

THE ELECTRIC RAILWAY OF TO-DAY.

By Joseph Wetzler, M.E.



IT has been remarked truthfully that the civilization of a country may be gauged by its methods and means of communication, and the transition from the stage-coach of old to the lightning express of to-day marks as great an advance in the methods of passenger transportation, probably, as does that of the telegram over the post message. But while these improvements in methods of highway transportation have been going on steadily for over fifty years, with the brilliant results well known to all, there is one class of traffic which, even up to within a short time, has remained perfectly stationary since its inception; and that is, the street-car or tramway traffic. Beginning with the horse as the motive power, over fifty years have passed without an essential change in the method of propulsion, and it has remained for that subtle and vigorous agent, electricity, to solve the problem which has taxed the capacity of engineers for half a century. Attempts, it is true, have been made to displace the horse by mechanical power, applied in the shape of the steam and compressed-air locomotives, and again by the more recent cable; but the objections to their employment in the crowded streets, together with the now acknowledged superiority of the electric railway, allow of the assertion being safely made that, except in very rare cases, the former must now be considered methods of the past, and that the long serfdom of the horse will be brought to an end by the electric motor applied to the street-car.

As brilliant an achievement as the electric railway of to-day undoubtedly is, it has had its period of development, like every other modern industrial application of importance; and the period from its inception to final consummation was indeed by no means a short one. The reasons for this are, however,

traceable to the same causes which so long retarded the introduction of the electric light, and which were very clearly pointed out by Professor Morton in the August, 1889, number of this *MAGAZINE*; the long delay being due to the absence of a sufficiently powerful and economical generator of electricity. To the student, the tracing of the history of this development presents a most interesting line of study and research, but the limits of the present article forbid our entering upon it except to briefly mention the early workers in this field.

As far back as 1835, Stratingh and Becker, of Groeningen, and Botto, of Turin, in 1836, constructed crude electric carriages. They were shortly followed by Davidson, a Scotchman, who in 1838-39, built an electric car weighing five tons, with which he obtained a speed of four miles an hour. These were contemporaneous with others in the United States, where Thomas Davenport, a blacksmith of Brandon, Vt., built a small circular railway at Springfield, Mass., in 1835, which he operated by means of electricity. It is also worthy of note here that to Davenport, probably, belongs the honor of having first printed a newspaper by electricity, one called *The Electro-Magnet and Mechanics' Intelligencer*, in 1840. Foremost in the ranks of American pioneers in this field, however, was Professor Page, of the Smithsonian Institution, some account of whose works is given in a previous issue of the *MAGAZINE*.*

The railroad experiments of this scientist consisted in the operation of an electric locomotive between Washington and Baltimore, in the course of which he obtained on one occasion a speed of nineteen miles an hour; but the difficulties experienced with the Grove primary batteries on the car were such as to force him to abandon the scheme. The work, in this field, of

* See "The Electric Motor and its Applications," by Franklin Leonard Pope, in *SCRIBNER'S MAGAZINE* for March, 1888.

Professor Moses G. Farmer, in 1847, and of Thomas Hall, who exhibited a model electric locomotive at the Charitable Mechanics' Fair in Boston, in 1851, can only be mentioned.

All these experiments, however, interesting as they were from a scientific stand-point, were destined to practical failure on account of the enforced employment of batteries as the source of electrical energy; and it was not until the invention of the continuous-current dynamo-electric machine that the actual solution of the problem became possible. Soon after the invention of the dynamo, Siemens and Halske, of Berlin, made some attempts to apply electricity to railroad purposes; but the imperfections of the early machines led to the abandonment of the project.

But the advances which had been made in the art of dynamo-building, and the discovery of the reversibility of the dynamo, so that it could be employed as a motor, led to renewed attempts, and at the Berlin Exposition of 1879, this same firm operated a small electric railway, which was perhaps the first commercial electric railway in the world opened for regular traffic. American inventors, however, had by no means been idle, since almost at the same time Stephen D. Field, the nephew of Cyrus W. Field, of Atlantic cable fame, and Thomas A. Edison, had conceived the idea of the modern method of operating electric railways; and it is interesting to recall these attempts, as showing the lines on which these early experiments were carried out. This is illustrated by the locomotive constructed by Mr. Edison at Menlo Park, in 1880, shown on page 433, in a drawing taken from a photograph preserved in Mr. Edison's library.

These experiments encouraged other inventors in this country, among whom may be mentioned Leo Daft, who, in 1883, operated the Saratoga and Mount McGregor Railroad by electricity. Edward M. Bentley and Walter H. Knight also deserve mention for their pioneer work, which tended mainly in the direction of supplying a practical system for operating railways by means of the conduit system; and finally C. J. Van Dempoel, to whom the progress which the

electric railway has made in this country is largely indebted.

With this brief review of the efforts which have led up to the electric railway of to-day, I shall pass to the consideration of the subject as it presents itself in its latest aspect.

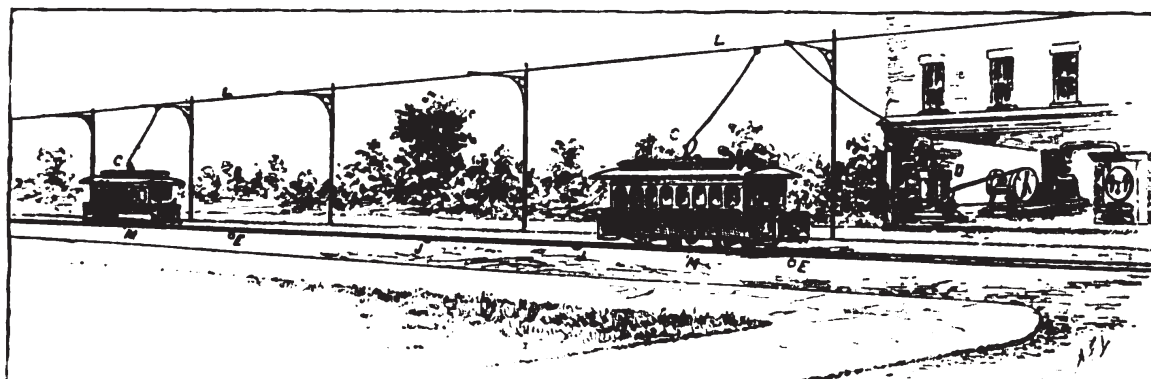
Broadly speaking, the electric car is a self-propelling vehicle, in which the propelling force is furnished by a motor actuated by an electric current. For the purposes of convenience, electric railways may be divided into three classes, depending upon the manner in which the current is supplied to the electric motor upon the car. These are:

1. The "*overhead system*," as it is called, in which the current is led from the generating machine at the station to the car through a wire placed above the ground.
2. The "*underground system*," or that in which the supply conductors are placed below the ground.
3. The "*storage-battery system*," in which the current is furnished by storage batteries carried on the car, which have been previously charged with the required current.

Though differing in name, these various systems are alike in principle, and, indeed, have much in common; but this artificial distinction may be conducive to a better understanding of the subject.

As the previous articles in this series have already given the reader a sufficiently good idea of the theory and action of the electric motor and the dynamo,* they need not be again described, and a view of the plan upon which the first of the systems of modern electric railways above mentioned is operated can be at once presented. The sketch [on p. 427] shows in outline the principal elements of this system. These consist, broadly speaking, of the generating station, the line, the car, the motor, and the return circuit. At the generating station there are an engine and boiler which furnish power to drive the dynamo, *D*. The current generated by this machine is conducted by a wire to the line *L*, which is strung on posts and

* See "Electricity in the Service of Man," in SCRIBNER'S MAGAZINE for June, 1899, pp. 653, 654; and "Electricity in Lighting," August, 1899, pp. 181-184.



Plan showing Principles of Operating the Overhead System of Electric Railways.

runs parallel with the track. The car, in order to obtain the current, makes continual contact with the line *L* by means of a trolley, the current passing down by wires to the motor *M*, connected with the axles of the car. After passing through the motor, the current passes into the wheels of the car, and thence into the track; the latter, it will be seen, is connected to the other pole of the dynamo *D*, and a complete circuit is thus formed. It will be noted that in addition to the track connection as a return for the current, the earth is also called into play, acting as a conductor in the same manner as it is employed in telegraphy, and with the same advantages. This is effected by connecting the track at intervals with large plates buried in the wet ground, and the integrity of the circuit is additionally enforced by connecting the rails electrically by means of copper wire, indicated at *J*, as the ordinary fish-plates joining the rails cannot be relied upon to give a continuous electric circuit such as required.

Some of the more important details, upon the success of which the operation of the electric railroad largely depends, should be next considered.

As recently remarked, with much truth, by a writer in referring to the electric street-car: "The truck is the car;" hence, as this element is common to the three systems above mentioned, it seems first in order to claim attention. The truck being the support of the car-body in which the passengers are carried, is necessarily limited to certain dimensions, and the problem of concentrating

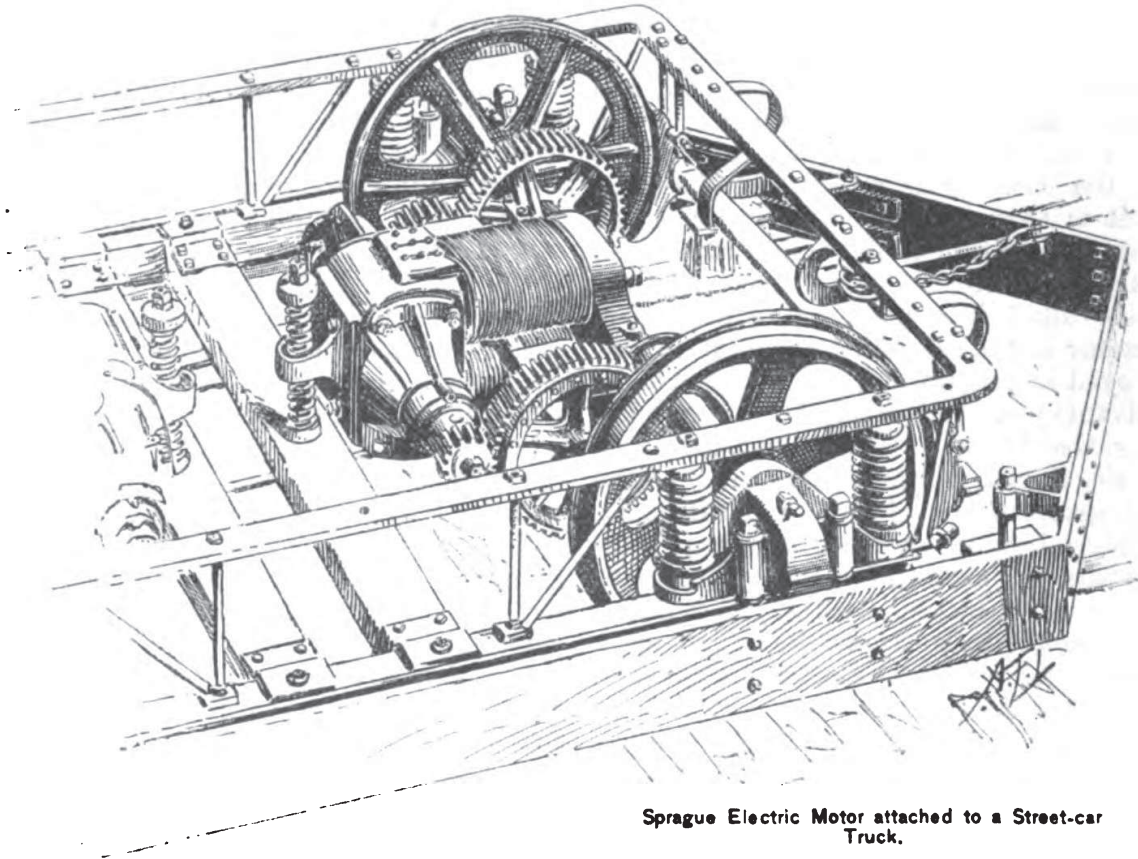
motors of sufficient power to propel the car, into the limited space available, afforded a good field for inventive genius. Again, the manner in which the power generated by the motor was to be transmitted to the wheels and axles, though apparently simple, was found to be by no means easy of solution; and even at the present time differences of opinion exist on this point. Economy in weight as well as in power requires that motors shall be run at high speed, and, as the car-wheel, as a rule, runs at comparatively low speed, it is evident that some method of reducing the speed of the motor to that of the car-wheel must be employed. Among the various methods which have been proposed and tried are friction gearing, connection by means of belts, the sprocket and chain, the worm and wheel, the direct crank action, and finally the gear and pinion. Of all these, the last may be said to be practically the only one which has thus far come into any extensive use, at least so far as this country is concerned; and, as the number of our railways in operation far exceeds that of all the rest of the world put together, it is safe, for the present at least, to designate this method as the typical one in use to-day.

In order that the reader may therefore clearly understand the construction of the ordinary electric railway truck, a view is shown on page 428 of the form designed by Frank J. Sprague, one of the most successful of the new school of electrical engineers. As the space between the bottom of the car and the ground is necessarily confined, it has been found expedient in practice to divide the motive power into two units by

the application of two motors, one to each axle, as it is evident that one motor sufficiently powerful to do the work would, as a rule, be very difficult to place under the car without interfering with its present construction. The manner in which the power of the motor is transmitted to the wheels is very clearly shown. The only moving part, the armature, has at one end of its shaft a small gear-wheel which meshes with a pinion placed upon a countershaft which passes through the legs of the magnet; and the other end carries a similar pinion, gearing with a toothed wheel connected to the axle of the car. Hence the armature of the motor, which runs at high speed, transmits its power to the axle at a lower

these wheels will always bear the same relation to each other and to the axle upon which they are mounted—a most essential point for their proper operation.

Provision must also be made for the easy starting of the car, and to prevent disagreeable shocks from the sudden starting of the motor when the current is switched on. This is accomplished by suspending the free end of the motor between a pair of springs, which are shown supported by cross-bars stretching from side to side of the truck. Thus the motor is given free vertical play for a short distance, and the shocks which would be caused by a rigid arrangement are taken up by the springs, and the car started with a gradual movement. It may be said that the advent



Sprague Electric Motor attached to a Street-car Truck.

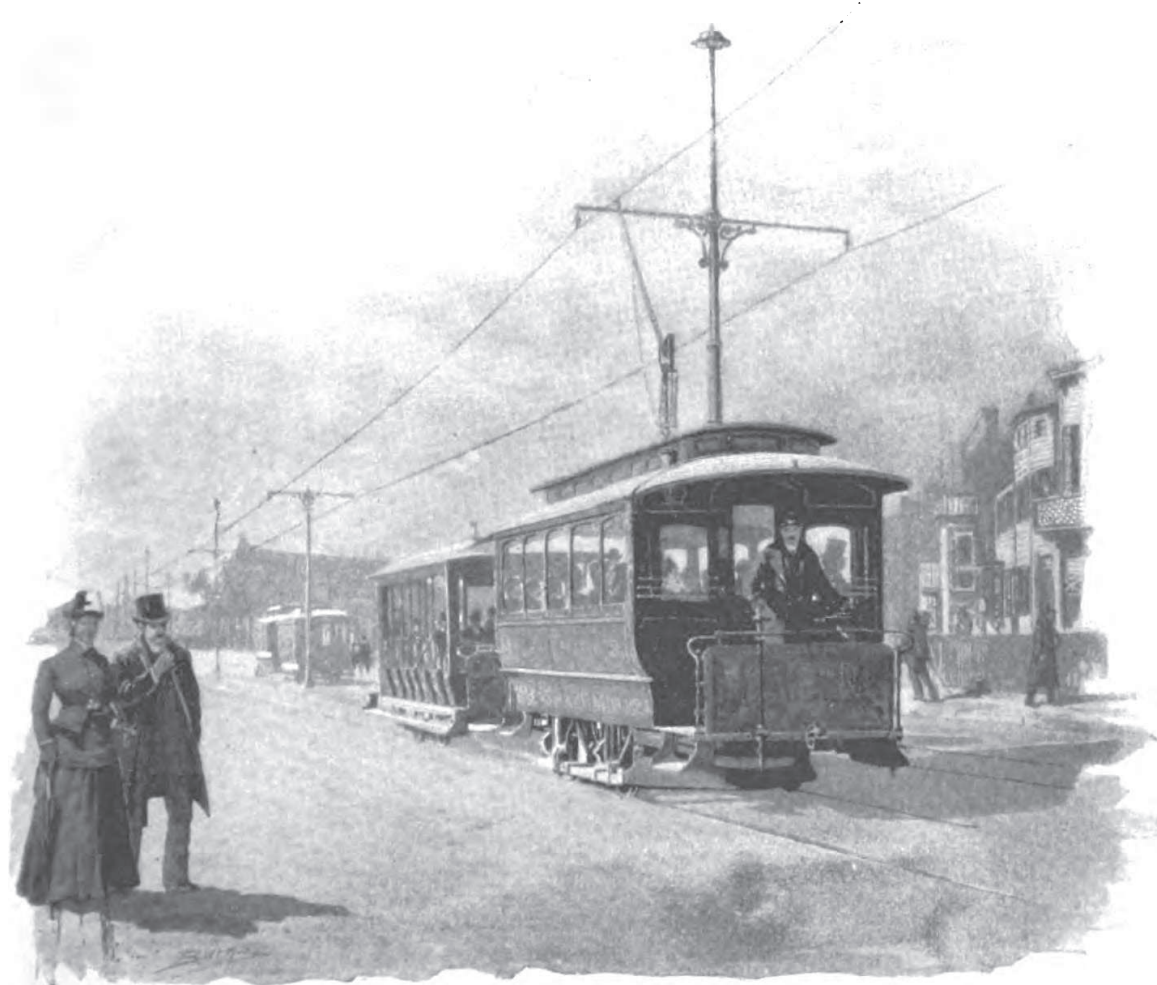
speed by means of this gearing. The successful operation of this gearing, however, requires that all these wheels shall remain in a constant fixed relation to each other, and in order to accomplish this the very ingenious expedient has been applied of centring the motor itself upon the axle of the car; thus, no matter how much the vehicle may be jarred during its passage over the track,

of the electric railroad has entailed an entire remodelling of the street-car truck formerly employed, and has indeed constituted an almost distinct, new field of invention.

It is upon a truck of the nature above described that the car-body is mounted, and the result of the construction adopted is that the working mechanism is entirely removed from view.

A small but very important detail, which has added much to the successful operation of the motor and the car, consists in the substitution of a carbon

to inclose the motor entirely within the car-wheel, and thus to relieve the axles of all strain due to the weight of the motors.



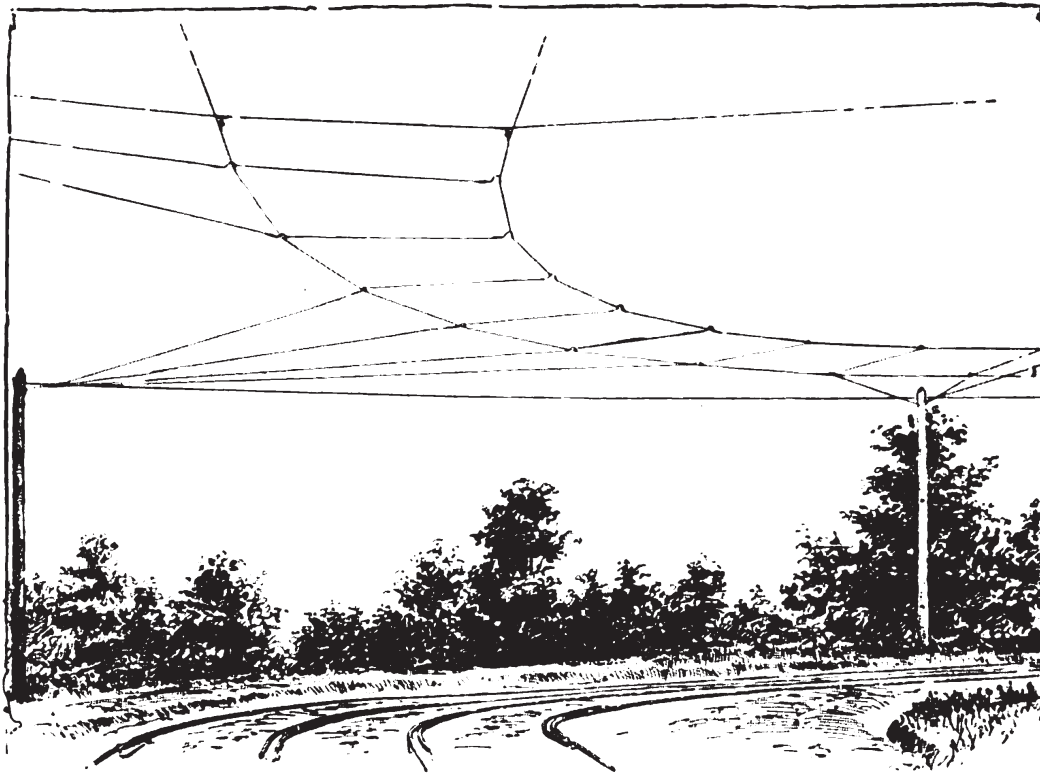
Overhead Wires for Double-track Road, suspended on a Single Line of Ornamental Poles.—Thomson-Houston Railway, Washington, D. C.

brush bearing against the commutator, in place of the copper brush which had until very recently been employed. Small as this detail may appear, it is almost safe to say that it constitutes one of the most distinct advances in the electric railway motor that has been effected since its practical application.

Another very interesting method that has been proposed for transmitting the power of the revolving armature to the axles and wheels consists in mounting the armature directly upon the axle of the car, so that no intermittent gearing whatever is required, the armature shaft and the axle being identical. The very latest idea in this department is embodied in the design of Mr. William Baxter, Jr., of Baltimore, who proposes

The consideration of the various methods by which the current is led from the generating source to the motor on the car, by means of the overhead wire, can now be entered upon. This, evidently, is most important, as upon the effectiveness and integrity of the "line" depends the successful operation of the road, just as in telegraphy the line wire requires to be maintained perfect in order to effect communication.

Looking back to the early electric railways operated by Siemens at Berlin, it is found that the same arrangement, long practised in telegraphy (which is depicted on p. 427), was there adopted; but the conductor, instead of being overhead, consisted of a central rail placed between the other two, but insulated



System of Overhead Wires, suspended from Poles on Opposite Sides of the Street. The above a curve on the Sprague Railway at Wilkesbarre, Pa.

from the ground. The current from the dynamo first passed through this central rail, then into the motor through the wheels, and then into the two outer rails and the ground, which carried it back to the other pole of the generating dynamo.

This construction was also adopted in his early work by Leo Daft, in this country; but it is evident that, except in special situations, it is not suitable on account of the danger of shock which it involves to persons and animals crossing the tracks, by coming in contact with the conductor. The two rails themselves have also been employed exclusively as conductors, the one rail being the positive side of the system, and the other the negative.

The overhead line of to-day, in connection with electric railways, is going through the process of evolution similar to that of the other elements of the system. The first attempts in this direction consisted in fixing upon posts a tube having a slot running along its entire length, and facing downward. Within this tube there was placed a slider, which was connected to the motor on the car, and which served to maintain a continuous contact between the moving

car and overhead conductor. The operation upon this method, though still continued in one or two instances abroad, was soon abandoned, however, and its place taken by the plain cylindrical wire upon which a trolley-wheel was maintained, which moved in connection with the car, and served to make the necessary contact between the motor and the overhead conductor. This trolley had therefore necessarily to be supported by the wire, and consequently demanded a wire of suitable strength to stand the strain of the travelling wheels. Hence, to avoid this difficulty the very ingenious idea was adopted of supporting the contact-wheel at the end of an arm resting on the top of the car, and pressing it in contact with the lower side of the wire; as a result of this it is evident that the wheel, instead of being a load upon the wire, actually serves to support the wire in its course; and, consequently, a much lighter construction can be adopted in this case than in that previously mentioned.

The manner in which the conductor carrying the current is maintained in position overhead is subject, naturally, to the conditions both of the traffic and

the nature of the road through which the tracks pass. Therefore there are various types of overhead constructions. In ordinary cases, in cities where two tracks are placed side by side in a street, there are two general modes of suspending the overhead wire. A very admirable example of the manner in which this can be accomplished, without obstructing the street or in any way marring its beauty, is that which is illustrated in the engraving on page 429 which represents the Thomson-Houston electric railway, operating in Washington. Here ornamental iron poles are placed at suitable intervals, and carry cross-arms, from the ends of which the wire is suspended by means of an insulator. This simple construction permits also the illumination of the street—for it may be noted that every second pole is surmounted by a cluster of incandescent lamps which light up the roadway both for the cars and for the traffic which may be passing on the streets. These lights may be run from the same current which supplies the motors on the cars, but where this is not considered desirable,

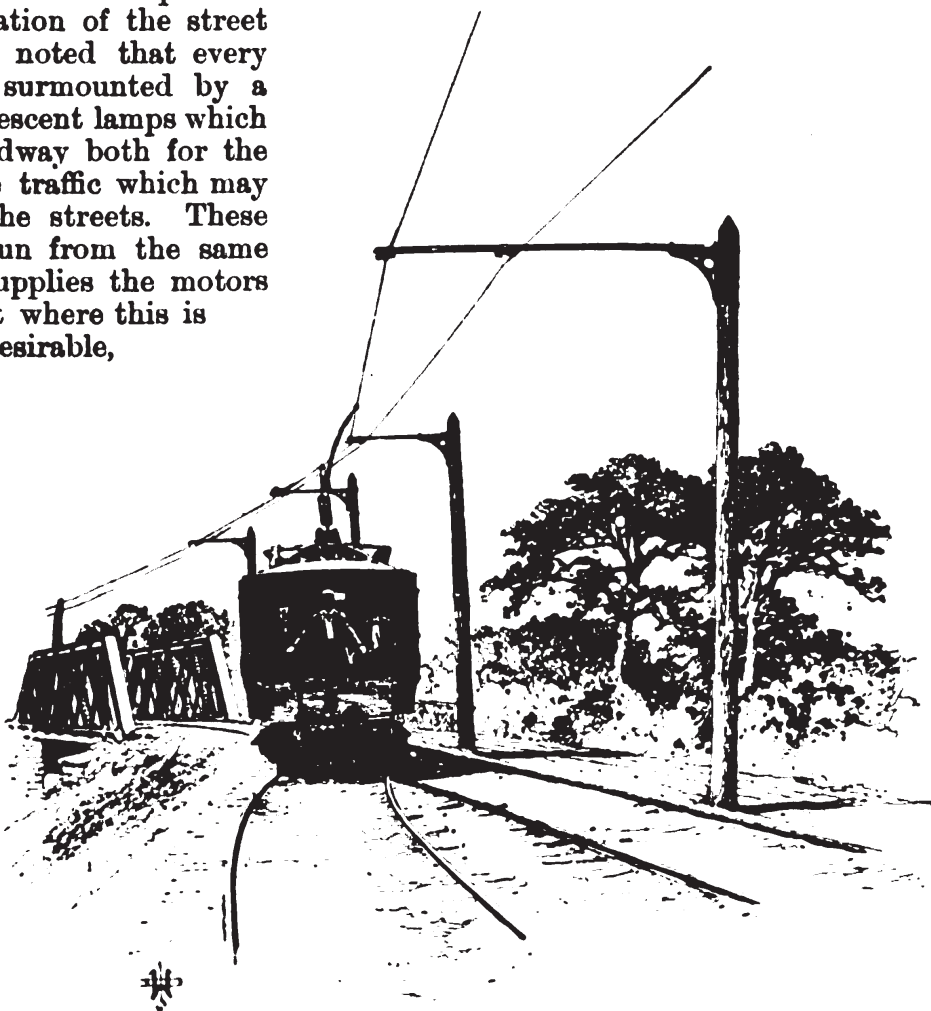
a separate conductor can be strung for that purpose; in either case the posts themselves afford a ready means for the suspension of the lamp.

Where the streets are not wide enough to permit of the adoption of a system of poles running along the centre, another method is frequently adopted, which consists in placing the posts at the curb line on either side of the street, and suspending the conductors by means of wires stretched from opposite poles across the street. This method of construction is shown

in the engraving (p. 430), which represents the operation of the Sprague electric railway at Wilkesbarre, Pa.

Electric railways in many instances connect cities with their suburbs, with tracks frequently running for considerable lengths. The method of overhead construction in such cases consists in using a line of poles having single arms extending from one side, a general type of which is well illustrated in the engraving below, which shows a section of the Thomson-Houston electric railway at Rochester, N. Y.

In the outline sketch (p. 427), the main conductor is represented by a single wire. It is evident, however, that any break in the overhead circuit, as



Poles with Single Arms for Suburban Roads. The Ontario Beach Railway, Rochester, N. Y.

there shown, would cause an interruption to the traffic. Hence at the present time there are, in fact, two systems of conductors employed; one of these, called the main conductor, is run out

from the dynamo-generating station to various parts of the road, and connects with the working conductor, as it is called, to which the trolley-wheel makes contact. The working conductor being thus fed into at a dozen places, a break in any one part of the circuit will not

upon which the contact-wheel is mounted is pivoted flexibly to the top of the car, a series of springs serving constantly to push the arm upward. It is at the same time sufficiently yielding to allow it to overcome any inequalities in the level of the wire or of the road. The

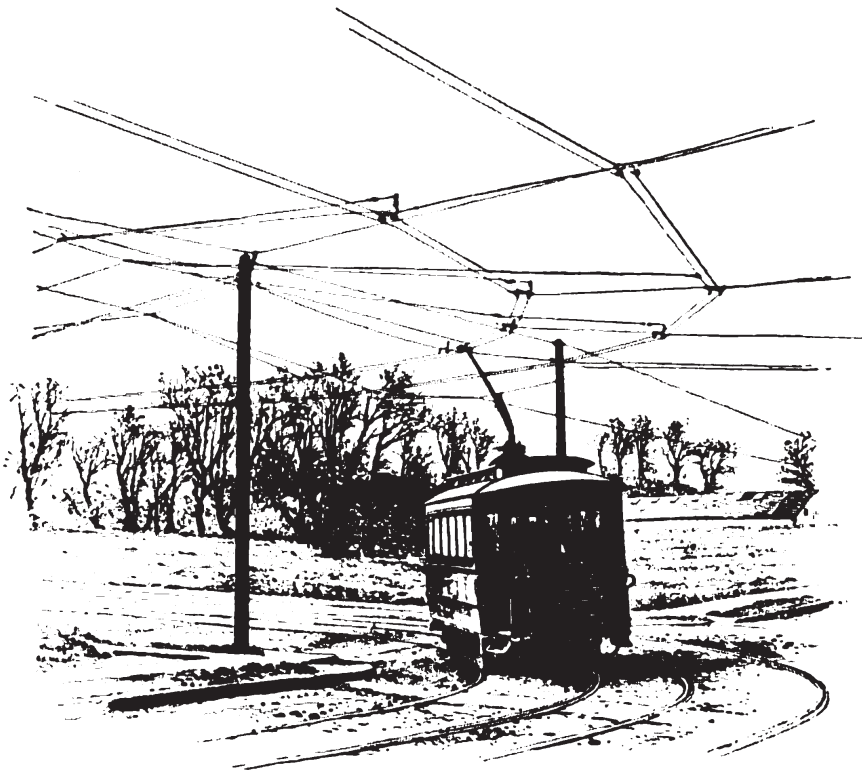
arrangement is such that the arm has a free motion from a vertical position to a perfectly horizontal one, so that electric cars may pass under bridges, for instance, reaching to within six inches of the top of the car.

The overhead system so far described consists practically of but a single overhead wire, with a ground return for the current; but there are still some who prefer to use a continuous metallic overhead circuit. This naturally entails the running of two wires instead of one; one wire serving as a feeding wire

and the other as the return wire. The principle of operation is evidently the same in both cases, and a very interesting example of this case of overhead construction is that afforded by the Daft electric railway operated in Cincinnati, a view of which is shown above.

It may be remarked that, although the large majority of the roads in operation to-day make contact with the underside of the wire by means of a wheel, there are still some who adhere to the older practice of maintaining a sliding contact with the conductor; among them being Sidney H. Short, who prefers a sliding contact at the end of the arm which is pressed up against the underside of the wire, and continually rubs against it in its passage.

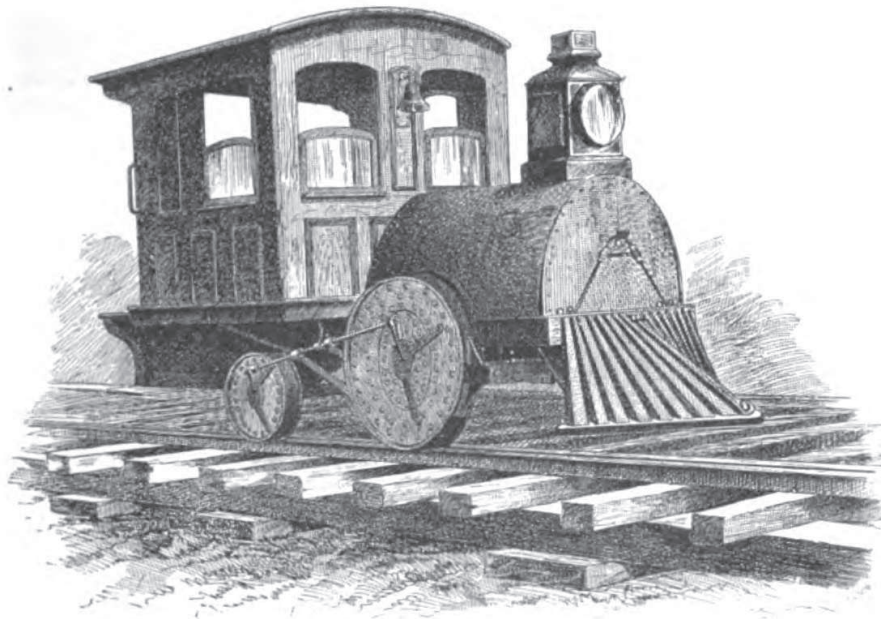
The adoption of the overhead system has been so general that but comparatively little has yet been done in the way of a practical application of running



The Double-wire, Continuous Metallic Circuit System.—Daft Railway, Cincinnati, O.

cause any interruption of the current, so that in reliability of operation the electric railway is far superior, probably, to any other method now in existence, and indeed much preferable to the cable railway, in which the operation of the road depends entirely upon the integrity of the cable, and any stoppage of which means a total interruption of traffic.

As simple a matter as it may seem, the successful operation of the "under-contact" trolley required an enormous amount of experimentation before the proper type of contact was obtained. The one in general use to-day consists merely of a grooved wheel, which is fixed at the end of the trolley-arm. As there is always more or less sag to the wire, some method must be provided for keeping the wheel in constant contact, which evidently could not be effected if the wheel were rigidly attached to the car-body. To effect this, therefore, the arm



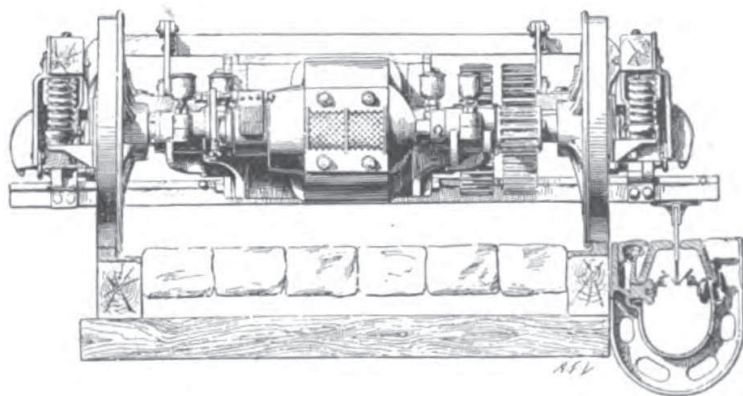
Edison's Menlo Park Electric Locomotive, 1880.

conductors underground. It is evident that by maintaining the system above the ground, it can be closely watched and readily inspected at all times, and the slightest fault which may be developed can be hunted up and remedied in the shortest possible time. Again—and perhaps this may be deemed the most important factor which has led to the preference of the overhead system to the underground—there is the small cost at which it can be erected and maintained.

But it was early evident that the demand of the public in crowded cities would in time force the adoption of some underground system, and various plans have been suggested with this end in view. Evidently the principle remains the same as that employed in the overhead system, but many are the difficulties which present themselves when the conductors are placed below the surface. The problem involves, in the first place, a construction which will effectually resist the action of all forces tending to disturb the relative position of the wires underground; and where the traffic on the streets is very heavy this involves a very strong construction of

the conduit. Again, it is absolutely necessary that the conductors shall remain thoroughly insulated from each other and from the ground under all conditions of weather. The frequent heavy rains and snows occurring in this country, therefore, necessitate the adoption of a construction which shall permit of a thorough insulation of the conductors and a drainage of

the entire system, not only to prevent an entire stoppage of the operation of the road by flooding, but also to avoid a continuous loss of current from conductor to conductor by leakage. To such general conditions are added others of minor importance. To meet all these, therefore, has been the subject of not a little study. Only a comparatively brief reference can be made to one of these types, the design of Messrs.

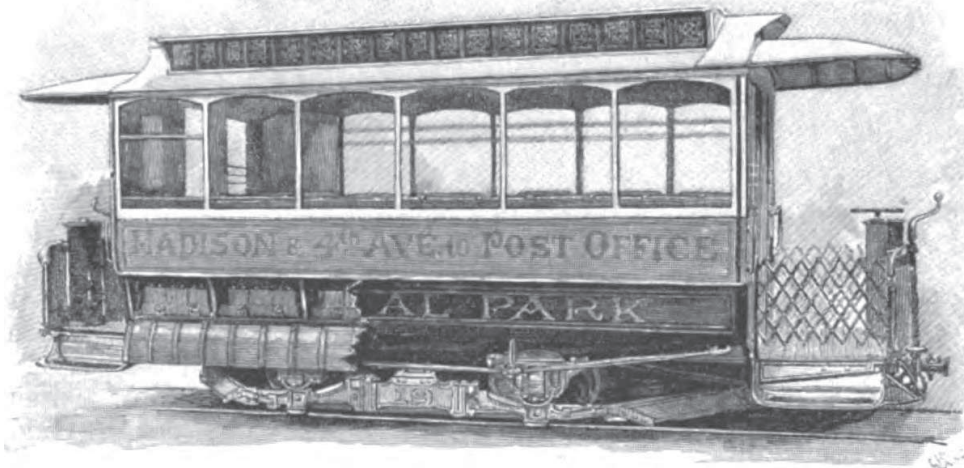


The Bentley-Knight Underground Conduit System, showing Cross-section of Track, Conduit, and Truck.

Bentley & Knight, as now put down in Fulton Street, New York, which has not yet, however, gone into operation, though one of their earlier types is in use in Allegheny City. The type of this conduit system is well illustrated in the engraving above. A number of constructors have arranged the

conduit to run along the centre of the track, but the objections to this method of operation have been overcome by placing the conduit at one side of the track. As shown in the engraving, the

tor than is afforded by means of a plough; moreover, a slot running along the surface of the street is also looked upon by some as an objection, the removal of which would be desirable. To



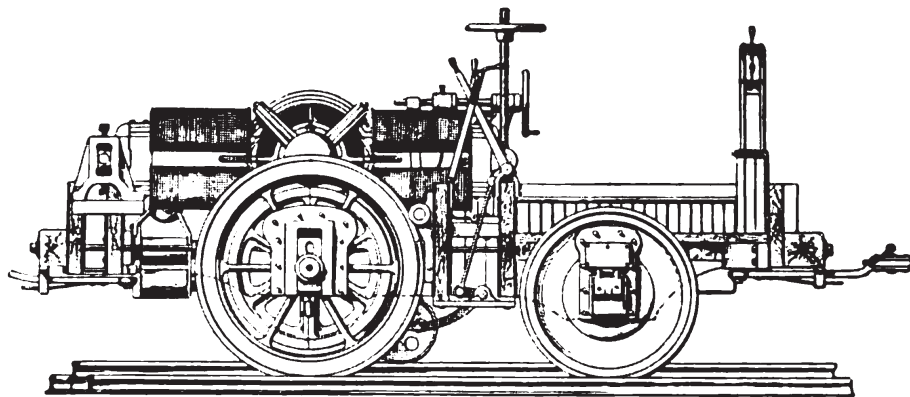
The Storage-battery System.—Car of the Julien Electric Traction Company, as run on the Fourth Avenue Road, New York.

two conductors are supported upon porcelain insulators fixed to the sides of the conduit. Placed directly above them are the two slot-rails through which a plough attached to a cross-beam on the car-truck enters. The lower end of the plough carries two contacts mounted upon springs, so that they are kept in continual contact with the conductors. The conduit is constructed of heavy cast-iron, horse-shoe shaped ribs, which are laid in the ground and connected continuously by an iron shell fixed to the flanges. For the proper and easy examination of the conduit, hand-holes are provided at short intervals, one of which is shown in section in the engraving.

Although a limited number of electric railways operating with the conductors placed in conduits are in successful operation to-day, the difficulties encountered in

their operation have led inventors to seek other means of communication between the conductors and the mo-

avoid both these a number of inventors have hit upon the idea which consists in laying the conductors underground, and, at short intervals, providing devices which shall close the conductor circuit through the car at whatever place the car happens to be. In one of these systems, that designed by Messrs. Pollak & Binswanger, a magnet carried at the bottom of the car acts upon a switch placed, every twenty or thirty feet, below the surface of the street, which switch closes the circuit and sends a current through the motor on the car from the main conductors. A system of a simi-

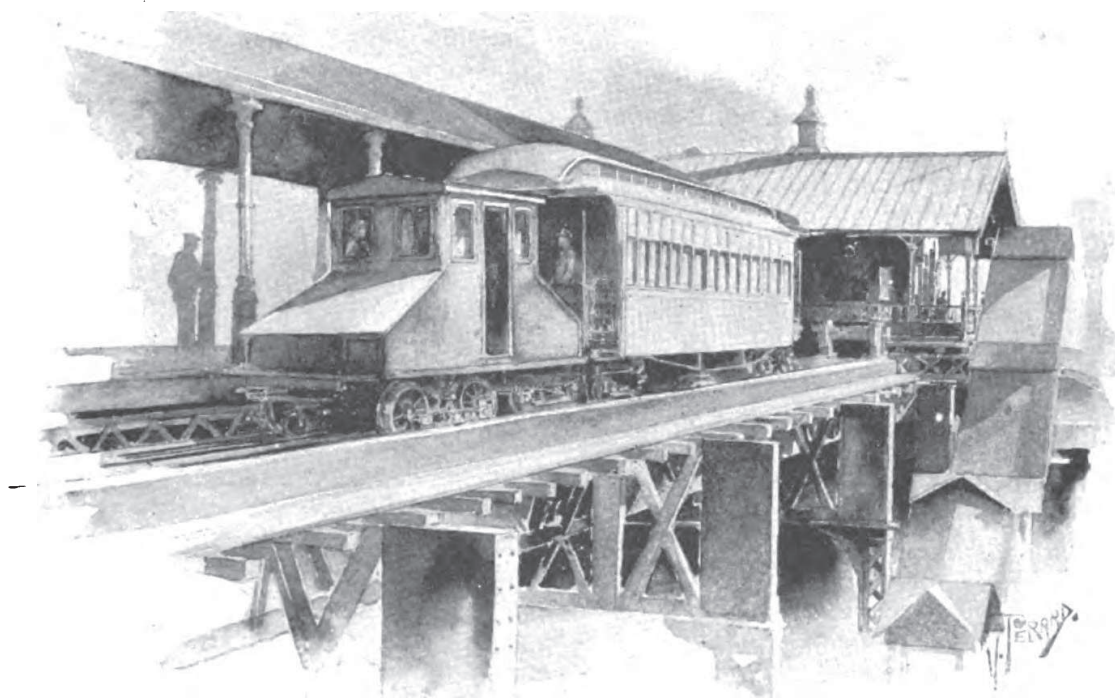


Daft Electric Locomotive for Traffic on Elevated Railroads.

lar nature has also been designed by Mr. McElroy, of Pittsburg. Though ingenious in their conception, none of these

systems has yet come into practical use. As remarked recently by a well-known electrician, the underground electric railway problem does not of itself present any inherent difficulties, but an essential element in its success is proper engineering, such as has been proved necessary as the result of past experi-

“series” system. Another method, however, which is that almost universally employed in connection with the incandescent lamp, is the connection of the lamps across the circuit, the lamps being, as it were, placed parallel to one another across the outgoing and returning wires, and each lamp obtaining its



Stephen D. Field's Motor.—Experimental Trials on the Thirty-fourth Street Branch of the Elevated Railway, New York City.

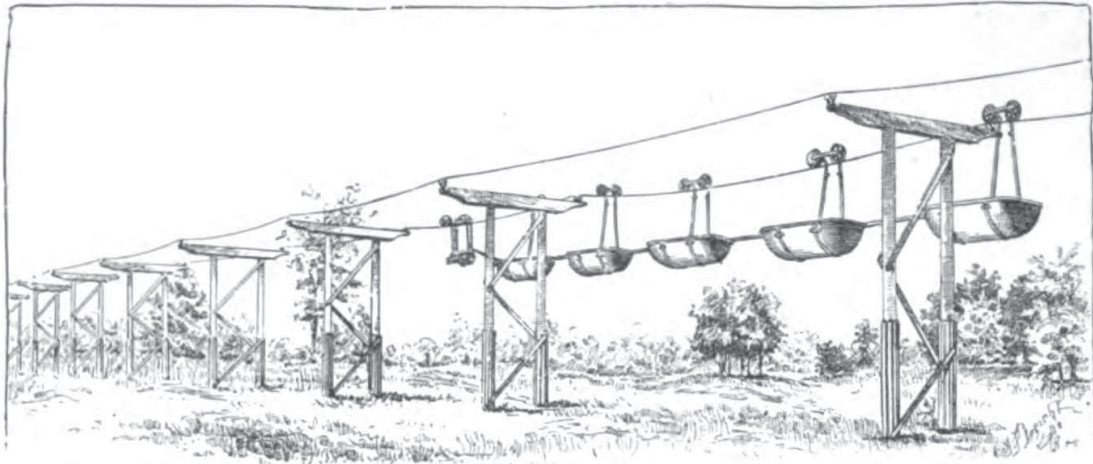
ence in cable traction. And, according to the same authority, the laying down of a cable conduit ought to be hailed with delight by electricians, as, sooner or later, it will most probably serve as a receptacle for electric railway conductors.

There are two different ways in which electric cars may be operated, considering their electrical relation to the conductor. As the readers of “Electricity in Lighting”* are already aware, electric lamps may be connected so that the current passes through each lamp in succession. This is the system upon which the large arc lamps for street illumination are connected, and is called the

* See SCRIBNER'S MAGAZINE for August, 1889, p. 194.

current independently of the other. This is called the “multiple arc” or “parallel” system. The latter method is the one upon which the large majority of electric railways running to-day are operated. It requires that the electric pressure at the terminals of the dynamo, and hence upon the line, shall remain constant, while the current passing over the line varies, of course, with the number of cars which are being operated at the time; ten cars, for example, taking ten times as much current as one car.

But the series system of operating cars still has its adherents, among them Sidney H. Short, of Cleveland, O. In his system the current is maintained at the same strength throughout, and

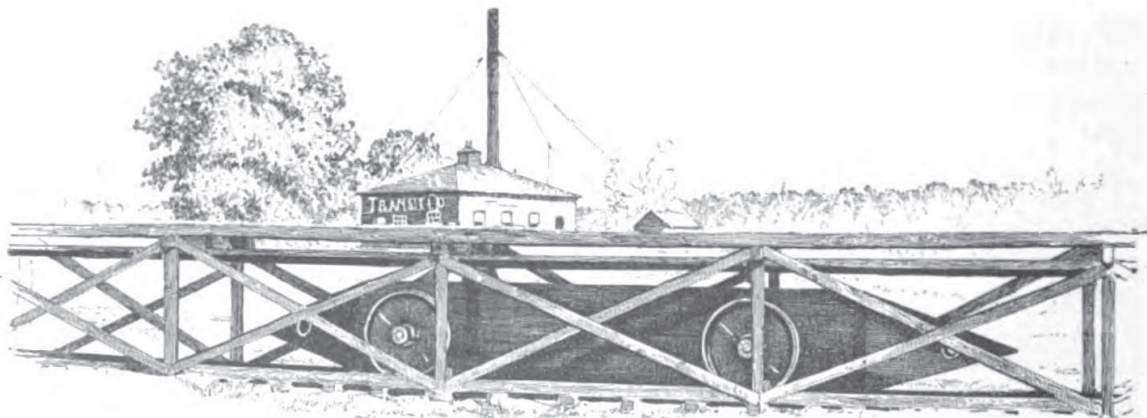


The Glynde, England, Telpherage Line, on the System of the Late Fleeming Jenkin.

passes from one car to the other undiminished in strength. It involves, however, a change in the electric pressure of the line, so that with ten cars the pressure would be ten times as great as that required with only one car in operation. Thus, although no actual power is saved, since in one case the pressure, and in the other the strength of the current, is varied proportionately, its adherents claim for it certain other advantages in operation, among others, a saving in the cost of conductors.

The storage-battery system is frequently called the ideal system of street-car propulsion. It is true it is the most pleasant to contemplate both from the stand-point of the public and the street-car manager. The objections which are held against the erection of wires and poles in streets, or the placing of conduits which necessitate slots in the

roadway, would evidently be entirely overcome by a system which should leave each car independent of every outward source of power. This great desideratum is undoubtedly best embodied in a car equipped with its complement of storage-cells previously charged, the car moving over the road as a single unit independent of all other conditions. These manifest advantages were early recognized, and hence it was not long after the practical storage-battery was invented by Faure, that attempts were made to apply it to storage-car propulsion. The first of these cars was put in operation in Paris, in 1882, and was followed by experimental operations in various other places. In 1885 a competition at the Antwerp International Exhibition, arranged between an electric car, steam locomotives of various kinds, and a compressed-air engine, resulted in the complete victory



The Weems System for a High-speed Electric Railway. More than one hundred and twenty miles an hour actually accomplished on an experimental track.

of the first. Progress has, however, been steadily going on, and though but few such roads are in operation as compared with their more vigorous competitor the overhead system, the belief is entertained by many that, with improvements that will undoubtedly be made in the storage-battery, this system will occupy a very prominent position in the future of electric traction. The reason for this will be apparent when we consider the very simple elements of which it is composed. The motive equipment of the car does not differ essentially from that already described in connection with the overhead system; but to this is added a set of storage-batteries which hold a sufficient charge to propel the car a given number of trips. The illustration (p. 434) shows such a car as operated at present by the Julien Electric Traction Company, in New York. The batteries are placed under the seats, and occupy no space otherwise useful. This system requires, of course, like those above described, a station in which a sufficient current is generated, for charging the cells. Here the cells are charged in regular rotation; the car after its run enters the car-house, discharges its exhausted cells, and is furnished with a new set, which have in the meantime been charged. This operation requires but a minute or two. The arrangement can be so made that the work of the engines at the station in charging the cells is practically continuous during twenty-four hours if necessary, which conduces to a well-known economy in operation.

Such, in general, are the main features of the systems of electric railways which have thus far been developed to any considerable extent. The rapid extension of the electric street-car system which has taken place (especially in this country), naturally leads to the question of the cause thereof. To have gained such pre-eminence it must be able to do not only what other systems can do, but, still more, it must be able to do it at a decreased cost. Again, removal of thousands of horses from the streets of a city, involving, as it does, the doing away with the noise and dirt, is another distinct gain to its residents.

But if one goes still farther, and contemplates the difference between a stable housing thousands of horses, and an electric-car station of sufficient size to operate a road with the same efficiency, one is at once struck with the advantages on the side of the electric system, which, indeed, are incontrovertible. Instead of a large, ill-smelling building whose odors are wafted for many blocks (making the tenancy of houses within half a mile almost unbearable, and involving a large depreciation of property in the neighborhood), there is a neat, substantial building equipped with a steam plant and dynamos, and occupying hardly one-tenth the space required for an equivalent number of horses. Therefore, not only is there effected a removal of the nuisances attached to a stable, but a large saving in the cost of real estate, and the far greater amount involved in the known depreciation of the surrounding property. Besides this, the stables are of necessity required to be in close proximity to the track, whereas the electric power station, which furnishes current to the car, may be situated a mile from the track in some suitable place, as, for instance, beside a river, where, with condensing engines, power may be generated at a minimum of cost.

Again, looking at the electric street-car from the stand-point of the engineer, it becomes evident that it is an undisputed rival of all other systems of mechanical propulsion. For example, it requires no device for the suppression of dirt, dust, and smoke in the streets, the necessary accompaniment of all steam locomotion. But most important of all is the consideration that the electric motor has, in fact, but a single moving part, the armature, the motion of which, unlike that of the steam and compressed-air engine, instead of being reciprocating, is rotary, and hence avoids the disagreeable jolting which attends the riding in cars which are of necessity frequently required to start and stop. As a consequence of there being but a single moving part, the cost and care required to keep the electric motors in running order is but a minimum, and the art of building them has to-day ad-

vanced to such a point that, with intelligent supervision, the life of the machine is equal to that of any similar mechanism.

It is fair to assume that but few roads exist which are so favorably situated that they encounter no grades in their course; and when the proposition to employ electricity as a traction agent was first projected, the difficulty as to the ascent of grades was held out as one of the drawbacks to the application of the system. But it required but a short period of actual experience to demonstrate that in just such situations the electric car was superior in every respect to the horse, and indeed to the steam locomotive. Grades exceeding ten per cent. are being overcome on roads now in operation, and others of lesser degree are now considered as of easy accomplishment with the electric car. In order to be able to cope with such grades it is, of course, necessary that the motor attached to the cars have ample power, and it has therefore become the custom to equip the trucks with two motors ranging from 10 to 15 H. P. each, thus giving the car an available traction power of from 15 to 30 H. P. Considering the fact that the ordinary horse-car has, as a rule, but two horses, this might to some appear an excessive amount of power equipment; but the fact must not be lost sight of, that while, ordinarily, two horses exert their normal, average strength in keeping the car in motion when once brought to its proper speed—the effort which they exert in bringing a car from a dead standstill to its proper speed often actually exceeds ten horse-power. Hence it is that the frequent heavy exertion required of horses in the street-car traffic results in their rapid wearing out and final disability for active service after three or four years' work. Therefore it is necessary that the electric car should be provided with the power corresponding at least to that which the horse exercises when required; but it is evident that, once started, the motor need only deliver a small part of its capacity, sufficient to keep the car in motion. But since electric cars are put upon roads having grades which have not been attempted with animals, additional

power is frequently required, and hence it is that as high as 30 to 40 H. P. are sometimes concentrated on one car which, under normal conditions, hardly requires more than three or four for its propulsion. This increase of power has also been necessitated by the practice which has sprung up of coupling one, and sometimes two or three tow-cars, with a motor car, so that in reality the motors of one car are required to do the work of two or three.

In this connection attention should be called to a phenomenon which may now be considered to be an established fact, in virtue of which electric cars are aided in ascending heavy grades. This phenomenon, which was probably first observed by Leo Daft, at his works in Greenville, N. J., in 1882, is that, when the current passes from the car-wheel to the track it causes an increased friction or resistance to sliding between them, the result of which is that slipping is to a large degree prevented, and heavier grades can be attempted; and, on the other hand, heavier loads taken up than would be practical with a system in which the current did not pass between the wheel and the rail. The explanation of this phenomenon, though not completely established, seems to lie in the direction of a slight welding action which takes place between the wheel and the rail, caused by the heat generated by the current.

In respect to the regulation and operation of electric cars, it may be remarked that there is no system which is more elastic. The driver at the front of the car has under his control the switch, so that by a simple movement of a handle he may regulate at will the speed of the car from a stand-still to full speed, as well as its direction of motion. Up to the present time the hand-brakes, as a rule, have been retained; but it is evident that with a motor under the control of a driver which can be instantly reversed, a powerful addition to the ordinary hand-brake is placed in the hands of the driver, and this has been often turned to good advantage to prevent accidents. In support of this it may be cited that since the inauguration of the electric railway in Cleveland, O., the number of accidents has been far less than for the

corresponding period during which the road was operated by horses, notwithstanding the fact that the electric cars are run at a higher speed.

The operation of street railways by electricity, although even now completely demonstrated to be more economical than by either horses or cables, is yet too recent to afford the more reliable figures which can only be obtained after extended use ; but from an investigation recently made on a number of roads by O. T. Crosby, some very interesting data are developed. The results of Mr. Crosby's investigation show that the average cost of motive-power for the roads in Washington, Richmond, Cleveland, and Scranton, was about 5.09 cents per car mile, and the relations of the various items which go to make up this total cost are exceedingly interesting. Thus it is shown that the interest on the investment constitutes about one-fourth or one-fifth of the whole ; that is to say, about one cent per car mile ; coal, as a rule, about twelve per cent. ; attendance, about forty per cent. ; and the machinery and line, without interest, the remaining twenty per cent. But with all these manifest advantages of the electric railway, the best proof of its superiority is to be found in the experience of those who are using it ; and if the unsolicited praise from that quarter is to be relied upon, then certainly the electric railway is an unqualified success.

At the eighth annual meeting of the American Street Railway Association, held last September at Minneapolis, the committee which had been appointed for the purpose of investigating and reporting upon electric railways, submitted a report which should finally set at rest the doubts of those who still believe the electric railway to be in the experimental stage. This committee reported in fact that, "if it is desired to make a change from horse-power, electricity will fill the bill to perfection, no matter how long or short the road, or how many passengers are carried. In the investigation of the subject the most satisfactory results have been shown ; it not only increases the traffic over the road, but reduces expense, and actually enables us to operate a line, which here-

tofore entailed a loss, at a profit." After discussing the various systems, the committee gives an estimate relative to the cost of equipping a railway on three systems, namely, on the cable system, the overhead wire, and the storage-battery system, which is as follows:

A comparative statement of the cost of construction of a ten-mile road complete, with 15 cars, would stand probably as follows:

Cable System :	
Cost of cable construction	\$700,000
Cost of power plant	125,000
Cost of cars	15,000
	\$840,000
Electrical Overhead Wire System :	
Cost of road-bed	\$70,000
Cost of wiring	80,000
Cost of cars	60,000
Cost of power plant	30,000
	\$190,000
Storage-battery System :	
Cost of road-bed	\$70,000
Cost of cars	75,000
Cost of power plant	30,000
	\$175,000

In the above cases of electrical construction, the motor-car would be capable of pulling one or two tow-cars, if necessary. These figures your committee have no doubt will be found to be calculated within a reasonable limit of cost.

Here, then, is at once a most potent argument for the adoption of the electric railway over the cable system, for (while answering all the demands which can be made upon a car) its cost of installation is nearly five to one in favor of electricity. To this must be added the fact that in the case of the cable, under favorable conditions, only eighteen per cent. of the power of the engine is actually employed in the propulsion of the cars, the remainder being consumed in the mere haulage of the dead cable ; while in the electric system at least fifty per cent. of the engine power is available for traction purposes. The cost of power, or coal required, is thus approximately 3 to 1 in favor of electricity.

As remarked in that report, the installation of an electric railway in place of horses is uniformly accompanied by a large increase in receipts, as well as a decrease in expenses. Both of these items working together have resulted in a most remarkable showing of earnings for such roads. Only a few instances

need be given to demonstrate this: The electric railway at Davenport, Ia., started on September 1, 1888, with five fourteen-foot cars. The road included a grade of seven and a half per cent. for sixteen hundred feet, and the following table gives a comparison of the earnings for four consecutive months, operating with horses and with electricity:

	1887.		1888.		Net increase per cent.
	With horses.		With electricity.		
	Gross.	Net.	Gross.	Net.	
September.	\$1,847 49	\$474 79	\$1,997 15	\$997 15	110
October ...	1,232 47	302 47	1,908 94	1,121 94	270
November.	1,181 49	231 49	1,886 06	986 06	820
December.	1,283 14	353 14	2,022 98	1,122 48	290
	\$1,255 40	\$340 47 Aver.	\$1,952 53 Aver.	\$1,056 91	210 Aver.

As here shown, there was an average net increase of two hundred and ten per cent. in the receipts. Other places have shown still more remarkable results, but the reticence of the managers of these roads naturally prevents the publication of what might otherwise almost be considered apocryphal earnings. One case may be mentioned in which, for thirty-one days, during the month of July, last year, the receipts amounted to \$10,605, and the operating expenses \$3,735, showing a net gain of \$6,870; and another in which, for the month of August, 1889, the operating receipts were \$4,317.46, while the total expense amounted to \$871.04, giving a net profit of \$3,446.42.

The popularity which the electric cars have obtained in cities where they have been employed is well known, and easily accounts for the remarkable showing made in the earnings of the road. The service, instead of being slow and uncertain, as under the régime of the horse, is now swift and sure, and delays are practically unknown. For a time doubts were expressed of the ability of the electric cars to cope with the conditions imposed by our harsh Northern winters, but the experience of the last two years has shown that such fears were unfounded, and the most severe storms which passed over this country last winter caused not the slightest delay in the operation of electric railways.

A good example was given of this immunity from delay by many of the Western roads, among them those of Omaha, Council Bluffs, Cleveland, Davenport, and St. Joseph, where the electric cars maintained schedule time, whereas the horse-cars were running at irregular intervals with double teams. It is evident that with a sweeper provided with powerful motors for removing the snow from the tracks, and kept constantly running over the line, there is nothing to prevent its being kept clear at all times. Even without the sweepers, the cars themselves have sufficient power to force the snow aside and maintain the track clear, as has often been demonstrated.

Our own country has made far greater progress in the application of electricity to railways than all the rest of the world included, and it is therefore not uninteresting to glance briefly at the rapid increase which the system has undergone. The first trustworthy statistics on the subject were given in a paper read by T. C. Martin before the American Institute of Electrical Engineers, in May, 1887, in which he showed that there were in operation at that time in the United States thirteen electric railways, carrying about three million five hundred thousand passengers annually. The latest and most trustworthy statistics relating to the same subject show that there are in operation in this country, and in course of construction at the present time, no fewer than 179 electric railways, operating over 1,884 cars with 1,260 miles of track. The number of passengers carried it would be difficult to estimate; but it must be considerably more than 100,000,000.

Among the larger cities in which electric railways have been put in operation, the foremost is Boston. W. H. Whitney, the president of the West End Railway, of Boston, after thorough investigation and trial of the electric railway, was finally so well convinced of its superiority over all other methods of street-car propulsion, that he recommended its general adoption on the street railways of Boston; and while more than one hundred cars are in operation there at present, preparations are going on which will culminate in the operation

of nearly one thousand electric cars in Boston alone. Among the other cities having electric railways is Cincinnati, with forty cars, and preparations for a large increase. Cleveland, O., has now several lines operated by electricity, as well as Harrisburg, Pa.; Kansas City, Mo.; Hartford, Conn.; New York City; Omaha, Neb.; Pittsburg, Pa.; Salt Lake City, Utah; San José, Cal.; Scranton, Pa.; St. Louis, Mo.; Tacoma, Wash.; Washington, D. C.; Wilkesbarre, Pa.; Wilmington, Del., and a long list of others.

Wherever the electric railway has been introduced a reduction in the schedule time, or, in other words, an increase of speed, has followed; and where the lines connect the suburbs of cities, not infrequently a speed of from twelve to eighteen miles per hour is attained by electric cars, thus affording to residents in suburbs the speed facilities of a steam railway.

For intra-urban rapid transit, evidently, electricity is superior in every respect to steam traction, and hence it was but natural that several electricians should have essayed the solution of the problem of affording the residents of New York a deliverance from the present overcrowded conditions of the elevated railway cars. Among the electricians who have submitted plans for this may be mentioned Leo Daft, who was the first to place an electric locomotive on the elevated railroad, and who has recently shown, as the result of his experiments, that he is able to increase the traffic of the road with a reduction in cost of operating expenses. The locomotive employed by Mr. Daft in his latest experiments, called the "Ben Franklin," is shown in elevation at the bottom of page 434.

Frank J. Sprague has also attacked the problem, his plan embodying the idea that the locomotive car shall also be a passenger car, only about one-half of its total length of fifty feet being occupied by the motive-power equipment. In this way the weight of the locomotive is widely distributed over the roadbed, a necessity with the present form of elevated railway structure.

Stephen D. Field has also turned his attention to this problem, and, like Leo

Daft, favors the employment of an electric locomotive independent of the rest of the train. His motor, as run on the Thirty-fourth Street branch of the elevated railway in New York City, is illustrated on page 435, and embodied a modification in the gearing of the motor from those heretofore employed. It will be seen that instead of employing intermediate toothed gear, or a similar device, Mr. Field connects directly to the armature shaft a crank which, through the medium of a connecting bar, transmits its motion directly to the wheels of the locomotive.

Though the experiments undertaken on the elevated railways have not yet led to the adoption of that system, it is only a question of time when it will become a necessity, and, indeed, the only way out of a constantly increasing difficulty. The elevated railroad presents ideal conditions for the application of such a system, and the cause of the delay which has thus far taken place must be looked for rather in a conservative management than in any lack of appreciation of the proposed system.

The advantages of the electric railway on the surface of the earth have been pointed out, but by those who have ever witnessed the operations of a railway within mines, the introduction of the electric locomotive will be admitted to be one of the most marked advances which have been made in that industry during recent years. Indeed, one of the first electric railways ever operated was a mine tramway. Removing at once the slow and obstinate mule, on the one hand, and the dust, smoke, and noise and poisonous gases of the steam locomotive, on the other hand, the electric locomotive does its work with "neatness and despatch," requiring but a fraction of the attendance necessary in the other methods, and promoting the comfort of the miner in the highest degree. The ingenuity of the electrician has easily adapted the electric motor to these purposes. A mine locomotive employed at Scranton, Pa., by the Hillside Coal Co., designed by C. J. Van Depoele, has already shown itself fully able to handle several hundred cars per day, and has entirely displaced the mules

formerly employed in the mines. Several other mining railways are running, or in course of equipment in this country and several are in operation in Europe. This mining branch of electrical development, though hardly touched at the present time, is certainly destined to equal, if it does not exceed, in extent the wonderful growth of the surface railroad.

Inventive genius early in the art looked to a further extension of electric traction, and as early as 1882 Professor Fleeming Jenkin suggested the idea of an electric transportation system in which the motor or car should ride upon a suspended cable, which should at the same time constitute both the track and the electrical conductor. This system, which was named by him "telpherage," has actually gone into operation at Glynde, in England, where it is employed in delivering clay from the mines for a distance of several miles. This system is illustrated on page 436. The great cheapness of this system of construction, together with its flexibility, seems to promise for it a bright future. The train is under complete control of the attendant at the station. As a feeder to the main railway lines of traffic it possesses unquestionable advantages, and for the transportation of ore, coal, and minerals generally, as well as corn and other agricultural products, it would seem to have many advantages.

These descriptions have thus far been confined to what has actually been accomplished; but it is not out of place to cast a glance into the future, in order to discern in what direction electricians are working in the domain of electric railways. One of their main objective points is to attain higher speed than is now reached with the fastest express train, and enough has already been demonstrated to show that this is by no means impossible. There has been for some time in operation at Laurel, Md., a system of electric railway, originally designed by David G. Weems. When it was recently inspected by the writer, with his watch in hand, he noted a speed of the electric locomotive of nearly one hundred and twenty miles an hour. The

electric car there employed is illustrated on page 436. The electric motors are constructed with a revolving armature which is mounted directly on the axle, so that no intermediate gearing whatever is employed. The curiously-pointed ends of the car, which might by some be considered fantastical, have their *raison d'être* in the fact that, at the high speeds at which this car is run, the resistance of the air is by far the greater retarding influence; much greater, in fact, than the resistance due to the axle and rolling friction, which at lower speeds is predominant. The electric current is taken from a conductor fixed above the car, to which a brush connected with the motor makes contact. The system has now been placed for its further development in the hands of O. T. Crosby, an engineer late of the United States Army, and will, it is hoped, soon be reduced to a condition of commercial practicability. There is certainly nothing in the new system which could prejudice its feasibility under suitable conditions.

There is also another system of rapid transportation which has been suggested, and has been put into experimental operation, known as the "Port-electric" system. In this system, invented by John T. Williams, a well-known principle is applied, namely, that of the sucking in of an iron core by the action of a current circulating in a coil around it. Mr. Williams makes his car or carrier play the rôle of an iron core, which is propelled by the successive action of coils of wire placed at suitable intervals along the track.

With the advantages of the electric railway so clearly pointed out, and so unquestionably demonstrated in actual practice, it would not be unsafe to hazard the opinion that, in ten years, at the farthest, there will not be a *single* horse-railway in operation, at least in our own country. The horse will then be once more returned to his legitimate field of labor, and the street-car passenger will be transported at an increased speed, and with all the comforts of easy riding, in cars propelled and lighted by electricity; while it is by no means improbable that, with further work on the line indi-

cated, the passenger may step aboard a train in New York at ten in the morning, and eat a five-o'clock dinner in Chicago on the same day. Enough has indeed been accomplished to show that electricity is destined to be one of the most

powerful factors entering into our social conditions, and that the ease of distribution and convenience of power afforded by it must bring forth changes in the social order which are even now hardly realized.

EXPIATION.

By Octave Thanet.

CHAPTER X.



FAIRFAX held his way after Barnabas, deeper and deeper into the swamp. One feature of the scenery is all that he remembers; everywhere, the microscopic softness of tree and shrub articulation was spattered with myriads of tiny berries, red like blood. Dick never looked behind. Betty Ward put her head down and galloped — galloped. Logs had fallen, their black pointed boughs sticking up in the air like javelins. There was a tangle of elbow-brush and briar. It was hard riding. Fairfax left the road to the horse. If she did not know it, the chase was lost, anyhow. He sat well back in the saddle, but with his body inclined a little; and his eyes never left the bare head in front, with the floating black hair which rose and sank as the mule's white flanks flashed through the cane. He felt no fear. When his father gave him Betty Ward hadn't he said, "Well done, Fair, you done well, boy. Dick belongs to you. Take Betty and catch him!"

The approval of one simple, rustic, heroic gentleman was more to Fair than all the world's, than Adèle's even; he felt that he could storm a fort. Gentle as his nature was, he was possessed by the hunter's fury and the terrible joy of fight.

And Dick? Who knows what were his thoughts, or why he chose the direction in which he sped. Perhaps it

seemed to him a temporary sanctuary protected by superstition (for it was toward La Rouge's farm that he spurred Ma'y Jane until her white sides were streaked with red), and his sole pursuer he valued lightly. He could soon quiet that boy. His revolver was empty, but so was the other's, or he would have fired. Little it mattered to Dick that the buzzards were skurrying along the sky over the murdered Frenchman's grave. Ma'y Jane floundered bravely through the morass. Where she climbed on firm ground, a broken-down corner of a fence stood, relic of one of La Rouge's rail-fences. Dick wheeled his horse to face Fair.

"Wa'al, Bud, come on," he cried, lifting his sword. Doubtless his intention was to set on his enemy just as he was struggling out of the mud. He stuck his spurs into the mule. Either he forgot Ma'y Jane's evil conditions, or, having mastered her once, he believed too fondly in his own powers. He essayed to ride at Fair, past the fence-corner.

Immediately he realized his folly; Ma'y Jane's head had gone in the air with her heels, while fire flashed out of her wicked eyes; she jammed Dick's leg against the rails with such force that he reeled in the saddle; and, the second after, he was hurled backward into the swamp. It was the deepest place; the wretched man sank up to his waist in mire.

Fair easily made a landing. His enemy was only a blasted torso rising out of black slime. Slime streaked his face and matted his hair. Before a word could be said, he threw up his hands, dripping hideously like the rest of him.