in all such cases, the proportionate profits are rapidly augmented as the capacity of the plant is increased.

A somewhat startling proposition in

connection with the general subject of the transmission of energy to a distance by electricity was advanced by that eminent engineer, the late Charles W. Siemens, of London, who, in 1877, expressed his conviction that by this means the enormous energy of the falling water at Niagara might be transferred to New York City, and there utilized for mechanical purposes. In 1879, Sir William Thomson, the electrician, publicly asserted his belief in the possibility, by means of an insulated copper wire, half an inch in diameter, of taking 26,000 horse-power from water-wheels driven by the falls, and of delivering



C. and C. Motor Running a Sewing Machine.

21,000 horse-power at a distance of 300 statute miles. He estimated that the cost of copper for the line would be less than 15 dollars per horse-power of energy actually delivered at the remote station. While Sir William

may be regarded as somewhat of an enthusiast, and has occasionally manifested a tendency to present matters of this kind in a sensational light, yet it cannot be looked upon as especially improbable that the realization of this apparently chimerical project will be witnessed by persons now living.

A series of extensive and costly experiments of this character have been zealously prosecuted within the last few years by M. Marcel Deprez, a French electrical engineer, who was fortunate enough to obtain the financial assistance of the Rothschilds. The results attained have been much criticised by the profession in other countries, but it seems indisputable that on at least one

occasion more than 35 horse-power was delivered at the terminal of a conductor 70 miles in length, 62 horse-power having been applied to drive the generator, showing a total loss of energy approximating 43 per cent., a result which cannot be looked upon as unsatisfactory. The whole question turns upon the practicability of employing high electric pressures, and hence the further development of this branch of the subject must await the march of progress in general electric science.

The experiment of Jacobi, who was the first to propel a vessel by electricity, has already been noticed. The records of electric navigation are a blank from that time until the commencement of the experiments of the ingenious and versatile Trouvè of Paris, who exhibited a small boat on the Seine in 1881, the electricity for which was supplied by a primary battery. Four or five passengers were carried at a speed of about three miles per hour. Between 1882 and 1886 quite a number of experimental launches were built in England and France, propelled by electric motors, and supplied with electricity by accumulators stowed in the bottom of the boat, which served also as ballast. The most noteworthy achievement of this character was the launch Volta, which in September, 1886, performed the trip from Dover to Calais and back, with ease and safety, the batteries being charged but once for the double journey. Seven passengers were carried on this occasion, and a speed of over twelve miles per hour was reached. The Volta was 37 feet long, seven feet beam and three and a half feet deep.

Quite recently a New York establishment, which manufactures small motors, one of which is shown in the accompanying illustration as applied to a sewing machine and deriving its power from a primary battery, has adapted a similar motor to the propulsion of a light canoe. The dimensions of the motor designed for this craft are so small that at first sight it seems almost absurdly inadequate for its intended purpose. But its performance is nevertheless excellent, and a considerable demand has sprung up for these neat and ingenious little vessels.

It would be impossible, within the

limited space at command, to attempt to enumerate the various future applications of the electric motor which suggest themselves to the enterprising electro-mechanician, but, in conclusion, the writer cannot refrain from expressing his conviction that the day is not far distant when rapid transit between the principal cities of America will be effected to an extent which to persons unfamiliar with the developments of electricity must seem utterly visionary and chimerical. Once admit, as we must do, the possibility of applying almost limitless electric power to each axle of a train, with the possibility of laying a track almost as straight as the crow flies

from city to city, rising and falling as the topography of the country may require, and the complete solution of the problem becomes little more than a matter of detail. Not that such detail is unimportant, nor that the innumerable minor difficulties can be overcome without much experiment and study, but it may nevertheless safely be affirmed that the ultimate result is already distinctly foreshadowed, and that we may expect within a few years to be transported between New York and Boston in less than two hours, not by the enchanted carpet of the Arabian Nights, but by the potent agency of the modern electric motor.



NATURAL SELECTION.

A ROMANCE OF CHELSEA VILLAGE AND EAST HAMPTON TOWN.

By H. C. Bunner.

PART III.



DORINDA threw herself upon the task of preparing Celia for the fray with a zeal and ardor that brought only dismay to her younger sister's breast. It having been decided that the victim of society must have some new gowns, Dorinda at once planned a wardrobe of variegated brilliancy. Celia strove with all her tact for a more modest working, but she had to stand up and do battle-royal for her own standards when Dorinda wanted her to purchase a certain "Dame Trot" garment, of a pattern which was at the time exciting the irreverent attention of the press. They came to an open rupture. Celia finally appealed to the head of the house, who decided, with masculine justice, that she was entitled to choose her clothes for herself. Dorinda writhed; but came

back to the fascinating employment more in sorrow than in anger.

When the little trunk was at last packed, Dorinda's verdict on the contents was that they were good enough, but had no sort of style about them. Celia, doubtful of their possessing any merits at all, took a negative comfort from this. Ah! if she could only gather an idea of Mrs. Wykoff's likes from Dorinda's dislikes!

The day came when Mrs. Wykoff's maid was to convey her charge to the further shore of Long Island. This relegation of Celia to a menial's care had somewhat troubled the family conclave; but it had been decided that, in view of the differences in social ethics revealed by past dealings with the Wykoff family, it would be fair to assume that the lady's intent was respectful, however much her course was open to the criticism of the right minded. The sun was shining on the mid-day dinner when the carriage