with worry, bounded forward in a madness of glee.

Trumpeting shrilly, the blind Habiba trotted awkwardly, actively ahead. She met Mahomet, and the two were instantly embracing. She heard his wild, soft speech of love, endearment, and reunion.

Then at last the faithful Blix was lifted down by Habiba herself and leaped upon his master in a frenzy of doggish adoration.

As Nichols took the four from the tree, they clung to him fondly, crying in his arms, and Ellen Watt declared he was the bravest man that ever lived.

Then, when they reached the road, they saw, almost down at the turn, the big gray form of Habiba, with Mahomet riding like a raja on her head. He waved his hand in token of his thanks. Habiba halted, wheeled in her tracks, saluted with a trumpet note from her upraised trunk, then turned and disappeared into the glory of the sunlit trees.

THE ELECTRIC RAILWAY

FIRST PAPER: A RÉSUMÉ OF THE EARLY EXPERIMENTS

BY FRANK J. SPRAGUE

Former President of the American Institute of Electrical Engineers

THE development of the trolley and other forms of electric traction is one of the most significant phenomena of our time. Its commercial and social importance is beyond computation. In the United States there are few communities that are not practically concerned in some method of its employment, present or prospective. In New York city alone above $80,000,000 is about to be invested in trunk-line terminals, made possible by electric power. Meantime there is a wide-spread agitation for the municipal ownership and operation of street railways. These considerations give timeliness and special interest to the narrative of Mr. Sprague, whose preëminence as an inventor in this field lends unique value to his record of the origin, growth, and present condition of transportation of this kind and of the part taken in it by various inventors.

Mr. H. H. Vreeland, president of the Metropolitan Railway of New York, writing in 1895 in "One Hundred Years of American Commerce," said: "In 1888 Frank J. Sprague, first among the younger electricians of America, obtained sufficient capital to make an actual test upon a street in the city of Richmond, Virginia. He brought together the best features of all the systems which had been devised, applied to motive power the fundamental principles which he had learned in building electric-light plants and establishing stationary motors, added new and simple but effective methods of motor control and suspension, and in general worked out a well-defined system, the essential features of which have not been changed in the seven years which have elapsed since he installed the first practical electric railroad in the United States."

In a second paper Mr. Sprague will continue the record by a fuller account of his own contributions to the subject, including a graphic narrative of experiments and successes in the establishment of the Richmond electric railway, the first to be operated on a large scale, with a further account of the later developments of the "art" and a forecast of its future development.—THE EDITOR.

THE honor of first suggesting an electric railway must be accorded to Thomas Davenport of Brandon, Vermont, blacksmith and electrician, inventor and scientist. In 1834 he ran a toy motor mounted on wheels on a small circular railway, and a year later he exhibited it at Springfield and at Boston. Then it gave up the ghost, and for more than twoscore years various inventors, in utter ignorance of the principles of the modern dynamo, and with no source of power except the zinc-burning primary battery, labored with small reward.

About 1838 a Scotchman of Aberdeen, named Robert Davidson, began the construction of a locomotive equipped with a motor similar to one used by Jacobi in experiments on the river Neva. Davidson's engine was tried on the Edinburgh-Glasgow Railway, and attained a speed of about four miles an hour.

In 1840 the use of the rails for carrying the electric current was indicated in an English patent issued to one Henry Pincus, and a like use in an American patent to Lilley and Colton in 1847. In that year Professor Moses G. Farmer, late government electrician at the Newport Torpedo Station, one of the ablest of the early investigators, operated an experimental car, carrying two passengers, at Dover, New Hampshire. Three years later Professor Page of the Smithsonian Institution, aided by a special grant from Congress, constructed several forms of motors, in one of which a reciprocating motion was obtained by two solenoids or hollow magnets which alternately attracted iron cores mounted on a rod which was attached to a crank with a fly-wheel. This was used as a locomotive, and, driven by a battery of one hundred Grove elements, was tried April 29, 1851, upon a railroad running from Washington to Bladensburg, and attained a maximum speed of nineteen miles; but this speed destroyed the batteries, and the experiments were given up.

In the same year Thomas Hall, an instrument-maker of Boston, made a small model operated by a current conveyed through the rails from a stationary primary battery; and in 1860 he exhibited another model called the Volta, at the Mechanics' Fair in Boston. Meanwhile patents issued in 1855 to an Englishman named Swear and to a Piedmontese named Bessolo indicated the possibility of taking current from a conductor suspended above the ground.

But every attempt made during this first period was necessarily doomed to commercial failure; for the source of power in all cases was a primary battery either carried on the car or supplying a current through rails or a wire, and all the motors were constructed on the crudest lines.

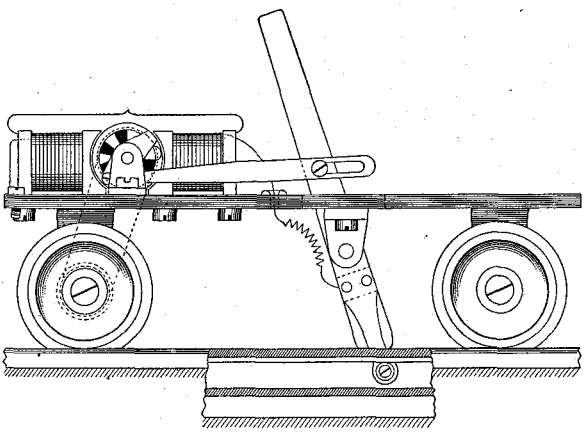
The evolution of the modern dynamo, however, was proceeding, although in a slow and labored fashion. First, electromagnets separately excited were replaced by permanent magnets, a system patented by Wheatstone and Cook in 1845. Other improvements by Hjorth, a Swede, followed in 1854. Then came an unknown inventor—such is the trick of fame—who, in 1858, clearly set forth the vital idea of self-excitation; but 1860 really saw the first great step toward ultimate success in the invention, by the Italian Pacinotti, of the continuous-current dynamo, which was followed by the announcement of the principle of complete self-excitation of the field-magnets, developed almost simultaneously and independently by Wheatstone, Varley, Siemens, Ladd, and Farmer in 1866–67.

Three years later, these two vital features were combined in a single machine by Gramme, who thus produced the first practical commercial machine for continuous-current operation, and made the world forever his debtor, following this achievement by a series of machines of high and increasing efficiency. The ring form of armature of the Pacinotti and Gramme machines, although for a long time widely used, ultimately gave way to the drum form of winding, proposed in 1872 by Von Hefner Alteneck of the Siemens firm, and also independently by the late Professor Henry Rowland.

Some time elapsed after the development of the self-exciting machine before the marvelous characteristic of reversibility of function was discovered, with the necessary corollary, the electrical transmission of energy by the use of two similar machines, one to be driven by power and to generate electricity, and the other to receive electricity and to develop mechanical power. It is claimed that this vital fact was discovered and described by Pacinotti in 1867; but, if so, the discovery remained dormant until 1873, when Messrs. Gramme

and Fontaine independently demonstrated it at the Vienna Exposition. The exact circumstances of this discovery will probably never be known, but one account says that it was accidental, and was due to the mistake of a workman who coupled a machine to a live circuit, and was astonished to see it begin to rotate. This is a quite natural possibility, as a similar thing has happened many times in recent years.

From 1851 to 1875, a period in which the modern dynamo and motor were created, seems a long time; but during those years, in the United States at least, there appears to have been an entire and incomprehensible cessation of electric-railway experiments. In the latter year, George F. Greene, a mechanic of Kalamazoo, Michigan, built a small motor which was supplied from a battery through an overhead line, with track return; and three years later he constructed another model on a larger scale. Greene seemed to have realized that a dynamo was essential to success; but he did not know how to make one, and, being without means to buy, his work came to naught.



From a patent drawing

SIDE VIEW OF THE FIELD CAR

Showing motor on the platform connected to the axle, and lever for reversing motion and making contact with the conductor in an iron conduit between the tracks.

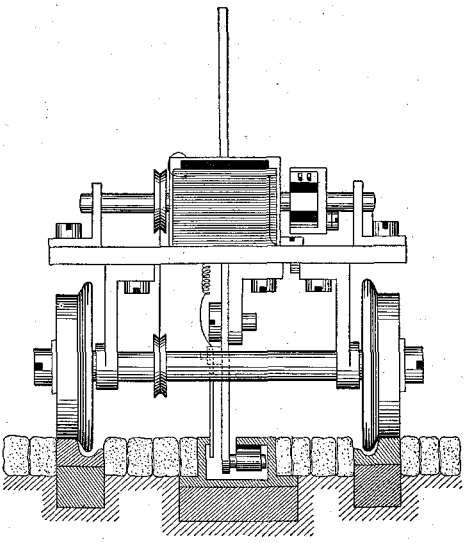
EARLY YEARS OF COMMERCIAL WORK

THE developments of the house of Siemens of Berlin in building dynamos for electric lighting and other purposes naturally soon tended to investigations into the transmission of power; and in 1879 the first electric railway which took current from a stationary dynamo, used a modern motor, and carried passengers was put in operation at the Berlin Exhibition. (See page 444.) This was about a third of a mile long. The dynamo and motor were of the well-known Siemens type, and the current was supplied through a central rail, with the running rails as a return, to a small locomotive on which the motor was carried longitudinally, motion being transmitted through spur and beveled gears to a central shaft from which connection was made to the wheels. The locomotive drew three small cars having a capacity of about twenty people, and attained a speed of about eight miles an hour.

At Vienna, in the following year, Egger exhibited a model of an electric railway, the current to be supplied through the running rails; and Messrs. Bontemps and Marcel Desprez made a study in Paris of a scheme for replacing pneumatic transmission of despatches by miniature electric locomotives.

Meanwhile two American inventors, Stephen D. Field and Thomas A. Edison, began electric-railway experiments almost simultaneously; but it would seem that, more than to any other, the credit of the first serious proposal of this period in the United States should be awarded to Field, who filed a caveat in 1879, following it by regular patent application in March, 1880, which disclosed plans for an electric railway designed to use current from a stationary dynamo, transmitted through a third rail or an insulated conductor inclosed in and protected by an iron conduit, the traffic rails, which formed the return circuit, being divided into sections.

In the patent the conduit was shown both as a part of one of the rails and as a separate structure. Contact was made by an underrunning wheel on the end of a lever the movement of which could make or break contact and also operated a rock-shaft so as to shift the contacts with the armature, and hence its direction of rotation. Curiously enough, in the spring and summer of 1880, Siemens and Edison also filed patent applications in the United



From a patent drawing

END VIEW OF THE FIELD CAR

Showing the iron conduit between the tracks, containing one conductor, the conduit being the other.

States, all being within three months of one another; but priority of invention was finally awarded to Field. In an account of his work published over twenty years ago it is stated that he early contemplated the operation of street-cars in San Francisco, but had not been able to conduct any experiments because of the lack of a dynamo, and that in 1878 he ordered both Gramme and Siemens machines for experimental purposes, the first being the operation of an electric elevator.

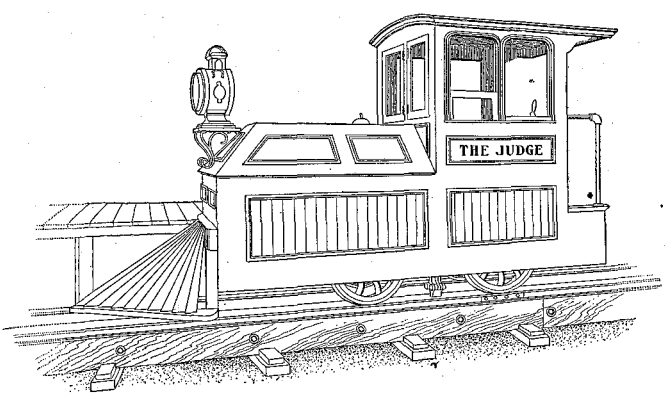
Edison was perhaps nearer the verge of great electric-railway possibilities than any other American. In the face of much adverse criticism, he had developed the essentials of the low internal-resistance dynamo with high-resistance field, and many of the essential features of the multiple-arc system of distribution; and in 1880 he built a small road at his laboratory at Menlo Park. There he ran a car operated by one of his earliest lighting dynamos as a motor, from which the power was transmitted to the axle by a belt; one set of wheels was insulated, and the two rails were used for current. (See page 445.) Experiments were conducted here for about two years.

In view of the general advance which had been made in dynamo-electric machinery and the novelty of the electric railway, the paucity of controlling claims obtained in these early patents is remarkable, and, save in a general way, the features shown do not represent the details of modern practice; in fact, save for some experimental work, and the taking out of some ingenious patents, Edison and Field early ceased to be active factors in the art.

The invention of accumulators, or storage batteries, about this time directed attention to the possibilities of a self-contained car; and in 1880 a locomotive with these was used in the establishment of Duchesne-Fournet at Breuil, and in the following year Raffard, with a large battery of Faure accumulators, made experiments on the tramway at Vincennes, France.

Meanwhile Messrs. Siemens and Halske were active in Europe, and the demonstration in Berlin was followed by others for exhibition purposes at Brussels, Düsseldorf, and Frankfort; but the first regular line to be established was a short one with one motor-car at Lichterfelde, near Berlin. This road was one and a half miles in length, used all rail conductors, and was opened for traffic in May, 1881. (See page 446.)

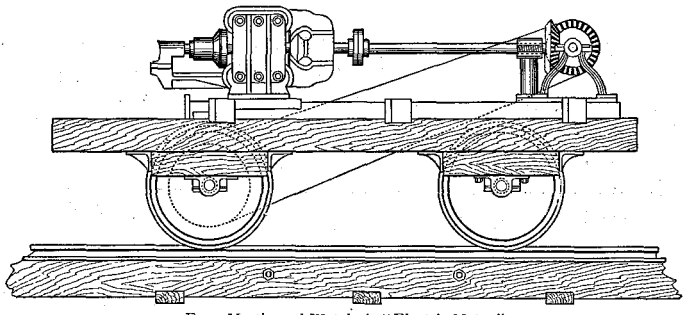
The motor was carried on a frame under the car, between the wheels, and the current was transmitted by steel cables from the armature to drums on the axles. The



From Martin and Wetzler's "Electric Motor"

"THE JUDGE"

Field experimental locomotive tried at the Chicago Railway Exhibition, in 1883.



From Martin and Wetzler's "Electric Motor"

SIDE ELEVATION OF "THE JUDGE" WITH CAB REMOVED

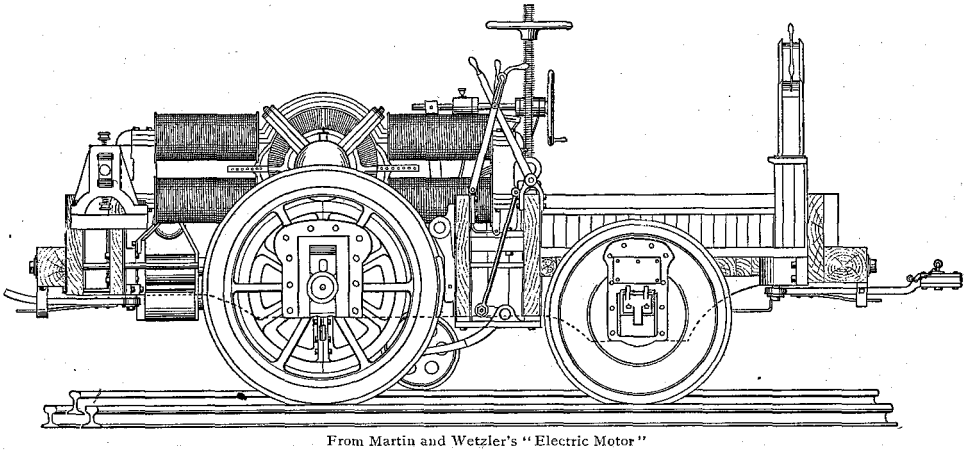
Showing the motor mounted on the platform and connected by gearing and belt to one axle.

car had a capacity of twenty-six passengers, and attained a maximum speed of about thirty miles. The electrical pressure was low, only about one hundred volts being used. This line was continued in regular service, but twelve years later the rail method of distribution was replaced by two conductors carried on the tops of poles, upon which ran a small carriage connected with the car by a flexible cable.

This equipment was followed by one at the Paris Electrical Exposition, where overhead distribution was used for the first time. In this case the conductors consisted of two tubes slotted on the under side and supported by wooden insulators. The tubes carried skids, which were held in good contact by an underrunning wheel pressed up by springs carried on a framework supported by the conductors, connection with the car being made by flexible conductors. The motor was placed between the wheels, and the power was transmitted by a chain.

About this time also Field constructed and put in operation an electric locomotive in Stockbridge, Massachusetts. Dr. John Hopkinson, an English scientist of exceptional ability and knowledge, in patenting the application of motors to hoists, proposed both for them and for tramways what is now known as the series-parallel method of speed control of motors. By this method two motors, or one motor with two armature circuits, can be run at half or full speed by providing a switch so that current from a source of constant pressure or potential can be sent through the two circuits in series, thus reducing the pressure and hence the speed one half; or each can have the full pressure delivered to it by coupling them in parallel, then running at full speed. The same method is available for three or more motors or armature circuits, with corresponding range of speed variation.

The change-over from one combination to the other with high electrical pressures or large currents would be, however, abrupt



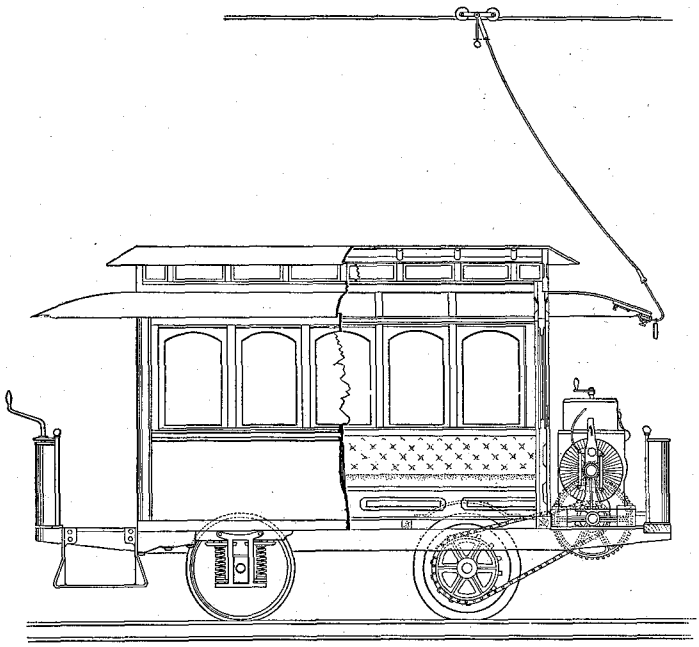
From Martin and Wetzler's "Electric Motor"

SIDE ELEVATION OF THE DAFT LOCOMOTIVE "BENJAMIN FRANKLIN"

Showing the motor hinged at one end and a screw for increasing the friction contact between the motor and the driving-wheel.

and destructive of the controlling switch, and some years later there was combined with the simple series-parallel control that known as the rheostatic method, or variation of current strength by altering resistances in the circuit of the motors. This makes the change-over much more easy, and also gives a possibility of additional speed variations. All use of resistance is wasteful, but it is a temporary necessity, and the combined methods are now universally employed on all tramway work where continuous-current motors are used.

becoming active. In the fall of 1882, Dr. Joseph R. Finney devised a system for operating electrically propelled omnibuses, the current to be taken from two overhead wires on top of which ran a small trolley connected to the vehicle with a flexible cable. In England, about the same time, following a paper on automatic railways read by Professors Ayrton and Perry before the Royal Institution, Dr. Fleeming Jenkin proposed a scheme of telpherage, or automatic overhead railway, which was largely developed by those gentlemen.



From an old catalogue (Van Depoele)

TYPICAL EARLY APPLICATION OF THE VAN DEPOELE ELECTRIC MOTOR TO STREET RAILWAY CARS

The motor is carried on the front platform and connected by counter-shaft and chain to one axle. The current is taken from an overhead wire by a traveling trolley connected to the car by a flexible cable, the track carrying the return current.

In the same year, 1881, I constructed independently a machine at the Torpedo Station, Newport, having two armature circuits, and a plug switch by which like series-parallel combinations could be made.

Soon afterward Siemens constructed an experimental road near Meran in the Tyrol to demonstrate the possibilities of electric traction for the St. Gotthard Tunnel, and later small lines at Frankfort, Molding, and elsewhere. These were followed by a comprehensive scheme for a combined elevated and underground road, submitted to the city authorities at Vienna.

Meanwhile several other inventors were

Opportunity is often responsible for inventions, and certainly largely so for my entry into the railroad field. While a midshipman in the United States naval service, I had become intensely interested in various electrical inventions, much to the annoyance, I suppose, of my shipmates, who were often compelled to listen to my descriptions; and during 1879–81 I was active in experiments with dynamo-electric machines. Ordered in 1882, at my request, to the Crystal Palace Electrical Exhibition at Sydenham, England, I soon became impressed with a belief in the possibility of operating the underground railway elec-

trically. I first considered the use of main and working conductors, the latter of moderate size and carried between the tracks, the return circuit being completed by the traffic rails—what may be called the third-rail or conductor system; but later, noting the complication of switches on certain sections of the road, I conceived the idea of a car moving between two planes which were to be the terminals of a constant potential generating system, the driving motor to complete the circuit between them. For practical application the lower of the planes was to be replaced by the running track and all switches and sidings, and the upper one by rigid conductors supported by the roof of the tunnel and following the center lines of all tracks and switches, contact to be made with a self-adjusting trolley-wheel carried on the car roof over the center of a truck. Although I did not apply for a patent on the latter idea until three years later, and was then partly beaten by Mr. Van Depoele,—my return to the United States being the earliest permissible date of reference,—I have always felt that this was really the forerunner of the modern trolley, or at least that Van Depoele and I had independently and almost simultaneously made similar inventions.

Keenly alive now to electrical developments, I soon afterward obtained leave, handed in my resignation from the navy, and, returning to the United States in the spring of 1883, entered the service of Mr. Edison, and, after spending a year on central-station work, began the development of various kinds of motors.

The year was prolific in experiments. Pending the settlement of patent issues, Edison and Field combined their interests in the Electric Railway Company of the United States, and operated a small locomotive called "The Judge" around the gallery of a building at the Chicago Railway Exhibition. (See pages 437, 438.) The motor used was a Weston dynamo mounted on the car, and connected by a beveled gear to a shaft from which power was transmitted by belts to one of the wheels. The current was supplied through a center rail and track circuit. A lever operated clutches on the driving-shaft, and the speed was varied by resistances. The reversing mechanism consisted of two movable brush-holding arms geared to a disk operated by a lever, each arm carrying a pair of brushes, only one of which could be thrown into circuit at a time in such a way as to give the proper direction of movement.

Early in the year, Charles J. Van Depoele, a Belgian by birth and originally a cabinet-maker, a tireless worker, ardent electrician, and prolific inventor, who had become interested in electrical manufacturing, energetically attacked the railway problem, on which his impress has been permanently left. His first experiment was conducted near his works in Chicago, in the winter of 1882–83, where a car was operated by a five-light dynamo used as a motor, the current being taken from a wire laid in a trough between the tracks. In the autumn a car was operated at the Chicago Industrial Exposition, and was the beginning of much work to which reference will be made later.

Among the American workers of this period one of the most active and prominent was Leo Daft, who, after considerable development in motors for stationary work, took up their application to electric railways, making the first experiments in 1883 at his company's works in Greenville, New Jersey, and resuming them in November of that year on the Saratoga and Mount McGregor Railroad. The locomotive used there was named "The Ampere," and pulled a full-sized car. The motor was mounted on a platform and was connected by belts to an intermediate shaft carried between the wheels, from which another set of belts led to pulleys on the driving-axles. A center rail and the running rails formed the working conductors. Variation of speed was obtained by variation in the field windings.

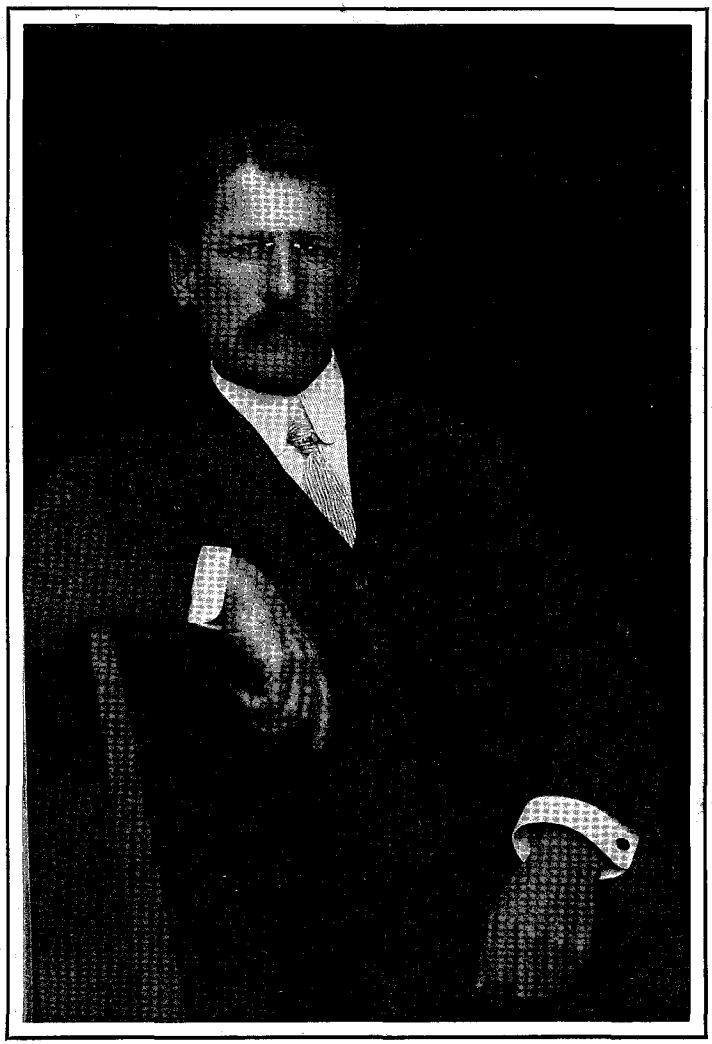
Meanwhile work had begun in Great Britain, where the first regular road put in operation was that known as the Portrush Electric Railway to the Giant's Causeway in Ireland, installed in 1883 by Siemens Brothers of London. Power was generated by turbines, and the current was transmitted by a third rail supported on wooden posts alongside the track, the running rails being used to provide a return circuit. The pressure used was two hundred and fifty volts. This was followed in the same year by a successful short road at Brighton, installed by Magnus Volk, the running rails alone being used; and experiments

SOME OF THE PIONEERS IN THE DEVELOPMENT OF ELECTRIC TRACTION

were also carried on with storage batteries at Kew Bridge, London, but these were soon abandoned.

The following year showed equal activity. Van Depoele operated a train by

Horse Railway Company. The equipped section of the road was two miles long, the conduits were of wood laid between the tracks, and two cars were employed, each of which was equipped with a motor car-



From a photograph by Hollinger

FRANK J. SPRAGUE

a dummy at the Toronto Exhibition, current being taken from an underground conduit; and Daft installed small showroads at the Mechanics' Fair, Boston, at Point of Pines, and at Coney Island.

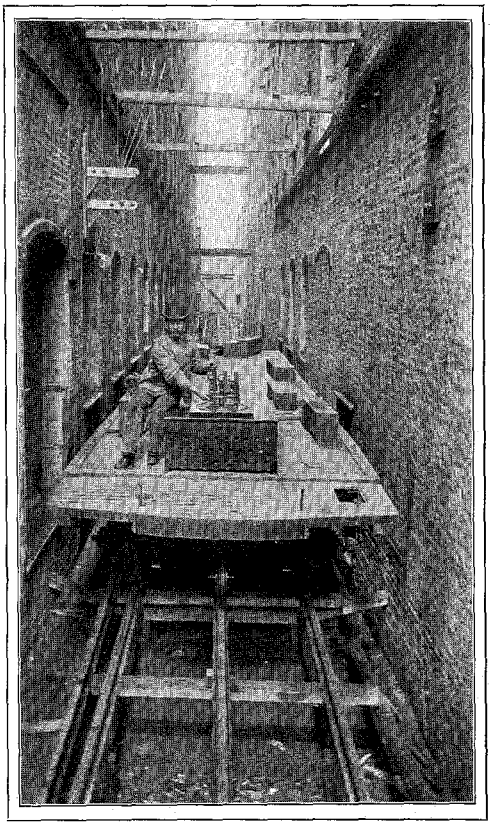
In August Messrs. Bentley and Knight, who had conducted some experiments in the yards of the Brush Electric Company in the previous autumn, installed a conduit system on the tracks of the East Cleveland

ried under the car and transmitting power to the axle by wire cables. This was operated spasmodically during the winter, and then abandoned.

In this year, also, Dr. Wellington Adams of St. Louis proposed a departure in motor mounting which recognized the necessity of removing the motor from the car body and directly gearing it to the axle. In his plan the armature was carried by

and revolved directly on the axle, and the field-magnets by a frame rigidly joined to the axle-boxes, this frame also carrying an intermediate gear which formed the connection between a pinion on the armature sleeve and a gear on the car axle. In operation, of course, the armature and axle revolved in opposite directions. The scheme was impracticable, and found no commercial application.

In 1884–85 John C. Henry installed and operated in Kansas City a railway supplied by two overhead conductors on each of which traveled a small trolley connected to the car by a flexible cable. The motor was mounted on a frame supported on the car axle, and the power was transmitted through a clutch and nest of gears giving five speeds, very much in the fashion of the automobile of today. Subsequently a portion of another road was equipped. A number of experiments seem to have been conducted there, and in some of them the rails were used as a return. The collectors were of different types, and it is said that, among others, one was carried on the car. The final selection was a trolley having four wheels disposed in pairs in a horizontal plane, carried by and gripping the sides of the wires. This feature, but using one wire and rail return, characterized a road installed by Henry at San Diego, California, two years later.



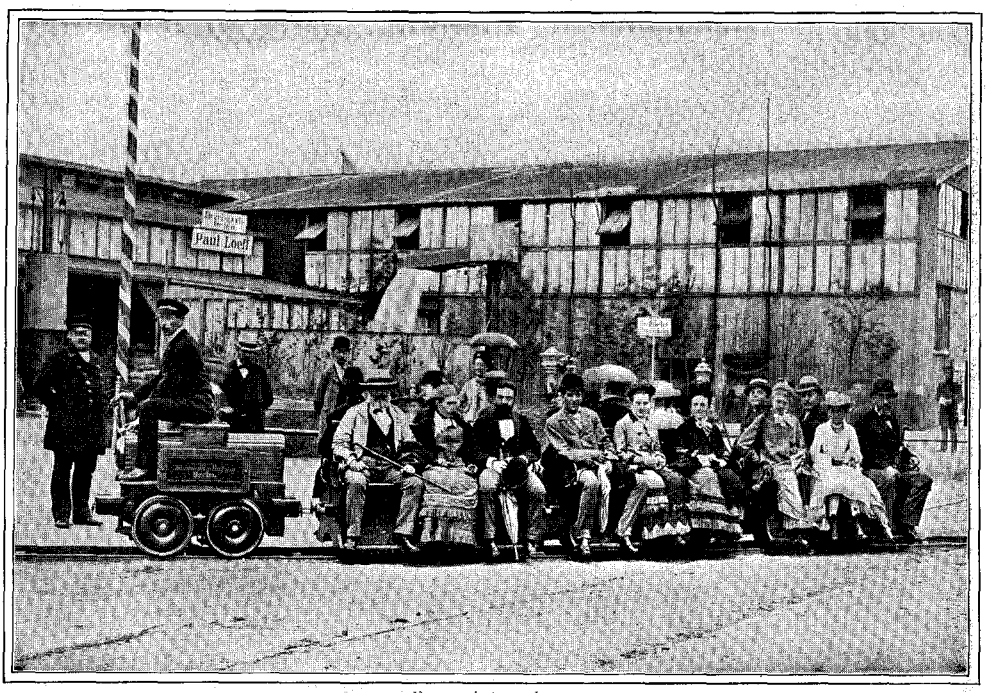
From a photograph

TWO SPRAGUE MOTORS BEING RUN BY JOHN CRAWFORD AT THE DURANT SUGAR-REFINERY, NEW YORK, WINTER OF 1885–86

The motors are mounted on the truck under the platform, and the current is taken from the third rail in the center.

The succeeding two years were marked by considerable activity. In the early part of 1885 Professor Short of Denver began a series of experiments on a short piece of track, which was followed by the construction, in conjunction with J. W. Nesmith, of a section of road for conduit operation on the series system—one in which the same current was sent through all motors on the line by automatically sectionalizing the conductors. This plan contemplated using a current constant in quantity, with variation of pressure according to the number of motors. The speed and direction were varied by shifting the commutator brushes or diverting a part of the current around the motor. These experiments were continued during 1885–1886, and were repeated at Columbus, but were doomed to ultimate failure because of the principles involved. Subsequently the multiple system of distribution, each motor of which is independently supplied from a source of constant pressure, having been proved the suitable one, Short adopted it, and for a time essayed the use of gearless motors for tramway work, but reverted later to the geared type.

Daft began work on the Hampden Branch of the Baltimore Union Passenger Railway Company in August, at first with two, and a year later with two more dummies, which pulled regular street-cars. A central and the running rails were used for the normal operation, but at crossings an overhead conductor was installed, and connection was made with it by a transversely hinged arm carried on the car and pressed upward against it by a spring. The driv-



From a photograph

FIRST ELECTRIC RAILWAY OF THE WORLD, INSTALLED BY SIEMENS AT THE BERLIN EXHIBITION, 1879

The current is taken from a dynamo and conveyed through the rails.

ing was by a pinion operating on an internal gear on one of the axles.

This was, I think, the first regularly operated electric road in this country, and the conditions under which the contract was taken, including waiting a year for payment conditioned on satisfactory operation,—and finally, even on these onerous terms, secured only in the face of an opinion by a well-known scientist that no one but "a knave or a fool" would undertake it,—were anything but encouraging. Fortunately for Daft, however, T. C. Robbins, the general manager of the railroad company, was strong in the faith.

This equipment was followed by a more ambitious one—that of a section of the Ninth Avenue Elevated Railroad for a distance of two miles, where a series of experiments was carried on, during the latter part of the year 1885, with a locomotive called the "Benjamin Franklin." The motor was mounted on a platform pivoted at one end, and motion was communicated from the armature to the driving-wheel through grooved friction-gears held in close contact partly by the weight of the machine and partly by an adjustable screw device. This locomotive, pulling a train of cars, made several trips; but the experiments were soon suspended, and they were not resumed till three years later, when, during several weeks, a rebuilt and improved "Benjamin Franklin" was frequently run between the steam-trains on the section between Fourteenth and Fiftieth streets, attaining at times a speed of twenty-five miles an hour, and on one occasion pulling an eight-car train up the maximum grade of nearly two per cent. at a seven-mile rate.

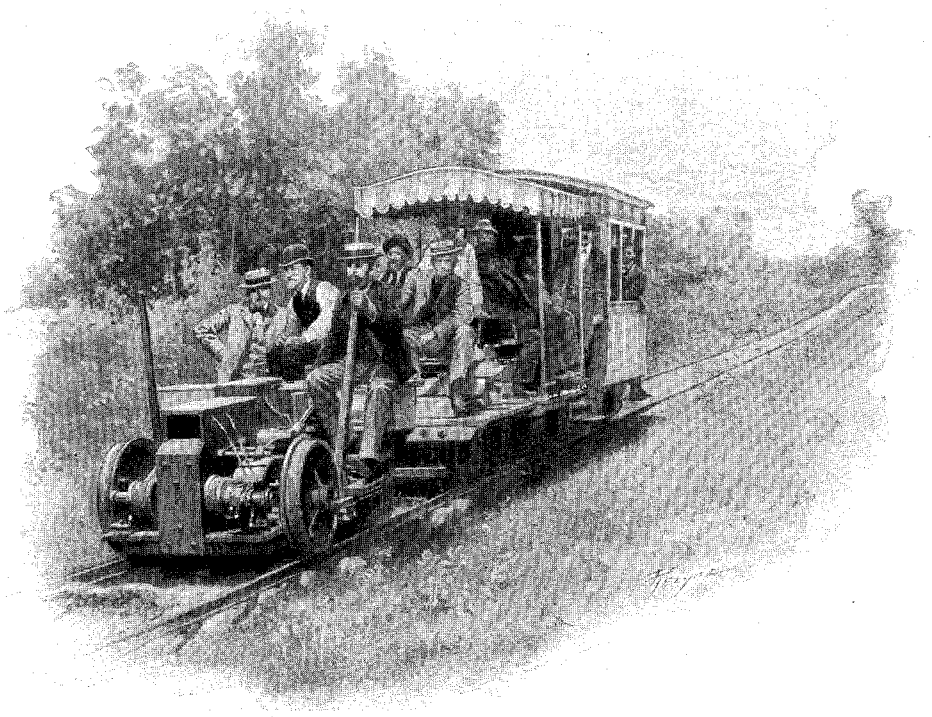
In the summer of 1885 Van Depoele resumed operations at the Toronto Exhibition, using on this occasion an overhead wire and a weighted arm pressing a contact-wheel up against it. His first commercial installation was made in the autumn on the South Bend, Indiana, Railway, where five small cars were operated; then one in Minneapolis, where an electric car took the place of a steam-locomotive. These were followed in the following year by small roads at Windsor, Canada; Appleton, Wisconsin; Port Huron, Michigan; Scranton, Pennsylvania; and Montgomery, Alabama; and one was also started by Fisher-Rae at Detroit, using a depressed third rail.

During this period little work was done

abroad. Mr. Anthony Reckenzaun, an ardent advocate of storage-battery operation, who in 1883 had conducted some tests with an electric launch, began the operation of a car at Millwall in the autumn of 1884, and another in the spring of 1885 at Battersea, following with a like demonstration in Berlin in December. His car body was mounted on bogie trucks, and the motors were connected by worm-gearing to one axle on each. Reversal was effected by using two sets of brushes, and regulation of speed by variously grouping the motor armatures and field circuits. There was also installed a short road at Bessbrook-Newry in 1885, under the direction of the Messrs. Hopkinson, and at Ryde in 1886, in which latter year was also installed the Blackpool road by Holroyd Smith. In the latter case the conduit system was used with complete metallic circuit. The motor was carried under the car, between the axles, and was connected by chain-gearing. Fixed brushes with end contact were used for both directions of running.

Meanwhile my early interest in electric-railway work had been renewed. On resigning from Mr. Edison's employ in 1884, I had formed the Sprague Electric Railway & Motor Company, of $100,000 nominal but no cash capital, with which I made a contract by which virtually all its capital stock was issued to me, on my agreement to assign patents and inventions, conduct experimental work, and pay myself the munificent sum of $2500 a year salary. Two friends took, I think, about sixteen shares of stock, the proceeds of which quickly went for personal needs; and, being without means, I made an agreement with Mr. E. H. Johnson, then president of one of the Edison lighting companies, by which he was to meet my financial obligations to the company for a portion of the profits. I was vice-president, electrician, treasurer, and general factotum. One small room sufficed for our needs, and much of the mechanical and electrical work I did myself.

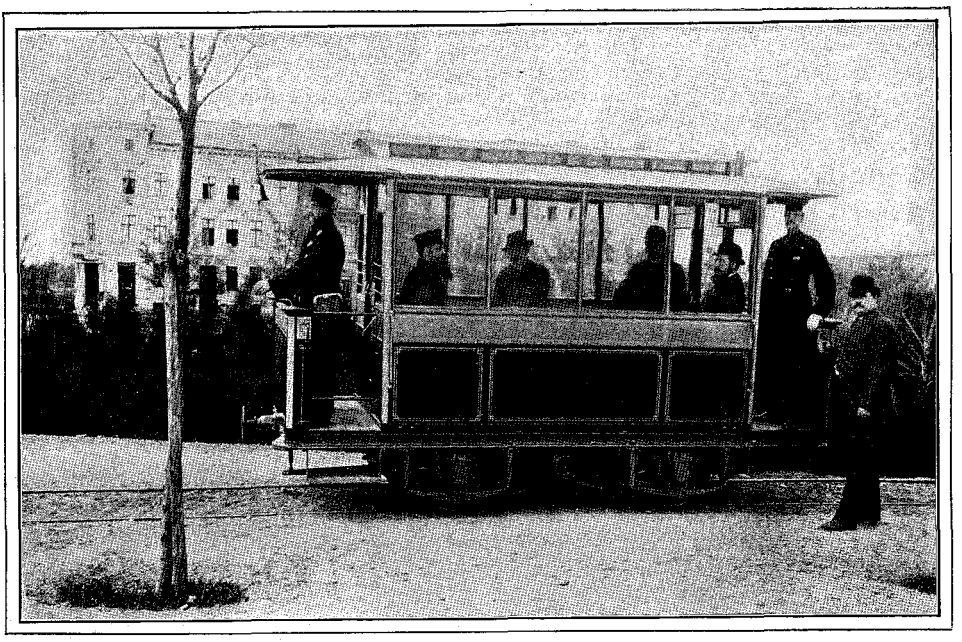
In the autumn of that year I sent to the Philadelphia Exhibition a number of motors which attracted considerable attention,



Drawn by C. M. Relyea from a photograph

EDISON ELECTRIC LOCOMOTIVE, OPERATED EXPERIMENTALLY AT MENLO PARK IN 1880

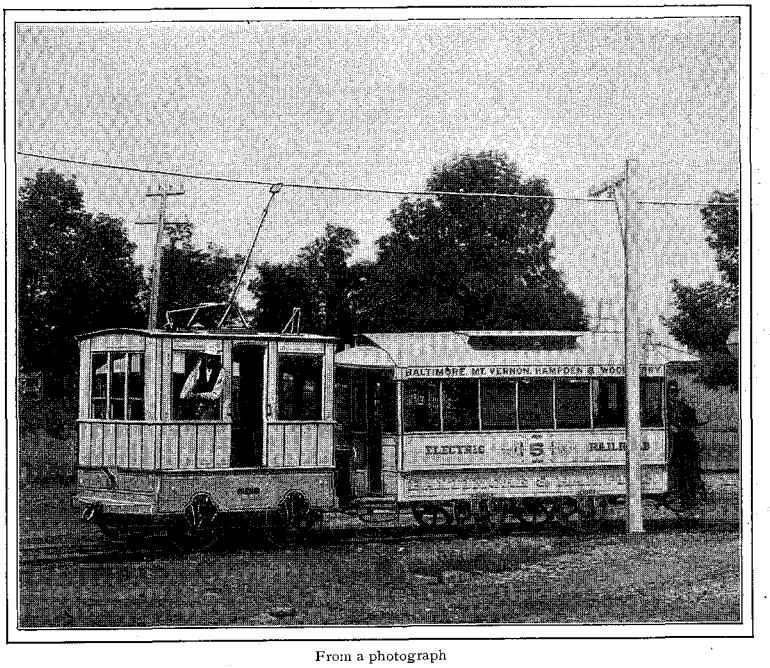
It is pulling two small cars. The current passes through the rails.



From a photograph

SIEMENS CAR AT LICHTERFELDE—THE FIRST REGULAR ELECTRIC RAILWAY, 1881

and one type was officially recommended for use on the Edison circuits; another was intended for railway work. This was a starter, and after making rapid advance in the installation of stationary motors, I took up the railway problem, and, having in 1885 schemed out a system using motors under each car, shunt-wound so as to enable current to be returned to the line in reducing speeds, I read a paper in De-

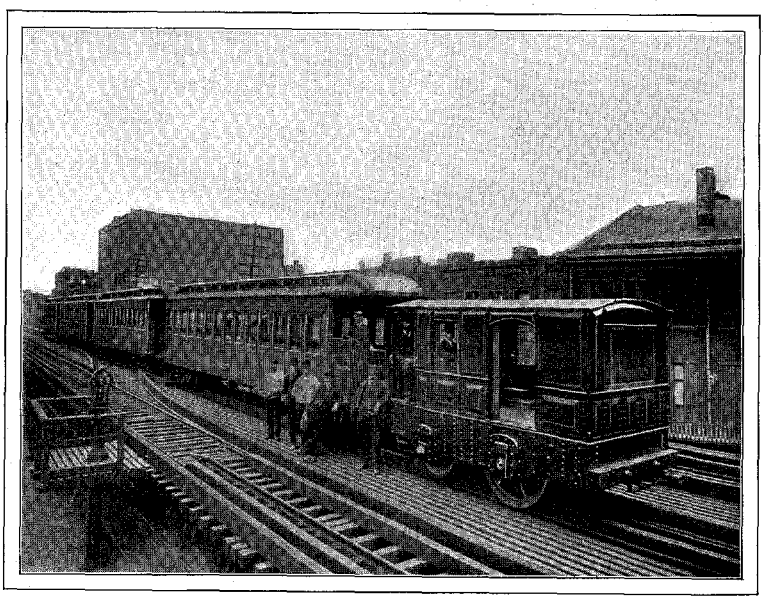


From a photograph

DAFT DUMMY CAR ON THE HAMPDEN ROAD, BALTIMORE, 1886

The under-contact trolley was used at crossings. This was the first regular electric road in the United States.

cember before the Society of Arts, Boston, in which I advocated the equipment of the Manhattan Elevated Railroad. I had already begun the construction of experimental motors. Shortly afterward a regular truck was equipped with two motors of an aggregate capacity of about twenty-five horse-power, and in the early part of 1886 a long series of tests was made on a private track between the walls of the Durant



From a photograph

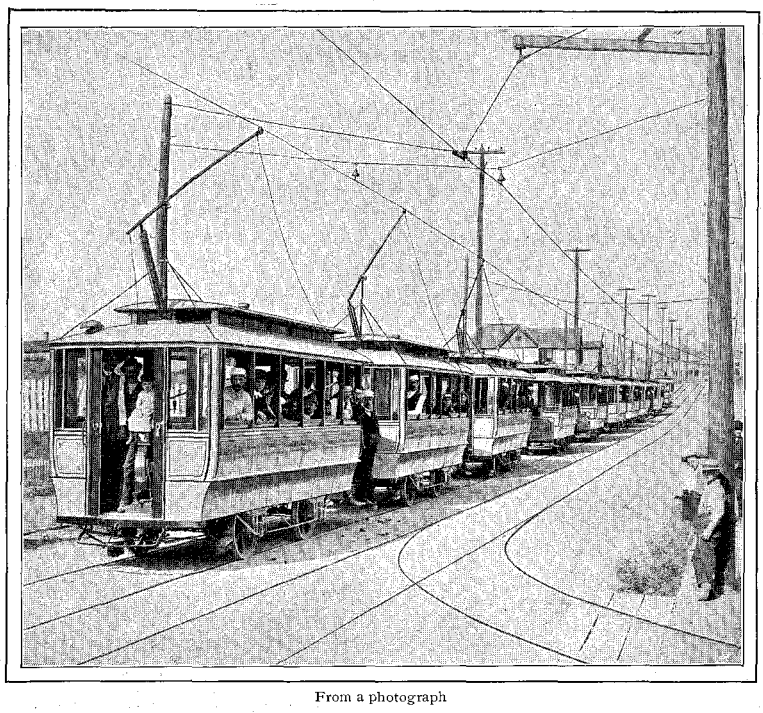
THE DAFT LOCOMOTIVE "BENJAMIN FRANKLIN" OPERATING A TRAIN ON THE NINTH AVENUE ELEVATED ROAD, NEW YORK, JULY, 1885

sugar-refinery on East Twenty-fourth street, New York, where the Edison-Field interests had installed a battery of dynamo machines for making tests of their own, which for some reason or other had been suspended. (See page 443.)

Two incidents connected with these experiments stand out vividly in my recollection. A number of people connected with the Manhattan Railroad witnessed them, and, among others, at one time the late Jay Gould. The motors were mounted on a truck placed under a full-sized car platform on which were loaded iron bars; the regulator was on top, and near by what is known as a safety-catch, a strip of lead, was inserted in the electric circuit. Keenly alive to the importance of the visitor, and confident in the possibilities of the machines and control, after several ordinary demonstrations I suddenly reversed them, when the instant excess rush of current blew the safety-catch into a small volcano, and Mr. Gould was strongly inclined to find interest elsewhere. He never came back.

About this time I was visited one day by Superintendent Chinnock of the Pearl-street Edison station, who congratulated me on the outcome of the experiments, and offered $30,000 for a sixth of my interest. His arguments were sound, being to the effect that if success came the remaining five-sixths interest would probably bring me riches; but if failure should be the outcome, $30,000 was not to be despised. Although I probably did not have money enough to pay my board for a month, I declined the offer, much to his surprise, expressed by the retort: "Well, you 're a —— fool!" Measured by every common-sense view, I was. But the story has a sequel.

At the end of April, while away getting a much-needed rest, I received a telegram from Johnson, who was, if anything, strenuous, stating that he had promised Cyrus W. Field that four days later he would show a car in operation on the Elevated Railroad. It seemed an impossibility, but I hastened back, and we got together car body, truck, and motors, and finished a



From a photograph

VAN DEPOELE ELECTRIC STREET RAILWAY AT DAYTON, OHIO, CONSTRUCTED IN 1888

An under-contact arm brings the current from the overhead trolley wire to the motor carried in the front end of the car.

controller, in spite of a strike, making our connections by candle-light.

At one o'clock on the appointed day an impressive crowd of railway and banking interests had gathered; and as we did not get current for testing until after their arrival, initial failure seemed assured, and I was fighting mad at the predicament in which I found myself. But I had to make an attempt; and finally, after trying first one machine and then the other with no response, in sheer desperation I threw both motors into circuit, moved the regulator, and the car responded perfectly. For two hours every feat which could be tried with the machines was performed without a hitch. With something of relief I finally saw the car deserted, and, exhausted by the exciting experiences through which I had passed, I sat pondering over the run, when Chinnock came to me again, apparently much impressed with what he had seen, and this time offered $25,000 for a one-twelfth interest. I cared little at the time, but he was persistent and finally got it; a few weeks later another twelfth went to some one else for $26,250. A curious rumor came to me later, to the effect that the first purchase was for a prominent spiritualist, and was made on spirit advice!

The result of the day's work determined us to continue the experiments, and they were not terminated until December of that year; but in all these months, so far as I remember, not a director or a stockholder of the road ever took the slightest interest in what was being done. During the summer the first pair of motors was supplemented by a second set, and, in addition to metal resistances, salt water was used as a regulator to vary the speed of the car. This latter accidentally led to a curious result—the maintaining at will of a brilliant electric arc under water.

The machinery used on these experiments may be termed the parent models of the modern railway motor. They were centered through their brackets on the driving-axles of the truck, and flexibly suspended at the opposite ends from the transom, wheelbarrow fashion, the elliptic or main springs intervening between this support and the car body, and hence not being affected. The motors were single-geared to the axles, had one set of tilting brushes, were run open,—that is, unpro-

tected,—and were used not only for propelling the car, but also for braking it.

One of them was put into service at the East Boston sugar-refinery, the current being supplied from a trolley carried on an overhead wire, and is, or at least was a few months ago, still in existence. Two others operated a snow-sweeper and an ice-cutter on the Alston division of the West End Railway in Boston; but these have gone the ultimate way of all pioneers.

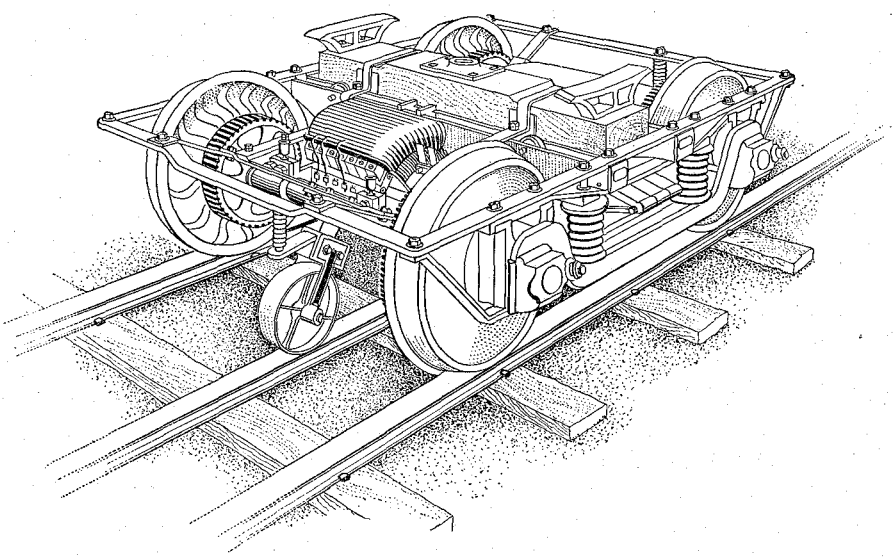
Work on the Manhattan system was evidently ahead of the times, and yet I was not sufficiently discouraged but that I immediately began the construction, on the suggestion of J. H. Vail, of a locomotive car to be equipped with four seventy-five horse-power motors, each with two armatures geared to the axles. But, the elevated field offering little of promise, I soon turned my attention to tramway work, and began the development of the type of motor finally adopted in Richmond, one earlier form being used in Julien storage-battery experiments in Philadelphia for William Wharton, where a Reckenzaun motor was also used. Here series-parallel grouping of both batteries and motor circuits was used on the Sprague car, and a series-parallel and resistance control of motors on the car operated by Reckenzaun and Condict. Then a storage trolley-car was tried in New York and one in Boston.

To illustrate the pessimistic attitude of the time, I recall that while preparing for one of these experiments that veteran father of tramways, the late John Stephenson, told me that he was acquainted with every trial which had been made with self-propelled cars in this country and abroad, and that he did not think the conditions met with on American roads and grades could ever be successfully overcome. I stated my intention to gear a motor to each axle, and to use all the weight of the car motor and passengers for adhesion; to which he replied that possibly that might accomplish the result, but it was the only way. He lived to see my prophecy come true.

A paragraph in the New York "Sun" about August, 1887, seems curious reading to-day. It was in part as follows:

ELECTRICITY ON WHEELS

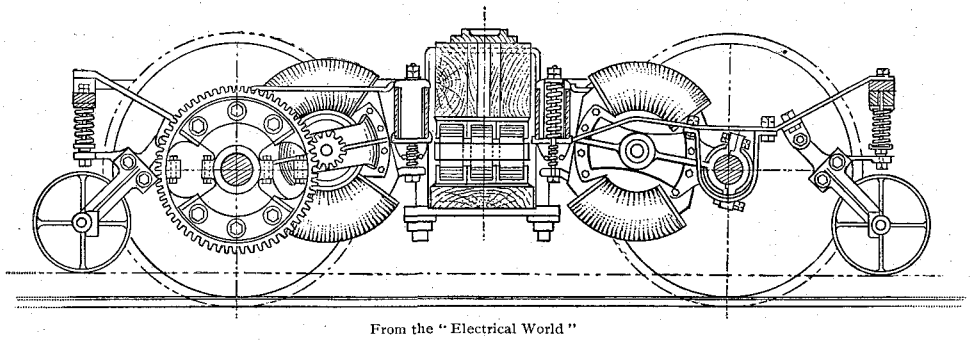
They tried an electric car on Fourth Avenue yesterday. It created an amount of surprise and consternation from Thirty-second street to One Hundred and Seventeenth street that was something like that caused by the first steamboat on the Hudson. Small boys yelled, "Dynamite!" and "Rats!" and made similar



From the "Electrical World"

TRUCK OF THE SPRAGUE CAR USED AT THE DURANT SUGAR-REFINERY AND IN THE ELEVATED RAILWAY EXPERIMENTS IN 1885–86

The two motors are centered on the axles, geared to them, and flexibly suspended from the transom. Subsequently this became the universal practice.



From the "Electrical World"

SIDE ELEVATION OF THE SPRAGUE ELEVATED RAILROAD CAR TRUCK, SHOWING THE METHOD OF CENTERING, GEARING, AND SUPPORTING THE MOTORS, AND THE CONTACT-WHEELS RUNNING ON THE THIRD RAIL

appreciative remarks until they were hoarse. Newly appointed policemen debated arresting it, but went no further. The car horses which were met on the other track kicked, without exception, as was natural, over an invention which threatens to relegate them to a sausage-factory.

Reviewing the conditions at the beginning of the year 1887, eight years after Siemens made the Berlin exhibit, statistics compiled by Mr. T. Commerford Martin, including every kind of equipment, summed up only nine installations in Europe and ten in the United States, with an aggregate of less than sixty miles of track and about one hundred motors and motor-cars. These were characterized by the utmost diversity of practice. There were high and low pressures, traffic-rail conductors and conduits, third rail and side, with rail return, slotted overhead tubes, single and double overhead wires, single and double travelers on them, and upward-pressing arms carried on the cars. The motors were of varied construction and control, and generally used two sets of brushes. One to a car usually constituted an equipment, and it was carried on a dummy or the front platform, and connected to one wheel by a belt or chain-drive. The cars were mostly single-ended and controlled from one point. The science was in a chaotic state, and commercial success on a large scale, involving radical departures in practice, was needed to focus the advantages of electric traction, even then thrusting themselves into prominence.

Supplementing small additional roads by Van Depoele at St. Catharine's, Ontario; Lima, Ohio; Binghamton, New York; and Jamaica, Long Island; and by Daft at Asbury Park, New Jersey, and Los Angeles, California, such an opportunity came in the spring of 1887—and, by good fortune, to my company—in the contract for the Union Passenger Railway of Richmond, Virginia; and about the same time one of somewhat different character to the Bentley-Knight Company, on the Observatory Hill Passenger Railway in Allegheny City, Pennsylvania; and that year may be said to mark the beginning of active commercial development.

The latter road was about four miles long, one quarter being of conduit construction, and the remainder of double overhead line on the side, with traveling trolley connected to the car with flexible cables. It presented unusual difficulties. There were thirty-four regular curves and numerous heavy grades, the maximum being over twelve per cent., and one averaging six per cent. for nearly a mile. The cars were each equipped with two fifteen horse-power motors geared to the axles and overhung. The control was by resistance variation. This line was opened early in 1888, and continued in successful service for some time; but the conduit was finally abandoned, and a new equipment was installed with underrunning trolley.

Reserving to another article the narrative of further progress, I may here emphasize the fact that whatever was accomplished was often in spite of most discouraging financial conditions, and was largely due to individual initiative and sacrifice on the part of the men in actual charge of the work. In this connection I may cite a few of the experiences of Elmer P. Morris, who was Van Depoele's immediate assistant, and engaged in actual construction for him during the six years beginning with his first experiment.

A personal letter is eloquent in the tale of lack of experience and funds, owing to which many amusing and annoying expedients were often necessary. For instance, in the winter of 1886, at Port Huron, Michigan, Mr. Morris states that their party, having much difficulty with the rail return, sent a man over the line with a bag of spikes. Standing on the rear end of the car, he watched the rail, and whenever arcing was seen at the rail joints he stopped the car and drove a spike between the rails. As the road was poorly constructed, the spikes gradually worked loose, and the replacing became a daily habit. Sometimes, as in Binghamton, New York, where an old horse-road was made over into a trolley-line, the rails, never heavy, were so thin and worn that the cars actually ran on the web of the rail. On the road between Brooklyn and Jamaica, which was constructed in 1887, in many places where the line crossed the roads used by the truckmen, rails were missing, and it became necessary to push the car across. The schedule achieved between Jamaica and East New York was six miles an hour. When on this work Mr. Morris's total personal receipts in eleven months were ninety-five dollars, and later being ordered to Ansonia, he had to walk part way for want of car fare. These were strenuous days, and it is to a number of devoted and resourceful men like Mr. Morris that the pioneers of electric traction are indebted for much of the success that attended their efforts at a time when hard work and loyalty were vital.

THE FUTURE OF POLAND

BY DAVID BELL MACGOWAN

LIKE conflagrations by night, mutinies of reservists, revolutionary outbreaks, and bloodily suppressed strike riots have forced Poland upon the attention of a world that seemed resolved to forget her. The last Polish uprising was coincident with the central year of the American Civil War. It may help to an understanding of the present situation of the ten provinces of the kingdom of Poland to assume that the Confederate States are still under martial law, and to imagine such a state of things as this:

All Southerners excluded from offices with salaries exceeding five hundred dollars a year, and the entire South run by corrupt "carpet-baggers" animated by racial hatred.

Scarcely a new school or post-office opened since the inauguration of Lincoln.

The States without legislatures; counties and cities handed over to Washington