ELECTRIC TRACTION.

By Montague Rhys Jones, C.E.

Whether the present generation has discovered the ultimate force in nature most applicable to the service of man is a question for the scientist of the future to answer. We can, however, claim this to be the electrical age, as in prehistoric times there were ages of stone and bronze, and in introducing the phenomenon of electricity, as applied to traction, we cannot help being forcibly reminded of the unity and continuity of nature, when we consider how the method of applying this unknown force has, like all other physical and social phenomena, "ever from simpler to more complex grown;" it now remains an important part of our environment and if we failed to correspond the result would be a retrograde movement of the human species.

Passing over its agency as a transmitter and reproducer of thought and sound, and other commercial and industrial functions, we come to its latest evolution in its application to the propulsion of railway and tramway cars. Its practical utility was first demonstrated at Berlin, in 1879, by Siemens and Halske, on an experimental line of 500 metres. The train consisted of a small electric locomotive and carriages, which had very small wheels, with two rows of seats running parallel with the rails. The locomotive was fitted up with one of Siemens' dynamo-electric machines, laid horizontally on a frame-work with wheels, the bobbin being parallel to the rails, and the field electric magnets perpendicular thereto. The rotary movement of the bobbin was transformed and transmitted to the driving wheels of the small locomotive by cog wheels, and a bevelled wheel completed the communication of the movement. A bar of iron, to introduce the current, was laid between the two rails, and encased in wood, to insulate it electrically from the soil; "two spring rubbers attached to the locomotive rested on the bar. The current was transmitted by these rubbers into the machine; after having done its work it passed through the wheels of the locomotive, and back to the generator by the iron rails. It was not necessary for the rails to be completely insulated, for if some of the current escaped into the earth, it still returned to the generator, that being equally connected with the ground."

The success of this experiment led to other attempts of an exhibitional nature, at Brussels, Durseldorf, Frankfort, and other places with the same result, and then electrical traction passed from the experimental to the commercial process of development, and the Lichterfelde Electric Tram near Berlin was the first of this kind. The length is one and a half miles, and the equipment in 1881 consisted of two motor cars, the motion being transmitted to the wheels by belts working on grooved pulleys outside the wheels. The prime source of power was a steam engine, with a Siemens' motor and generator; but the installation differed in some respects to the Berlin line, the central rail not being used, but the one rail acting as a lead, and the other as a return for the current. Up to 1887 this line carried a hundred thousand passengers yearly. These instances are merely recorded to show that the inception of Electrical Tramways took place in Europe, the principle being the generation of electricity by dynamo, and conveying the current through conductors connected by sliding contact with the cars while in motion. Modern electrical railways are now built chiefly on this principle, although America has far superseded Europe in the improvement and perfecting of the system.

After the year 1881 the commercial aspect of electric traction was carefully considered, and numerous lines were constructed both in Europe and America. In the former the mines of Zankeroid and Hohenzollern constructed short tramways the system of conductors, being overhead inverted T rails. They each carried 300 tons daily, at a cost of a halfpenny and three farthings respectively. The first electrical tramway in England was projected and constructed by Mr. Mangus Volk, at Brighton, in 1883. It runs along the sea beach for about one mile, and includes some heavy grades and sharp curves. The speed was limited to eight miles per hour, but twenty-five miles has been done. The current is transmitted along the rails, with a gas engine as prime power. One million passengers are carried yearly, at a cost of 1·92 pence per car mile, and nearly 50,000 miles are run during the year. In 1883 followed Port Rush, in Ireland, with a six mile length of single track, the current being sent along a third rail by water power. And here let me state that, in my opinion, both Hobart and Launceston are eminently suitable for electrical enterprise, and that a well digested scheme of electrical tramways could be devised for both places, as would compare favourably in point of economical working with any system in the world, owing to the existence of an abundant and permanent head of water, which could be utilised for the generation of electrical power, but a radical alteration would be necessary in respect to the permanent way which is now being laid down in Hobart. The rolling surface is of such a crude character as will not only seriously affect vehicular traffic, but the successful operation of electrical trams.

In rapid succession followed Blackpool with an underground system, technically known as the conduit system. Mordling, Frankfort-Offenbach, with overhead slotted tubes as conductors. Brussels and Hamburgh followed in 1886 and 1887 with the Juien system of storage batteries, which, as will be subsequently explained, proved a failure. So far as America is concerned she has left us far behind in the race for cheap transit.

The first electric railway in America was exhibted at the Chicago Exhibition, in 1883, by Messrs. Field and Edison, the track running round the gallery of the main building, curving sharp at both ends, with a radius of 566 feet. The total length was 1,500 feet. The gauge was three feet, with a central rail for the current, and the two outer rails for returns. On June 5th, the "Judge" and its car, loaded with sixteen passengers, was started. The railway ran for a fortnight, completing a mileage of 446, and carried 27,000 passengers. The trial was considered a success. Mr. Leo Daft then began experimenting with his electric locomotive, the "Ampere." The actual performance was the hauling of a railway car weighing ten tons with sixty-eight persons in addition to the motor, which weighed two tons and carried five persons. The speed was eight miles per hour, upon a track having a gradient of 93 feet to the mile, and included a 20 degree curve. A maximum duty of about 12 h.p. was registered; and, although the actual efficiency was not determined, the 25 h.p. engine which actuated the primary machine was also doing other work at the factory.

The first electric tram open for traffic in America was the Baltimore Union Passenger Railway, in 1885; it had two miles of single track, six cars, and 260,000 passengers were carried yearly up to 1887, at a cost of 16s. per car per day, each running 73 miles daily; a third rail was introduced as a conductor, also an overhead wire. Electrical progress in America since that date has been simply astounding. In the beginning of 1890, one hundred and fifty towns had electric trams, aggregating 1,670 miles of track, with 2,650 motor cars, equivalent to 70,000 h.p., running 150,000 miles per day, and carrying 200 millions of passengers yearly. The prime source of power required to meet this gigantic traffic is estimated at 40,000 h.p., and it is stated, on the authority of those competent to form an opinion, that 3,000 motors will be at work this year, carrying 3 millions of people, and calculated to return in fares about 3 millions sterling.

It is always a profoundly interesting thing to know something of the historical development of a force which is destined to greatly modify the physical and mental attributes of man, and if an apology be needed for entering so fully into the historical detail connected with the subject, that is my sole excuse.

Before proceeding to describe the methods of application, and so as to afford those who have not had an opportunity of studying the subject, it is proposed to briefly enter into an historical and physical description of the dynamo and motor, two of the most important agents in the application of electricity as a motive power, which will, it is hoped, enable them to have a thorough grasp of the principle.

Before explaining the physical theory of the dynamo, it may not be outside the scope of this paper to briefly refer to Faraday's discovery in 1831 of the laws of magnetic-electric induction. He found that induced currents could be started or stopped in an adjacent coil, which led to the further discovery that currents could be generated in a coil moved in the poles of a powerful steel magnet. He then made what he termed a "new electrical machine," whose parts consisted of a copper disc 12 diameter, and one-fifth of an inch in thickness, fixed on a brass axle, and mounted in frames so as to revolve, its edge being placed between the poles of a large compound permanent magnet. Copper and lead conducting strips were placed in contact with the edge of the disc, a wire from the galvanometer was connected to the collecting strip and the other to the brass axle. On revolving the disc a deflection of the galvanometer was obtained, which was reversed in direction when the direction of the rotation was reversed. Here, therefore, was demonstrated the production of a permanent current of electricity by ordinary magnets. From 1832 many inventions and improvements followed, until 1848, when Brett made the important suggestion of causing the current developed in the armature by the permanent magnetism of the field magnets to be transmitted through a coil of wire surrounding the magnet, so as to increase its action. This improvement marked an era in the evolution of the dynamo, being the first suggestion of the self-exciting dynamo. Then followed a period of great activity, when further improvements were effected, and in 1867 Dr. Werner Siemens described in the Berlin Academy a machine for generating electric currents by the application of mechanical power, the currents being induced in the coils of a rotating armature, by the action of electro-magnets, which were themselves excited by the currents so generated. To mark the importance of this departure, Siemens coined the word "dynamo-electric machine," which now is shortened into "dynamo," and which has now become the name for all these electric machines driven by mechanical power, whether self-excited or not. Brush introduced his famous dynamo of a shunt and series winding for the purpose of enabling the machine to do either a large or small amount of work. Many other Americans produced dynamos, amongst them being Edison. The dynamo was now brought up to a great state of perfection, and since the year 1883 the chief progress made has been in details of design and mechanical construction.

I will now proceed, as briefly as possible, to illustrate the physical theory of dynamo-electric machines, which I hope will enable us to understand more clearly the part they play in the propulsion of tramway cars. Professor Sylvanus Thompson defines a dynamo-electric machine as " a machine for converting energy in the form of mechanical power into energy in the form of electric currents, or *vice versa*, by the operation of setting conductors to rotate in a magnetic field, or by varying a magnetic field in the presence of conductors." Projected on the screen is a magnet with electric tufts from the North to South poles. (Plate I.) If iron filings were placed in these magnetic fields, they would arrange themselves thus :—(Plate II.) Now, if we place a conductor, such as a piece of copper wire, in this magnetic field, as it is technically called, and moved it about intercepting these lines, an amount of electricity would be generated in the conductor at right angles to the course of the movement of the conductor, and also at right angles to the direction of the lines of force. "This induced current is purely conditional on the intensity of the magnetic field, and the length and velocity of the moving conductors, as well as the resistance of the wire to the current." Now, as to what this current is, no one knows. It is one of those ultimate scientific facts at present behind the veil. Here is another diagram showing the magnetic field surrounding the conducting wire, end on. (Plate III.) Every wire, as Professor Thompson puts it, "is surrounded by a sort of magnetic whirl," thus:—(Plate IV.) To do this wants energy, and that constant, if to be maintained. It is these whirls which act on magnets, and cause them to set, as galvanometer needles do, at right angles to the conducting wire. It must, however, be remembered that a moving conductor in its motion must cut the lines of force that pass through the circuit of which the moving conductor forms part. I cannot illustrate this fundamental truth better than by throwing upon the screen a few diagrams of Professor Thompson's, and by quoting him on the subject :—"If a coil or wire circuit be moved along in a uniform magnetic field, as indicated in this diagram (Plate V.), so that only the same lines of force pass through it, no electric current will be generated; or if, again, as in this diagram (Plate VI.), the coil be moved by a motion of translation to another part of the uniform field, as many lines of force will be left behind as are gained in advancing from its first to its second position, and there will be no current generated in the coil; but if, as in this figure (Plate VII.), the coil be tilted in its motion across the uniform field, or rotated round any axis in its own plane, then the number of lines of force that traverse it will be altered and currents will be generated. These currents will flow round the ring coil in the positive sense. 'The positive sense of motion round a circle,' I may here add, 'is here taken as opposite to the sense in which the hands of a clock go round.' If the effect of the movement is to diminish the number of lines of force that cross the coil they will flow round in the opposite sense. If the effect is to increase the number of intercepted lines of force, if the field force be not a uniform one, then the effect of taking the coil by a simple motion of translation from the place where the lines are more dense to a place where they are less dense, as from position 1 to 2 on this diagram (Plate VIII.), will be to generate currents, or if the motion be to a place where the lines of force run in the reverse direction the effect will be the same, but even more powerful."

From the foregoing simple facts some very important consequences are apparent, the principal of which are these:—"Currents can be generated in conductors by setting up magnetic whirls round them. We can set up magnetic whirls in conductors by moving magnets near them or moving them near magnets. This means energy and an expenditure of power. The more rapid the motion the stronger the current, and by using a suitable commutator or guide all the currents, direct or inverse, produced during recession or approach can be turned into the same direction in the wire that goes to supply currents to the external circuit, thereby yielding an almost uniform current."

A very large number of dynamo-electric machines have been constructed on the foregoing principles, and the variety is legion, but the ones most used for the purpose of electric traction are those in which there is a rotation of a coil or coils in a uniform field of force, such rotation being effected (as in this diagram—repeat Diagram VII.) round an axis in the plane of the coil or one parallel to such an axis.

An electric motor is the reverse in its action to the dynamo, the latter converting mechanical energy into electrical force, and the former conversely transforms the current of electricity supplied by the dynamo from electrical force again into mechanical energy, thereby propelling the cars. The electric motor "includes all apparatus through whose employment work is performed." Everyone, no doubt, has heard of "Barlow's wheel." This was the first elementary electric motor. He found that by passing a current from the centre to the circumference of a copper disc between the poles of a magnet the disc would revolve. Faraday, you will have observed, in his researches in induction, reversed Barlow's experiment, but those discoveries resulted in the dynamo. It was not until 1873 that the reversibility of the dynamo was discovered, although for many years previous to this motors for driving machinery were operated, but depended on the galvanic battery for a supply of current. This process, being a very limited one, went to the wall when a cheaper current was effected by the discovery of the dynamo. The action of the practical and commercial motor now used is that of a magnet and a wire conveying a current, and is the reverse action of the dynamo, in which the motion of the conductor generates the current. On the other hand, a current in the conductor creates motion.

The law of the survival of the fittest has been an important factor in reference to types and varieties of the motor, not only in many mechanical appliances, but other resources resorted to to intensify the currents.

Having, it is hoped, given a clear insight into the theory of these electrical machines it is to be regretted that the limits of this paper will not permit a detailed description of the mechanical parts (Diagram of Sprague's Motor—A); but so long as the elementary truths have been retained, and that they will be brought to bear on the more descriptive portions of this paper, the object of the same will have been attained.

There are two methods of applying electricity for traction purposes—(1) by storage batteries; and (2) by metallic conductors over and under the track, known as the "overhead system" and the "underground" system respectively. These methods, however, are both of a direct nature, the motors being supplied with current from the conductors as wanted. As an ideal method of propulsion the storage or accumulator system stands pre-eminently foremost, and the best electrical intellects of the day are devising and improving with a view to eliminate the many defects which prevent it from being introduced commercially. The batteries occupy but little room, and are placed under the seats, and the motor is placed under the body of the car. There is no smoke or dust or accompanying noise and no street gearing, and the æsthetic sense is greatly conciliated by its attractive and graceful movement without contact. This is all very well on paper, but when brought into actual experience, like all ideals, it falls short of expectation. The serious objections to its commercial employment are that the accumulators are composed of lead, weighing altogether about 3,500 lbs. in an ordinary street car, thereby reducing the electrical efficiency by nearly 60 per cent. These cells, stored with power, have to be always carried about, whether over heavy or light grades, and if the car has to surmount any grade over 5 per cent., which is common in streets, the capacity and discharge rate is so limited that it is with only great difficulty and serious injury to the mechanical parts that they can be negotiated, and the chemical energy of the cells instead of supplying current developes heat and buckles the cell plates. Platinum or gold might withstand this constant molecular activity; but then, again, it does not do away with the dead weight, to say nothing of expense; but I believe gelatinous cells are spoken of as being highly probable in place of the lead cells. Last January I was asked to value the assets of the Eaglehawk Electrical Tramway Company, which was operated on the storage system for about three months or more, and which proved an entire failure. Its cost amounted to £40,000, and the debris was worth about £5,000. It could have been nothing but ignorance that suggested the storage system for Sandhurst, as the street conditions were entirely unfavourable for such. It is indeed difficult to speculate what the ultimate destiny of the storage car will be, but if improved up to present commercial requirements the most perfect ideal of street transit will have been accomplished.

The underground system, in point of construction, is very much like the cable system, so far as relates to the conduit for carrying the conductor, and the chief objections to it are cost of construction. The conduit in a busy thoroughfare would probably have to be excavated without the use of explosives, at a great cost; and without a large wetted perimeter is allowed for during heavy rains the channel would be flooded, and the water and street debris would come in contact with the conductor, which cannot be fully insulated owing to contact with the trailer, which is suspended from the car, and from which the motor takes its supply of current. The efficiency is entirely destroyed by short circuits and leakage. There are many other mechanical difficulties to be overcome, and one of the great drawbacks which militate against its success is the large amount of ironwork on the surface of the street, together with difficulties of switching and cost of maintenance.

We now come to that system which has been most successfully operated, commercially and practically, throughout the world, and whose adherents and supporters are growing yearly, namely, the "overhead system." Overhead conductors consist of two elements, one having a metallic circuit of two parallel wires, and the other only one overhead wire, the rails and earth forming the return current. There are various methods of contact between the car and the overhead wire, but the one universally used is the single wire under contact system, with bearing wires suspended crossways in narrow streets and centre pole suspension in wide streets, the chief points in favour of these arrangements being the neatness and simplicity of construction, the ease and perfection of all switching, and the well designed and permanent attachment of the trolly arm, a balanced and pivoted pole attached to the car rendering the danger of a falling trolly a very remote contingency. (Plate VIII.)

There are two prominent firms in America who by their great ability and energy have been instrumental in carrying out most of the electric roads in America. I refer to Sprague and Thomson-Houston. There is little in point of difference between the systems of either firm, but I shall describe Sprague's system as a type of this modern electrical railway, having been in communication with that firm in reference to the design of a plant for an electrical tramway, whose conditions were of an exceptionally difficult character, there being a grade of 1 in $8\frac{1}{2}$ for a distance of eight chains.

We have to consider five points in connection with the overhead system:—1. The power-house or generating station. 2. The conductor from the power-house to the car. 3. The motor attached to the car. 4. The connection between the motor and the axle of the car. 5. The return of the current to the power-house.

Thrown on the screen is one of Sprague's power-houses (Plate IX.), supplied with Armington and Sims' engines connected up to the dynamos, and thereby supplying the necessary mechanical power for the production of the current, and in designing these engines it is desirable that they should be so constructed that no variation of more than 2 per cent. in the speed should take place, whether there is a small amount of work to do or whether they are called upon to develop their highest capacity at any given moment, and it is always necessary to have the chief parts in duplicate in case of accident.

The conductor from the power-house to the car has undergone many modifications, but the plan which is now generally adopted is a trolly wheel, firmly fixed to a balanced and pivoted pole having a universal movement. This projects from the roof of the car, and is kept in contact with the conductor or overhead wire by aid of springs from below pressing it underneath and against the overhead wire.

With regard to the overhead work a three-tenths of an inch copper wire is stretched over the centre of the track. At every 120 feet it is suspended about 20 feet above the level of the street. This is done either by means of a bracket, as shown on the diagram (Plate X.), or from a thin cable stretched across the street from kerb to kerb, attached to poles either of wood or iron. This, of course, necessitates the insulation of the main wire by means of a small insulator made of mica and indiarubber.

The poles are planted in concrete to a depth of 6 or 8 feet and a good earth connection made, so that leakage of current can be grounded. The poles are very ornamental in design, and are capable not only of any amount of artistic embellishment, but can be practically used for electric lighting. On short roads the overhead wire provides current for the whole of the motors on the track, but on long lines, where traffic is heavy, feeders are resorted to, carried overhead or underground, and connected with the main overhead wire at intervals of 400 to 500 feet by small lateral or sub-feeders. The important features of this excellent system are the maintenance of a constant potential along the entire length of the road, avoiding a breakdown of the system in case of fires, congested street traffic, or the rupture of the overhead lines. Traffic would still be carried on at either side to the breach, or if by placing cross-over roads in the track at the ends of these sections the inconvenienee would be slight.

The next point to be explained is the motor and the connection between the motor and the axle of the car. (Plate XI.) You already know the main functions of the motor. The current is conducted to the motor under the floor of the car. The mechanism consists of a motor fixed under frame of car. On the end of the motor shaft a pinion gears into a spur wheel on an intermediate shaft. On the other end of the latter another pinion gears into a spur wheel on the driving axle of the car, and motion thereby being communicated. The Sprague motors are perfectly automatic, running at nearly the same speed for all roads up to the maximum, and adjusts itself to normal speed under sudden changes in load. A diagram showing a street railway current curve gives an idea of the erratic power-calls on the motor. (Plate XII.) As regards the system of braking, when a motor is in operation it is generating an electro-motive force. In other words, it is acting like a dynamo, and since this depends upon the strength of the field magnet and the intensity of motion, and since the field magnet strength is under positive control, it follows that the electro-motive force can be made to equal the initial motive force, and even to exceed it when this electro-motive force of the motor thus predominates. The machine will then become a generator and give current to the rails, and its mechanical effects are reversed, so that it brakes the train instead of propelling it.

For controlling the cars a series of levers are worked on the platforms, and a "rheostat" is used for throwing machines into circuit. The last item to be determined is the return of the current to the power-house. There are many methods, as have already been pointed out, namely, by earth plates being buried in damp soil and by rail; but in recent practice the complete metallic return, the same as the overhead wire laid on the top of the sleepers and between the rails, and connected with the latter close to the joints, is pronounced to be satisfactory.

Of course many objections of an æsthetical nature have been urged against the overhead gearing, but they are more apparent than real, and those who take their stand on such paltry objections I would recommend to look at the telegraph and telephone cables so obtrusively conspicuous in big towns. The telephone people have also complained that the ground return interferes with the successful operation of the telephone. The same argument could be brought against electric lighting and telegraphs. The telephone people could meet this chief objection by having a metallic return constructed, the cost of which would be a mere bagatelle. As regards the risk to human life by shock, the working potentiality of 500 volts is so low that it is hardly worth considering. Having touched the fringe of the principal objections a brief comparison, *pro* and *con*, with other systems of traction will be considered. Traction expenses on horse tramways amount to two-thirds of entire working expenses, to say nothing of its inhumanity; and as to steam, it is a clumsy but effective method of applying force, and the citizens of Hobart would be wanting in public spirit if they ever permitted steam engines to run along their streets. If a draughtsman sat down and deliberately attempted to design an affront to a decent community he could not have succeeded better than at Sydney. The working expenses of the steam trams there amount to 3s. per train mile. It is now generally admitted that the struggle for existence lies between the cable system and the electric. The cost of the construction of the former in Melbourne amounted to £34,000 per mile, and 75 per cent. of the available energy is lost by dragging the cable itself, while the whole of the energy can be utilised by the overhead system, excepting a few points per cent. due to resistance of the current by the overhead wires, to say nothing of numerous mechanical defects. At Minneapolis £80,000 was spent in the purchase of cable plant, but was cast on one side as scrap iron to make way for an electrical system. The cable system can certainly surmount phenomenal grades, but on the other hand the electrical tramway can negotiate 1 in 8 grades, or even less; it is only a question of power; and Mr. Reis, an electrical engineer, has made some very valuable discoveries as to electrical braking and adhesion, which I hope to see practically demonstrated at an early date.

As much as one would like to submit these different tramway systems to a searching analysis of cost, not only as regards construction, but working and maintenance; but having already overstepped the limits of a paper, I can simply record the fact that the Frankfort-Offenbach line in Germany is the most expensively worked tramway in Europe or America, the cost amounting to 4½d. per car mile. Mr. Crosby summarises the cost of working, etc., three of the principal lines in America:—"Interest on investment, one-quarter to one-fifth of the whole, *i.e.*, 1 cent per car mile, or, say, 20 per cent. of the total. Coal is about 12 per cent., attendance 40 per cent., machinery and line (without interest) about 20 per cent."

Here is a view of the Telpherage system. (Plate XIII.) It requires no earthworks, bridges, culverts, etc., as railways do. There are three lines worked on this system in England—Alexandra Park, half a mile; Glynde, a mile and a half; and Eastpool a mile and a half; the latter two for mineral purposes. I throw the suggestion out that they are admirably adapted for the developments that are taking place at the present time on the West Coast. It is difficult indeed to surmise what shape electrical developments will take in the future, its potentiality being apparently infinite. It is, however, no stretch of the imagination to say that it is the locomotive power of the future. In preparing this paper I have consulted Professor S. P. Thompson's works, Professor Ayrton, Du Moncel, Martin and Wetzler, and other scientific papers. (Plate XIV.)

DISCUSSION.

Mr. Macfarlane said:—Your Excellency and Gentlemen,—Having been asked to take part in the discussion following Mr. Montague Jones' excellent paper, I have pleasure in doing so, as I have had opportunity of gathering some information on this interesting subject, being in correspondence with a manufacturing company, makers of electric railway plant, the Thomson-Houston Company. There are only two or three points which I would desire to emphasise as of special general interest to the public, and the first point is that electric traction is not now confined to the region of scientific experiment, but is an established commercial success. In the United States there are 310 tramways or railroads worked by electricity, with 4,000 cars and 7,000 motors. In the city of Minneapolis a new and expensive cable has been abandoned and electricity adopted, and it is estimated that one-third of the street railway mileage in the States is worked by electric traction; and further, the following tramways, amongst others, pay a dividend of 8 per cent.:—The West End Road, Boston (probably the largest tramway company in the world), the Springfield, Troy and Lansenbury, and Utica and Mohawk tramways. These facts are sufficient to show that electric traction for tramways and railroads is a commercial success. I am speaking now of the overhead system, and on the general principle, for, of course, there are electric railroad companies which do not pay dividends, as in all commercial ventures. With regard to steep grades I may add 1 in 7 is not too steep for working. I believe the steepest grade in the proposed Hobart line is 1 in 16.

It is interesting to note further that electric traction has also been successfully applied to tramways for mills and manufactories, as well as to street railways, and is found a convenient method of transporting raw materials, manufactured products, coal, and other commodities from one part of the works to another. Electricity fully meets the requirements of such a case. The special advantages claimed for electricity over steam motors or locomotives are three in number, viz., safety, the removal of obstacles presented by grades, and economy. Its safety is seen from the fact that the road may be run through the mills and store-houses without increasing the insurance rates. Steam is unsuited to indoor work, and even when used entirely out of doors there is always some danger of fire, and there is the smoke and the noise and dirt arising from the locomotive. In the matter of grades, whilst 4 per cent. (1 in 25) is about the maximum which steam can overcome, grades of 12 per cent. (1 in $8\frac{1}{2}$), or more, are easily surmounted by electricity. The expense for horse-power of running a steam locomotive in comparison with a large stationary engine, where all the advantages of concentration are available, shows decided economy in favour of the large plant. Electricity furnishes a means for transmission of power with minimum loss and cost, permitting the concentration of the generating plant, whether steam or water power, and thus appeals strongly to the business man on the ground of economy. One advantage possessed by electricity alone is that the overhead wire may be tapped anywhere, and a stationary motor, an electric hoist, a pump, or any form of electric-power machine operated from it. Electric traction is in use at the works of the Baltimore

Sugar Refinery, Pittsburgh Plate Glass Company's, Trenton Iron Works, and many other mills and factories.

As to the safety of the overhead wire system in regard to freedom from accident or danger to human life, it is very satisfactory to have reliable and independent testimony apart from experts or officials connected with manufacturing companies. The *Boston Daily Advertiser*, the well-known Conservative journal of a Conservative city, addressed letters to the Mayors of the various cities in which the overhead system of electric tramways was in use. The questions submitted were:—1st. What system of electric cars is in use in your city? 2nd. Whether any persons have been seriously injured or killed? 3rd. Whether any apprehension is felt among your people as to safety on account of this electric system? 4th. Whether, as a result of its introduction, the street car service is improved? 5th. Whether popular feeling is in favour of the overhead wires, or hostile to it? In reply 69 answers were received from as many cities, which were published in the *Advertiser*, appearing on the 26th August, 1890. In regard to the third, fourth, and fifth questions the consensus of public opinion is exceedingly favourable; and on the point of danger raised by the second question the *Advertiser*, in summing up, says:—"We find that of the 69 cities reports of accidents are confined to 15. Of these only 8 resulted in serious or fatal injuries to human beings, the others being the killing of horses by falling wires. Of the human beings killed, in all but two cases the accident was due to other causes than the electric wires, and in both cases where the wires apparently brought death they were by electric light wires. We have not heard of a single death from the trolly wire." It must be admitted this independent testimony is very satisfactory.

Nashville, Tennessee, claims to have the largest electric railway system in the States, excepting the city of Boston. And I will conclude this short sketch with an extract from the Mayor of Nashville's letter in reply to the questions submitted by the *Boston Daily Advertiser*:—"No person has been injured by the system. Three horses have, however, been killed, caused by rusted telephone wires falling across the trolly wire and conveying the current from the trolly wire to the ground. In one instance when one of these accidents occurred a Negro woman, in attempting to pass, grabbed"—[Excuse the expression; it is not mine, but the worthy Mayor's.]—"the telephone wire, and was thrown to the ground. She naturally did right smart 'high kicking,' but she immediately arose, much frightened, but in nowise injured. From this it seems that while the trolly wire conveys sufficient electricity to kill a horse, yet there is not sufficient current to kill a human being."

Mr. C. W. S. James, C.E., said he had been deeply interested in the paper read, and had tried to think how far the electric traction system could be applied to Hobart. A few months ago he had estimated what could be done in Launceston by utilising the South Esk River, and he thought that there from 1,000 to 1,300 horse-power could be available. In regard to Hobart, however, there was not the same power available, and he believed they would require to look to generated power in any electrical system introduced. He thought the system could be usefully applied to carrying minerals on the West Coast, and that the "overhead system" was well adapted for the streets of Hobart.

Mr. J. Fincham, C.E., said he had followed the paper with interest, but they had no reference to the length of the steep grades surmounted. He believed that in any scheme for electrical traction in Hobart this would be one of the difficulties. He was aware that there were about 300 tramways in America, but he had not been able to get any particulars as to the grade, or whether it was equal to such a grade as they had to contend with in going up Elizabeth-street.

Mr. A. W. Lawder, C.E., thought the length of grade to be overcome simply resolved itself into a question of the power of the accumulator.

Mr. Fincham said that was just the difficulty the engineers found. They had not been able to provide enough accumulation to overcome a sustained strain.

Mr. Jones, in reply, said Mr. Fincham appeared to associate the "storage system" with the practical operation of electric trams, but it was clearly pointed out that the "storage" up to the present time was an ideal method, and that the "overhead system" was the only one of practical value. The main defects of the former are the limited capacity of the cells, and when brought to bear on a grade of 5 per cent. heat instead of current was developed, which buckled the cell plates, rendering them useless; and, again, the cells are composed of lead, weighing altogether 3,500lb., which has to be carried about over light as well as the heavy grades, losing 60 per cent. of the available efficiency. Coming to the "overhead system," the question of surmounting heavy and continuous grades resolves itself into a question of increased power, which is always to be obtained from the central station, and herein lies the great advantage the overhead system has over any other. All the available energy can be utilised excepting a few points per cent., due to the resistance of the current by the conductor. The maximum grade in Hobart is 1 in 16, and is slight compared with some of the towns where cars are being operated by electricity. The following is an extract from a letter from the directors of the "Richmond Union Passenger Line" to Mr. Sprague:—"The road which you have equipped under most trying conditions has been one of the most, if not *the* most, difficult which could be met with in street railway work. The excessive and continuous grades, the numerous sharp curves, the gradients in these curves, the weight of the cars, and the heavy loads which they have been required to carry, together with the extent of the system, and the number of the cars in operation (about 40), constitute the enterprise the largest and most difficult yet inaugurated in any part of the world. We acknowledge the successful fulfilment of all the terms and conditions of the contract, and compliment you upon having achieved so signal a success." The number of street electric railways at work, and the number contemplated, is quite sufficient to prove that it has long since passed the experimental stage of development. Citizens of Hobart should keep these facts in view, and refuse to listen to any argument stating it to be impracticable to introduce an electric service here. The wretched apology for a permanent way will certainly have to be removed, and a neat steel-grooved rail put in its place, as the basis of efficient street transit is a smooth and sound rolling surface. I would also like to see a 4ft. 8½in. gauge, instead of a 3ft. 6in. gauge, as the latter might create mechanical difficulties which cannot at present be foreseen, as all the electric roads, or nearly so, are built to 4ft. 8½in. requirements. Of course these difficulties would be overcome; still it is just as well to be on the safe side. As regards a prime source of power for Hobart, it is a simple question of cost and maintenance whether water or steam would be better. There is plenty of water, and the cost to supply a constant head would be, I think, much less than coal Two hundred h.p. would be more than sufficient force for a service of 12 cars, and as to the mechanical power for equipment it does not make much difference whether the grades be 1 in 5 or 1 in 10, as the motors used are of a standard size, having a capacity of 15 h.p. each. Where the grades do not exceed 4 to 5 per cent., one motor could do the work, but where the grades exceed 5 and run up as high as 10 per cent., then it is unsafe to operate, except by driving both axles, and then the equipment must be two 15 h.p. motors. The average weight for street motors' equipment is about 100lb. per h.p Hence 2·15 h.p. motor equipment will weigh about 3,000lb. I have deduced this to mathematical formulæ following:—H.P.=4·75=M.T. (C x 1), where M=miles per hour, T No. of tons, C rise in feet per 100. The cost of single line "overhead" construction, including permanent way material, under average conditions should not amount to more than £3,500 per mile. This, in comparison with the cable system at Melbourne at £34,000 per mile is very marked, and the economy of the overhead system is so manifest that Mr. Henry Peabody, of Boston, wrote to me as follows, in reply to inquiries:—"There is a feeling among all Municipal Councils, where railways apply for overhead lines, that the increased economy warrants their asking for a decrease of fares, hence their desire to keep quiet about their balance-sheets." Mr. James asked me to explain the Telpherage system. There are two, "the series," and the "cross ones parallel." The latter is now being operated in many places. The skips or trucks are suspended and supported by iron rods, which are likewise supported by poles, and the lower rod, acting as a conductor, is constructed on the "break and make" principle at every 120ft. or so, taking its supply of current from a dynamo fixed at a convenient place. The "makes and breaks" are normally closed, so that a current of electricity may flow from end to end; but when the first wheel of the skip of a train touches the "break," the circuit is closed, and the current runs back to the last wheel of the train, and into the skip containing the motor, and thereby energising the train. The same operation continues at the intervals stated to the end of the journey. It can be worked up to 15 miles per hour with ease, and the cost of carrying is about one halfpenny per ton per mile. Unlike most new inventions, "Telpherage" does not persist in adhering to any principle of an obsolete type, but is an innovation so extraordinary as to pass all practical experience. As feeders to the West Coast lines nothing could be more admirable, and not in the remote future we shall see it universally adopted, instead of those useless unpayable lines and costly roads that cripple the resources of new countries.