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ELECTRIC TRACTION.

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THE practical demonstration of the applicability of the modern electric-motor to the propulsion of vehicles with flanged wheels, may be said to date from the year 1879, when Messrs. Siemens and Halske laid down a small model railway at the Berlin Exhibition. The length of the track was about 500 metres, and the train composed of a small electric locomotive and carriages for the passengers, which were simply small platforms mounted on low wheels, with two rows of seats facing outwards, parallel with the track. The locomotive was composed of one of Siemens' dynamo-electric machines, laid horizontally on a frame-work with wheels, the bobbin was placed parallel with the line, the rotary movement of which was transmitted to the driving wheels by means of spur and bevel gear. The electric current was transmitted to the locomotive by means of rubbers sliding along a bar of iron, fixed to the sleepers midway between the rails by wooden chairs to insulate it electrically from the soil, and extending the whole length of the track. The return current passed through the wheels to the rails and back to the generator. A lever served to connect or to interrupt the current, and thus to set the train in motion or to stop it. This experiment proved entirely successful, and led to the construction of an electric tramway of a permanent character between Lichterfelde and the Cadets' College, near Berlin, which was opened for traffic on the 12th May, 1881. The length of this line is about 1½ miles; the vehicles are ordinary tram cars, carrying 26 persons, and each carries its own motor, the motion being transmitted to the wheels by belts working on grooved pulleys outside the wheels. The electricity is conveyed from the generator to the motor by one rail, the other giving the return. The rails had naturally to be insulated, and this led to a considerable amount of trouble; it was therefore decided not to repeat this method in future installations. This somewhat detailed description of the first electic tramways may be excused on the ground that it is thought desirable to place here on record the fact that Europe is the birthplace of the system of generating electricity at a fixed point by dynamos, and conveying the current through conductors, and sliding contact to the car whilst in motion, which forms the basis of most of the modern electric tramways now at work; although our American cousins have long since outrivalled and put in the shade the more conservative and slow-going Old World.

However, the ice was broken, and the application of the Electric Motor for rail-roading soon engaged the minds of the foremost men of the age. The installations at Portrush, Brighton, Moedling (near Vienna), Frankfort, Blackpool, Bessbrook and Newry, Brussels, and Hamburg, followed in rapid succession in Europe, and in America, Messrs. Field and Edison, at the Chicago Railway Exposition in the year 1883, showed the practical working of electric locomotion for the first time in public, and with most astonishing success so far as the electrical apparatus was concerned, although Mr. Edison had been experimenting at his laboratory, at Menlo Park, N.J., since 1880.

This was followed by the experiments of Mr. Leo Daft, with his electric locomotive Ampère, on the Saratoga and M'Gregor Railway. The performance of the Ampère, which weighed two tons, consisted in the hauling of an ordinary railway car, weighing ten tons, containing 68 persons and five persons upon the motor, the speed obtained was eight miles up a gradient of 1 in 57, with a curve of about 20deg., equivalent to a maximum duty of about 12 h.p.

About August, 1884, the Baltimore Union Passenger Railway Company opened for traffic the Hampden Branch, worked by electric motors on the Daft system. This road is just two miles long, with heavy grades and sharp curves, and was the first electric railway constructed in America for business purposes. At the outset a third rail-conductor was used, but overhead construction took its place at a later period. This road proved entirely successful, and is running to this day.

At the beginning of 1888 there were about 20 roads in operation in America, aggregating about 80 miles of track and about 90 motor cars; also about 20 roads constructing.

Since then progress in America has been phenomenal, while in Europe only a few roads have been put in operation in addition to those mentioned before. Early in the present year one or more electric railways were in operation or under construction in about 150 towns in the U.S. with about 1,670 miles of track, 2,650 motor cars aggregating 70,000 h.p., with a daily mileage of about 150,000 miles, carrying about 200 millions of passengers per annum and requiring 40,000 h.p. at the generating stations. It is estimated that 3,000 motors will be in operation during this year, with a traffic of 300 millions of passengers, and a return of more than three millions pounds sterling in fares.

In view of the foregoing the author will doubtless be excused for omitting almost entirely from further reference the European roads, as our local conditions have much more in common with those obtaining in the U.S. of America, and it will be to the practice in vogue in that progressive country that we shall have to look for a model for our requirements.

After these introductory remarks, the author proposes to consider in detail the various methods of applying electricity to the traction of vehicles in use at the present day.

Electricity is applied to traction in two very distinct ways, namely by means of storage batteries and secondly by conductors fixed along the tracks from which the motor-cars take the current as required.

Considered from a technical point of view, there is something very attractive in the proposal of having each vehicle to contain the power required for its propulsion, and it is to be hoped that eventually a successful storage-battery will be invented. Commercially however, at the present day, there are a number of serious objections to their use for traction-purposes. In the first place you have to carry about dead weight amounting to something like 3,500 pounds for an ordinary street-car, and this cannot be reduced until some other material can be substituted for the heavy lead plates. Then again in working steep and long grades, the chemical energy instead of exhibiting itself in the form of electrical energy, exhibits itself in the form of heat, with consequent injury to the battery; cars will ascend steep grades, but it is not deemed economical to attempt grades of more than about 5 per cent., and they must be short at that rate. There may be isolated cases in which storage cars might be used with advantage, such as comparatively long lines with easy grades and limited traffic; but the author is of opinion that the introduction of storage cars at the present stage for lines of any considerable extent, and where steep gradients exist, would almost of necessity lead to serious breakdowns.

Conductors, according to their location, may be classed as underground and overhead conductors. The first, which are fixed in conduits similar to those in use on cable tramways, are represented by Mr. Holroyd Smith's design for the Blackpool electric tramways, the Bentley-Knight system at Denver, Cleveland, Alleghany City and Boston, and at Buda-Pesth, where Messrs. Siemens have a conduit system in operation. However, the conduits in the American cities have all been abandoned, and the Blackpool and Buda-Pesth lines are, to the author's knowledge, the only ones now at work. The great first cost in constructing conduits makes the system equally expensive with the cable system, and while it is certainly undesirable in the latter to get the conduit almost charged with storm water and street detritus during heavy rains, this does not seriously interfere with the working, while, on the other hand, it may be the cause of entirely stopping the running of electric cars for considerable periods on account of leakage and short circuits. It is also difficult of inspection and troublesome to keep the insulation in reasonably good order, on account of the continuous jarring to which the whole structure is subjected from the heavy traffic passing over it. The author does not wish it to be understood that he does not consider it practicable that a conduit could be constructed which would be fairly satisfactory, but the cost of such a one would be very great, and the mechanical details at switches, turnouts, &c., very complicated, requiring no end of attention. The fact that the Blackpool line has found no imitators in Great Britain is fairly conclusive evidence that the conduit system is not considered as being likely to return large dividends to possible investors, and as the average cost of working that line is stated to amount to about 4½d. per car mile, and storage cars can and are now being worked at the same figure in London, there is no likelihood of any more conduits being built. Another drawback which the conduit system has, in common with cable roads, is the introduction of a large extra amount of ironwork on the street surface.

Overhead conductors may be divided into two classes, the one having a complete metallic circuit consisting of two parallel wires; the other only one overhead wire, the rails and earth forming the return circuit, and further, whether contact with the conductor is made on top, on the sides, or from below, and again as regards the manner of suspension, whether cross-suspension, side-suspension, or centre-pole-suspension is used. It would engage too much time to balance up the pros and cons of the various methods; suffice it to say that nearly all roads of importance now running, and, so far as the author knows, all roads building, use the single-wire under-contact system, with cross-suspension in comparatively narrow streets, and centre-pole suspension in wide streets; the principal points in favour of these arrangements being the neatness and simplicity of construction, ease and perfection of all switching, and the substantial and permanent attachment of the trolly arm to the car, rendering all danger from a falling trolly impossible.

It may be well, before giving a description of the details of the overhead system, to consider the principal objections raised against its introduction ; these are, the danger of the current, obstruction by wires and poles, and unsightliness. This latter objection is rather more æsthetical than practical, for these overhead lines and poles can be constructed so as to be hardly noticeable, the poles being of an ornate description, rather pleasing than otherwise. They also form an excellent opportunity for the attachment of electric lamps, either arc or incandescent, and this advantage in itself should compensate for all æsthetical objections raised. As regards obstruction, this cannot be regarded as serious, there being only one wire for each track, and a pair of poles, and crosswire every 120 feet about, or in wide streets a centre pole, which latter would be rather an advantage, as it would divide the road traffic, and give pedestrians a better chance in finding security in crossing over wide streets, as refuges could be arranged with very little additional expense. In a city like Sydney, where we have hundreds of telegraph and telephone wires in our streets, the few extra wires would certainly not cause much additional inconvenience, if such there is, as the author has never heard any complaints raised against these wires.

Considering the danger of the electric current to life, in case of a person accidentally coming in contact with a railway wire carrying a potential of about 500 volts, we find that Mr. Edison, the champion of low-tension currents, in his celebrated article in the *North American Review*, mentions that to insure safety he would recommend no current should be used with a higher potential than 700 volts ; as this is actually 200 volts more than that used for traction purposes, and in view of the fact that there is no instance on record of any one having been injured by a current from a railway wire, although a great number of employés have taken it under many varying combinations of circumstances and being persons of all ages and various physical conditions this objection may fittingly be buried finally. In case of an accidental cross between a railway and a telephone wire, which might lead to danger by fire, inexpensive and simple cut-outs are known, the use of which will make it an impossibility for a dangerous current to enter any premises. Other safety appliances, such as "Young's Automatic Safety Cut-out," make provision in case of a railway wire breaking, to automatically and instantaneously cut off the current, thereby preventing all possibility of any person, outside the generating station, to come in contact with a charged wire.

We will now shortly consider the elements constituting the overhead electric road as used by the two American companies, who have between them constructed nearly all electric roads of any consequence which are at work at present, namely, the Thomson-Houston and the Sprague. We have :—1. The generating station. 2. The conductor from generator to car. 3. The motor on the car. 4. The gearing from motor to car-axle. 5. The return circuit to the generator.

Considering each element separately, we first have the generating station. This does not vary much in detail from electric lighting central stations, and as you all are no doubt acquainted with their construction a detailed description is superfluous. Special steps should, however, be taken to provide plenty of steam power behind the generator; and the engine should be of a type that will not vary much more than 2 per cent. in speed between running light and having to develop its full capacity almost at a moment's notice.

The conductor from generator to car, as now used on overhead lines may be properly described as the survival of the fittest. Siemens at first employed slotted tubes in which travelled a shuttle connected to the car by insulated wires. Next we find solid wires either singly or in pairs, superposed or side by side with a trolly running on top and connected to the car similarly to the one described above. This plan was, however, found to contain many drawbacks and the single wire under-contact method, in which the trolly wheel is fixed firmly to a mast projecting from the roof of the car, and is kept in contact with the conductor by means of springs from below, pressing it against the wire is now almost universally employed, the advantages being many, and some of which will be enumerated later on.

Turning our attention now to the construction of the overhead work, we find it to consist of a bare wire stretched over the centre of each track, somewhere about $\frac{3}{10}$ of an inch in thickness, of hard-drawn copper or silicium bronze. This is suspended at about every 120ft., at from 18ft. to 20ft. above rail level, either by means of a bracket, as in the centre or side pole construction, or from a thin wire cable stretched across the track from two poles fixed on the kerb-line, and is insulated therefrom by trolly line insulators composed of mica and india-rubber. The poles may be constructed of wood or, as is the case now in the best class of work, they are built up from wrought iron pipes of varying diameter, and admit of being ornamented to any desirable degree. They cause no more obstruction than an ordinary verandah post, and can be utilised—as mentioned before—for the attachment of electric arc or incandescent lamps without extra expense, and as they would, in that case, take the place of the existing gas pillars, the actual number of poles in the street would not be increased to any great extent. The poles are planted in concrete to a depth of between 6ft, or 8ft., attention being paid to make a good earth connection, so that in case of any leakage from the conductors passing down the poles, the electric current would be grounded, thereby preventing the possibility of a person leaning against the pole getting an electric shock. On short roads the conductor wires carry the whole current from the generator to the various motors along the track, but on long roads with heavy traffic, the fall in potential in such an arrangement would become serious at the more distant parts from the central station. Feeders are, therefore, employed, carried either parallel with the track, and connected with the conductor at short intervals, or the road is subdivided into sections, each section being fed by an independent feeder or feeders, carried overhead or underground, thereby not only keeping the potential fairly constant along the entire length of the road, but also avoiding the possibility of an entire break-down of the system, in case of fires, street blocks through processions, or even the rupture of a conductor wire; traffic could then still be kept up on either side of the break, and by putting in cross-over roads in the track at the ends of these sections, the inconvenience would be only small and of short duration. Feeders, in the author's opinion should be put underground, as being less liable to interruptions, and for this purpose it appears to him that the construction of the conduit on the Callander-Webber system would be particularly suitable. Samples of this are before you, and, no doubt Mr. Callander, junr., will be good enough to furnish us with a few particulars thereof, during the discussion. The principal advantages of the single-wire under-contact method of constructing the overhead work are:—Neatness and simplicity of construction, ease and perfection of all switching, and the substantial and permanent attachments of the trolly stand to the car, rendering all dangers from a falling trolly impossible.

The next element to be considered is the application of the motor to the car, and we will here also at once include the consideration of the gearing transmitting the rotary motion of the motor to the car-axle. These portions of the electrical equipment will more than any other be instrumental in determining the mechanical as well as the financial success of an electric road, on account of being subject to great strains, and comparatively rough usage. We cannot do better than quote copiously from Mr. F. H. Whipple's book on "The Electric Railway," who deals very exhaustively with this subject. For comparisons only the two best known systems have been chosen, as almost all others are still more or less in the experimental stage, and have not given proof by lengthy records of satisfactory working.

Mr. Whipple says: "One of the most important subjects which can be considered is that of applying the motor to the car. Some inventors have maintained that the motor should be placed upon the front platform of the car-body itself, and that the rotation of its armature should be transmitted to the wheels by means of chain gearing. Others have maintained that the motor should be rigidly attached to the axles, and with direct gearing between the armature and the axles, and have one end supported from the car body. This would give great flexibility and ease to the entire car