upon starting. Others have maintained that the truck should be self-contained and that the car body should rest upon it by means of post gearing, as is the general custom in the horse car practice of the day. This latter system seems to possess the greatest number of advantages, and seems to have met with the most general approval.

"The Thomson-Houston Company started out with this general idea, and have elaborated their motor truck to almost a perfect degree. The truck of the day seems to consist of the wheels and axles connected by means of some rigid framework resting upon the journal boxes, which framework supports and carries that portion of the weight of a motor which is not carried by the axle. Direct gearing is employed in every instance. Chains, belts, rope, and wire rope of all descriptions have been tried, but all possess inherent difficulties which render their general adoption impracticable and impossible.

"In controlling the motors, inventors have brought forward a great many schemes. Some have been put forward upon the basis of simplicity and practicability. In the two most prominent systems of to-day a radical difference is observable.

"In one, the motors are so wound that all controlling influences are brought to bear upon the motor itself. In this system it can be readily seen that there is introduced a liability to accident in the very worst place possible. The motors themselves should be so built and constructed that they, above all other parts, would be free from any liability of breaking down.

"In the other system the motors are constructed with this primal object in view, and every precaution is taken to insure their longevity. The control of the current is made through what is known as a rheostat or resistance box. If this breaks down the motors still remain intact, and the car can be run to its destination. The rheostat, however, can be so constructed, that nothing short of the most extraordinary accident should cause it to give out.

"In street railroading, fine points in electrical science must be sacrificed. What is wanted is the motor that will go under all circumstances, that can be depended upon, and that will stand the severest strain from year to year. A commercial efficiency on the repair sheet is much more desirable than a small electrical gain of efficiency in the motor itself. There is no possible condition that can be worse for electrical apparatus than under a street-car, and it has been only by the most patient and careful study that the most prominent systems of the day have been brought to the perfection which they have, and it has been done only by going frankly to the street railway men, ascertaining their views and studying into the difficulties which were to be overcome.

"The motor-trucks, as they are being built to-day, are proving themselves thoroughly capable of withstanding the severest of conditions, and it would seem to-day in considering the marvellous strides which have been made, that the highest point had been very nearly reached. It is certainly true that by far the majority of changes have been gone through, and that but slight improvement, if any, will be made in the future."

The Thomson-Houston system is the one using the rheostat, while the Sprague Co. use the commutated field for the purpose of controlling the motor. Sir John Fowler in his report sums up also in favour of the Thomson-Houston motor. The Spragueomotor has no doubt a slightly higher electrical efficiency; but so would also a locomotive fitted with an automatic variable expansion gear have an advantage over the ordinary locomotive in use as regards consumption of steam, but for all that no locomotive-engineer would propose the use of such an appliance, as this saving of steam would not compensate for the extra complication and liability to get out of order; that type of locomotive or electric motor, which can do the greatest mileage without requiring to be taken to the hospital is the most valuable and economical in the end, notwithstanding the consumption of fuel may be slightly higher.

The last link to be considered is the means employed to conduct the return current, after having done its work, from the motor to the generator. In a great many installations this is done by conducting the current through the car axle to the wheel, and thence by means of the rails back to the generating station. The rails are connected electrically at the joints by means of bent copper strips, as the fishplates are not often in a fit condition to conduct the current from rail to rail; sometimes earth-connections are also introduced at suitable intervals by plates buried into the damp subsoil, the earth in this case, acting as a conductor in the same manner as it is employed in telegraphy, and with the same advantage. The Thomson-Houston Co. in their more recent work, make use of a complete metallic return, consisting of a bare copper wire of same section as the overhead conductor, which is laid on top of the sleepers, midway between the rails and connected with the latter close to the joints. This is found to work most satisfactorily.

Having now described the component parts of the *typical* American electric street-railway of to-day, and which comprise three-fourths of all electric roads in existence and building in the United States, it may not be out of place to compare the various systems of traction in use at present for street-railway or tramway work. We have the horse, the steam, the cable and the various types of electric roads, of which we will, however, only consider the overhead system as described on the foregoing pages. It is generally admitted that cable-roads are vastly superior to horse and steam-roads and we shall therefore confine our comparisons to cable and electric roads. It will not be necessary to here recapitulate the advantages of the cable system, suffice it to say, that the electric system possesses all these and many in addition, except perhaps when it comes to working steeper gradients than one in eight. This latter, and almost as steep grades, have been worked successfully for about two years under the trying conditions of an American winter, with ice, snow, and sleet; a splendid performance of an electric car on a steep grade, being described in Sir John Fowler's report as follows: "On the Highland Electric Railway, at Lynn, Mass., there is a twelve per cent. grade, and a Thomson-Houston motor car, containing ninety-six passengers descending that grade was reversed and returned to the summit. Indicator cards taken at the time at the power station showed that ninety horse-power was used in the maximum efforts." You will, no doubt, admit that this is a splendid performance, and as these motor cars are fitted with thirty horse-power motors, it goes to demonstrate that when a sudden call is made upon them, they can work up to nearly three times their nominal efficiency.

The advantages of the electric over the cable system are many, and may be classed as mechanical and financial; we will, however, consider only a few of the more important.

A complete stoppage of traffic, due to a break-down at the power station is almost impossible, the generating plant being made up of a number of individual steam-boilers, engines and electric generators; should any one of these give out at any time, a spare one can be started up at a moment's notice. With the cable system this is not the case, as the driving and compensating gears are all inseparably bound together; an injury to one of them stops the whole machinery, and, in consequence, the cars also.

Curves, switches, turn-outs, and cross-overs, which are admittedly all particularly objectionable in cable-roads, are no more trouble in the electric over-head work than similar constructions in ordinary surface track-work.

Single track roads on the electric overhead system can be worked as easily as in steam roads, while on cable-roads they are highly objectionable, as the cable has to be a complete loop.

The trouble of keeping the electric conductors in place and insulated is not one-tenth of that necessary to maintain the sheaves, curve wheels, &c. In the electric system there is nothing subject to any great strain or special wear, the main point being the preservation of the insulation, while in the cable system everything is constantly moving and wearing, necessitating frequent attention and repairs.

In the cable system the whole working depends on the cable, and if that breaks, traffic is at a standstill and cannot be resumed under much less than 10 or 12 hours. The breakage of an electric conductor is a very rare occurrence, it being constantly under the observation of the line men, and as a weak place would generally show itself by an undue deflection of the conductor, could be attended to before an actual severance took place; however, should a break occur, this could be repaired in almost as many minutes as it takes hours to re-splice a cable, and as traffic could be still carried on on either side of the break up to where the feeders connect, only very little inconvenience—and that of short duration—would result therefrom.

The facilities for extending electric lines, running branch lines or increasing the power required to run additional cars are perfect. All you have to do is to put down the track and fix the overhead construction. If more power is required, add more generators at the station and provide additional feeders. In the cable system, on the contrary, the junctions are difficult to make, and if the gearing and power has not, at the beginning, been designed to provide for possible additions, a complete reconstruction may be required, and for branch lines a new power station will almost of necessity have to be provided.

The ease and certainty with which electric cars can be controlled is one of the most valuable features of the system under consideration. A cable car can only go at one speed—that of the cable; it cannot travel slower except at the expense of ruining the cable, and cannot make faster time, as it is not safe and practicable to run down inclines by momentum. The electric car can travel at any desirable speed, from a snail's pace to twenty miles an hour or more, can stop at top speed in a very short distance, and back out of danger if required. In crowded streets these advantages alone, even if in all other points the electric car were no better than the cable, would almost as a certainty procure for the electric the preference, more especially in an extensive system of tramways, where crossings of the tracks of different routes have to be provided for. It is here where the cable is at its worst; the crossing has to be negotiated by momentum, and should the car have to be stopped on account of danger ahead, we would (and the author has) witnessed the beautiful spectacle of the gripman and conductor pushing the cars the remaining distance to where the rope could be gripped again. How different with the electric car; it approaches the crossing at moderate speed, crosses over at a walking pace, stops or backs if required, and so causes no more inconvenience than a horsed vehicle, while the cable car temporarily clears the road and stops all other legitimate traffic at these particular and generally congested parts of public streets.

There are many more mechanical points which might be urged in favour of electric over cable traction, but we will consider shortly a few of the financial advantages.

It is known that the cost of construction and equipment of a first-class overhead electric road is at least thirty-five to forty per cent. cheaper than a cable road. We know also that in the latter we can only get at the best about twenty-eight per cent. of the power generated at the station, as useful work at the wheel, while with the electric we obtain from fifty-five to sixty per cent. Again, the running expenses are from thirty to thirty-five per cent. less for the electric than for the cable. The location of the power-house for a cable road must, of necessity, be in close proximity to the track, whereas it does not matter much at what distance it is from the electric tracks. In the first case land of great value will most likely have to be purchased; the fuel will have to be carted, and water for condensing purposes, in all but exceptional cases, will not be readily available. The power-house for an electric road can be located either near a railroad or at the water's edge, resulting in a great saving as regards handling of fuel; land will be most likely obtainable at a cheaper figure, as you are not bound to any particular spot, and the chances are that condensing engines can be made use of, with consequent beneficial result to the exchequer.

In view of what has been said in the foregoing it is no matter for astonishment, that in the short space of time elapsed since the introduction of electric traction on a commercial basis, it has altogether outstripped cable traction, viewed from every standpoint. When we see that the West End Street Railroad Company of Boston, with about 217 miles of track, carrying daily about 300,000 passengers, after careful consideration of the various mechanical systems of traction, have decided to use electricity, in place of horse traction, and which change will involve the expenditure of some-where near one million pounds sterling; again, when we consider that in Minneapolis a cable plant which had been bought to supersede horse cars at a cost of about £80,000 sterling, is thrown on the scrap-heap, even before being put in the road, to make room for an electric equipment; and further, when we read the following extract from the *New York Times*, viz.: "The forthcoming equipment of seven lines of street railway, and ninety-two miles of track in St. Louis with electric power, is an especially noteworthy indication of the superiority of the electric system on such roads, because of the extensive use of cable-motors in that city. Horse power was supplanted on several important lines not long ago by cable power, and probably cables would be put in now for the use of some of the seven lines just mentioned, if the owners of the property were not convinced that with electric power they could make more money and give better service. It is noticeable that they are not restrained by the large cost of making the change, which is estimated at 3,500,000 dollars." The natural inference is that the days of the cable road are past, and such will be henceforth only constructed in isolated cases. There is no doubt that cable traction was an enormous advance on all other known systems some years back, but it had to go down before the modern system of electric traction, for the reasons set out in the foregoing.

The experimental days of the electric tramway are past, their cost of construction and working are well known, and the commercial success of such an undertaking can be foretold with an equal amount of accuracy as in the case of a cable or steam road.

A glance into the future as to the probable limit to which it may be desirable to employ electric traction in place of steam locomotives may not be out of place. The author is of opinion that in the near future electric locomotives will be used extensively for suburban and branch line traffic, of which illustrations are already at hand in the United States. The Thomson-Houston Company have built for the West End Railway Company, of Boston, an electric locomotive, weighing seven tons, on four wheels, of 36 inches diameter, fitted with two 20 h.p. motors, and capable of drawing four cars at a speed of 20 miles an hour, for heavy suburban traffic. It is also fitted with a small 1 h.p. motor working the air brakes. Another example is that at Sunbury, Pa., the connecting link between the Lehigh Valley and Reading railroads is an electric railroad, which is operated at a speed of 25 miles an hour, and which carries both freight and passengers between the two systems. The motor of the electric car in this case is single, and of 30 h.p.

The valuable experiments of Mr. Leo. Daft on the elevated roads in New York demonstrate that large trains can be hauled successfully, as, in October, 1888, his electric locomotive "Ben Franklin," hauled a train consisting of eight coaches, each weighing 12 tons, up a grade of 98·7 feet, at a speed of 7½ miles per hour, making an average speed of 14 miles over the distance run. These experiments were carried on for several weeks, during which time valuable data and measurements were collected, from which it was calculated that by the substitution of electric for steam locomotives more than half the cost of fuel could be saved on the elevated roads.

However, even this may not be the limit, and the question, whether main lines can be worked successfully by electricity, suggests itself. The travelling public is constantly clamouring for higher speeds; to obtain these with steam locomotives either the diameter of the driving wheel has to be increased, or higher piston speeds would have to be used. To do the first we reduce the tractive capacity, and the piston speeds cannot be increased to a great extent without loss of economy.

It is at fairly high speeds that the electric motor, as now constructed, is at its best; motors of sufficient capacity to propel a heavy train can be constructed, and as there are no reciprocating parts, high speeds could be worked with more safety and less damage to permanent way than would obtain with steam locomotives. It is quite possible, that many of us here assembled will see the day when electrically propelled trains will cover the distance between Sydney and Newcastle in two hours, or even less.

The application of electric traction in mines has already assumed considerable proportions, and it is to be hoped that our mine-managers will soon avail themselves of this appliance, to take the place of the horses now employed, which would result in a purer atmosphere for the miners to work in and also reduce the cost of underground haulage, with a further possibility of being enabled to increase the output from the mines.

The author regrets much that the time at his disposal did not permit of his presenting a more elaborate and better-digested treatment of the subject; what has been said is intended more as the basis for a discussion, which he hopes will be vigorously indulged in.

The following works on the subject have been consulted in the preparation of the paper, viz.:—"The Electric Railway," by Fred. H. Whipple; "The Electric Motor," by T. C. Martin and Joseph Wetzler; "Electricity as a Motive Power," by the Count Du Moncel; also the various scientific periodicals dealing with the subject.

Description of Plates.

Plate I.—Represents an 80 h.p. Thomson-Houston generator, specially designed for power transmission.

Plate II.—Is an illustration of a Thomson-Houston 30 h.p. nominal motive truck.

Plate III.—Is a copy of an Ampère-Diagram clearly illustrating the enormous variations of power the motors are called upon to perform at very short time-intervals.

Plates IV. & V.—Are views of electric tramways on the overhead conductor system, from which the unobtrusiveness of poles and wires can be seen.