Discussion.

Sir Benjamin Baker.

Sir BENJAMIN BAKER, K.C.M.G., moved that the thanks of the Institution be accorded to the Author for the valuable Paper he had communicated on an interesting and important branch of electric traction.

Major-General Webber.

Major-General WEBBER thought engineers would be impressed by the conditions on the continent of Europe, as compared with those existing in England, as to the facilities for the construction of electric tramways. The method of laying tramway rails on a macadamised road, in which a plank was placed alongside the rail with its upper surface level with the top of the rail, had been referred to in the Paper, as a means of preventing the wheels of the ordinary traffic cutting a rut along the rail. It would be interesting if the Author would explain how it was that a rut was not caused equally alongside the plank. The advantage existing in Montreal, and no doubt in many towns, not only in the United States, but in Canada, arising from the permission to carry feeder-wires overhead was also brought out in the Paper. Although overhead conductors were allowed in many of the most important continental towns, he did not remember a case in which the ordinary trolley-wire had been supplemented by overhead feeder-wires attached to brackets from the poles. All, or most of, the feeder-wires on a well-constructed line, were laid underground, and they were therefore more costly than when carried overhead. That applied to a most excellent arrangement also existing in Europe—the use of heavy return conductors. If he understood the Paper rightly, these were also carried overhead. That was a factor of economy which he did not think would be allowed in Europe. The spans between the poles—about 120 feet—were, he thought, rarely allowed in any town in Europe, where, in most cases, they did not exceed 90 feet. He had lately inspected some of the most important tramway-systems in Germany, and he could not help thinking that, although there might be a considerable difference in the actual conditions of old towns like Hamburg, the suburbs presented very similar aspects to what might be found in most of the newer cities in America. He did not regard Montreal as a new city, but so far as the suburbs were concerned he could well understand that an overhead system was allowed, and was not a disfigurement. But the more he saw of the overhead systems

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in the suburbs of the towns he had visited, the more he felt that the only reason why those lines of gallows were permitted was that most of the roads were so dreary in character that the overhead trolley line was an ornament rather than a disfigurement. The only case in which he recollected an overhead trolley-line having been allowed with little or no objection in a picturesque place was the first line of the kind erected in Europe, with the design of which he had been concerned, at Montreux, alongside the Lake of Geneva. When he last visited it the trees had so concealed the poles that they were not noticed. In Hamburg, where there was a system almost identical in size and power with that described in the Paper, one great objection was removed in the narrow streets, that there were no poles, the trolley-lines being suspended by wires stretched from house to house. The effect on the expenditure of energy of a considerable length of the line referred to in the Paper, having heavy gradients, had been illustrated by some of the figures if his deduction from them was correct. The 151 cars in fine weather increased the current to 5,750 amperes. In bad weather this would run up to 25 per cent. higher, or to 7,190 amperes. The average might be taken as 65 per cent., or 17 units per hour per car, or 2·25 units per car-mile in bad weather. In Hamburg, where the length of steep gradient was much less of the total of 94 kilometres, the 310 cars always on the line did not use much more than half that amount, measured at the terminals of the generators. If the Author would show how many car-miles were run with the motor-cars, and how many with motor-cars and trailers, it would be easier to judge better of the results. The average speed of $7\frac{1}{2}$ miles was the resulting factor of a large portion of the length of the line having heavy gradients. In Hamburg, with a lower consumption of electrical energy per car-mile, the cars attained on some roads a speed of 19 kilometres per hour without appearing to cause danger to the pedestrian or wheel-traffic. There was one point which was of great interest in this country—the question of stopping-places. He should be glad to know whether the municipality of Montreal allowed a regulation by which the cars might stop at certain points at the corners of the streets, not making it obligatory to stop wherever any old apple-woman hailed the car. Any one who observed what happened in Streatham, where there was an analogous case, must be struck with the way in which the tramway traffic was interrupted by unnecessary stoppages. Passengers using the line seemed to take pleasure in requiring the car to be pulled up every moment. The

Major-General Webber.

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Major-General Webber. inconvenience would occur just as much with electric-traction as with cable-traction.

Mr. Dawson. Mr. P. Dawson remarked that the capital investments in electric street-railways in the United States, which amounted to £50,000,000, and the aggregate station I.HP. used to propel electric cars in America was about 1,500,000. With reference to the Author's statement that there were 15 miles or 20 miles of accumulator storage-battery roads running in the United States, he should be glad to know in what other places they were running. The only one of which he knew was in New York, and on that road at the end of 1895 there were only two experimental cars running. Cars carrying accumulators, self-contained motor-cars, had been used 10 years or 15 years, and had always proved a financial failure. For practical purposes the conduit system was perfectly satisfactory, and had been running for some years on the Continent. At Buda-Pesth it had been running on a line 4 miles in length. It was also used in Lennox Avenue, New York, and had been likewise working successfully at Washington. The only objection to it was great prime cost. The cost of equipping the installation in Lennox Avenue was about £17,000 for a single mile of line. The cost of the trolley system was only one-third of that amount. On the tramways in the United Kingdom where the dividends were not very large, such an increase of capital expenditure could not be recommended from the investor's standpoint. There was also a conduit in course of construction in Brussels. There had been already an overhead wire there for some years, which had been most successful. It was built mostly with bracket arm-poles, 120 feet apart, with ornamental brackets running out along the Boulevard, and it was quite practicable, and no eyesore. There was another line, in the heart of the city of Bristol, with which he had been connected. It had been running since October, 1895, without a hitch. The placing of tramway rails on ordinary macadam roads had been referred to by Major-Gen. Webber. A small line had been running for several years at Guernsey, three miles in length, one mile being laid with tramway rails on a macadamised road. There was a fairly heavy traffic, and the road was well maintained, there being no rut whatever. As to the question of bonding, he did not think the corrosion of water- and gas-pipes, and possibly of telephone- and telegraph-cables, which might be caused by the escaping of the electric-current over the rails on its way back to the generating station was to be feared in England on account of the stringent Board of Trade rule, which could easily be complied with, as had

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been proved at Bristol. Two conditions were necessary: the first was that the rails were connected together and to the return circuit, so that the current would have an easier path to get back by the rails than by the earth, or the water- or gas-pipes in the neighbourhood. The second was to insulate as far as possible the rails from the earth. The bonding adopted at Bristol, Dublin, Cape Town, Port Elizabeth, and most of the continental lines now being equipped, was that known as the "Chicago" bond. He had placed a section of a rail on the table. It was practically a one-piece rail bond, having large tubular terminals, which were connected into the rails by inserting them into the holes drilled to fit them, and permanently expanded by stretching or swaging the metal composing them into contact with the holes. The expansion of the terminals was accomplished by driving drift-pins into them about $\frac{1}{16}$-inch larger than the openings in the tubular terminals. As the conductivity of iron was one-sixth that of copper, the contact of the copper with the iron must be six times the sectional area of the copper. That was met by making the terminal of the bond very much larger than the ordinary section. The Board of Trade enforced that there must not be a fall of potential on the return circuit, between the furthest end of the line and the station, of more than 7 volts. In Bristol, where the end of the line was 2 miles from the station, there was a regular service of twelve motor-cars, and by the use of good bonding the fall of potential was only $1\frac{1}{2}$ volt. Another point of importance in English tramways, where a concrete foundation was generally used for the rails, was that the rails were practically insulated from the earth. When there was a short-circuit on the overhead line the leak did not exceed 60 amperes. This was owing to the fact of the poles supporting the wires being bedded in concrete, which acted as an insulator, and prevented the great rush of current which would otherwise take place. With regard to the question of iron or steel poles, it was important that they should be strong enough to support the very heavy strain which they were called upon to bear. He might be permitted to read the specification of the poles used in Bristol, Dublin, and on all the recent American lines:—"Five grades of poles are called for, all of them 31 feet long, to be set in the ground to a depth of 6 feet. No. 1 is to stand a lateral strain of 350 lbs. applied to the top without showing a temporary deflection greater than 6 inches, and a strain of 700 lbs. without showing a permanent deflection greater than $\frac{1}{2}$ inch. No. 2 is to stand a strain of 500 lbs. without deflecting more than 6 inches, and a strain of 1,000 lbs. without more than $\frac{1}{2}$ an inch permanent Mr. Dawson.

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Mr. Dawson. deflection. No. 3 is to stand a strain of 700 lbs. without deflecting more than 6 inches, and strain of 1,200 lbs. without permanent deflection of more than $\frac{1}{2}$ an inch. No. 4 is to stand a strain of 1,000 lbs. without temporary deflection of more than 6 inches, and 1,700 lbs. without permanent deflection of more than $\frac{1}{2}$ an inch. No. 5 to stand a strain of 2,000 lbs. without permanent deflection of more than 6 inches, and 2,600 lbs. without permanent deflection of more than 6 inches. The poles are to be as nearly round as possible. A difference of $\frac{1}{8}$ inch between maximum and minimum diameter is all that will be allowed. They must all be as nearly uniform as possible, $\frac{1}{16}$ inch more or less than specified dimensions is all that will be allowed. One quarter of an inch is the greatest distance out of the true that will be allowed at the top of the pole. Ten per cent. of each lot of poles will be tested. Should three poles fail to come up to the specification, the engineer shall have the right to reject the entire lot. These poles will be dropped, butt foremost from a distance of 6 feet on to some solid substance three times, and must show no signs of telescoping or loosening in the joints." It would be seen that that was a very severe test. All the poles used in England and abroad had passed that test. It was difficult to obtain the poles in England, owing to the small demand existing for them. With regard to the question of guard wires, they had been employed in the United States, and had proved more a nuisance than a benefit, and in many installations they were left out. It had been found that telephone- or telegraph-wires fell and whipped round the guard wires, came on the trolley-wires, and caused short-circuiting. An alternative which had been applied was a small rectangular strip of wood fixed to the top of the trolley-wire by means of clips. Wherever those wires crossed the trolley-wires another system had been adopted at Dublin, an arrangement had been entered into with the telephone authorities to replace their telephone-wires on that portion by an insulated telephone-wire, so that if it dropped it would do no damage. He observed that most of the generators in the station were driven by belts. Nearly all the generators used in Europe and in America, were direct-driven when their duty exceeded 300 HP. Very large generators were at work in Brooklyn, St. Louis, Philadelphia, Boston, and several other cities. In Brooklyn there was a system working 1,500 cars from three stations. The units were 2,000 HP., and each generator was directly coupled to a triple-expansion condensing Corliss engine, running at 75 revolutions per minute. The fly-wheel was 24 feet in diameter, and

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weighed 65 tons. The main bearings were 18 inches by 48 inches. Mr. Dawson. The armature was 120 inches in diameter, and 36 inches wide. The generator had twelve poles, and the weight of the armature was 27 tons. The complete engine and dynamo weighed 360 tons. The ratio of E.HP. at the switch-board to I.HP. at the engine was 87 per cent.; and the average coal consumption per Board of Trade unit was 2·4 lbs. The machine gave a pressure of 550 volts at no load, and 600 volts at full load. It would stand sudden variations of load equal to the total of its capacity without sparking, and it would bear 50 per cent. of overloading for several hours without danger. The machine had been working at the Brooklyn Power Station two or three years, and had been designed by Mr. H. F. Parshall. The Paper had described several trucks used at Montreal, and he had thought it might be interesting to bring for inspection the model of a truck such as was now used at Bristol, Coventry, and Dublin, and to a very large extent in America. There were two G. E. 800 motors capable of exerting a pull of 800 lbs. on the periphery of the wheels at the normal speed for which they were designed. It would be seen that the truck was very different from the type of truck generally used in England. The weight of the motor-car was much greater than that of the horse-car. The two motors weighed about 30,000 lbs. and each motor was rated at 25 HP.; the motor, car-body, and passenger load would not weigh far short of 10 tons. At Bristol the directors of the company had realized, when electrical power was introduced, that the frequent stoppage of the cars would cause a great waste of energy. The amount required to start a car was far more than that necessary to run the car, and therefore the average cost would be greatly increased. There were consequently fixed stopping-places, indicated by marks on the poles, a plan which had succeeded from the first and involved no trouble. The trucks had two sets of elliptical springs when the truck was lightly loaded, and heavy coil springs acting when the car-body was nearly loaded with passengers. The truck was suspended from the axles by a double set of springs. There were two coil springs, one outside the other, and one heavier than the other. They bore the jars of the road according as they were lighter or greater. Both passengers and motors had a double spring suspension between them and the rail. There was a different condition from that prevailing in America. In America there were very few top-seat cars. In England they could not be dispensed with. It had been said that that was against electrical traction being introduced in this country, but that was not the

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Mr. Dawson. case. In Guernsey top-seat cars were used; also at Bristol, Dublin and Coventry. Top-seat trolleys ran quite easily, and were used in Bristol without the slightest difficulty; he had brought for inspection by the members a trolley he had recently designed. There was another advantage in the system adopted, namely, that it gave a very large amount of play to the trolley-arm. The trolley-wire could have a deviation of 12 feet on either side of the centre line from pole to pole. A smaller number of insulators was therefore required than would be needed in America. The system was often described as darkening the street, but that did not apply to that system at all. He should be glad to know the number of trolley-cars used, and the average amount of power required to drive them, the car-mile being generally one-half to one-third of that required for the motor-car.

Mr. Parker. Mr. THOMAS PARKER believed that the overhead system was the only one applicable to the particular climate of Montreal. With regard to batteries, he might mention that at Birmingham, four years ago, he had designed and erected an installation of accumulator cars which had been running to the present day. He did not think they had been worked as well as they might have been; he was convinced that there were possibilities in connection with the accumulator-cars which had not yet been obtained, and there were cases in which accumulator-cars might be run with advantage. There was a statement in the Paper respecting the cost of power, $\frac{1}{2}d.$ to $\frac{3}{4}d.$ per car-mile per hour. There was also another statement with respect to $5\frac{1}{3}d.$ per car-mile, which included a number of conditions of service which could scarcely be compared with other results. Therefore the $\frac{1}{2}d.$ to $\frac{3}{4}d.$ for power seemed to be the feature which might be discussed. He should be glad if the Author would give a statement of figures or curves showing what were the conditions on his line—the speed he ran on the various gradients, stating the gradients and the current he used and their voltage with a load. It would be interesting, also, if he would state the full features of the motor termed 25 HP., giving the torque of the motor with given current at varying speeds with the necessarily varying voltage, weight of motor, length of active conductor and density on the armature, and the temperature to which it raised itself after six hours' running. The weight of the generators, the length of their active conductors on the armature, their peripheral velocity, the density of currents in the copper on the armature, their output in amperes with voltage, and the temperature after say six hours' running, would also be interesting. With regard to the conduit system, it would be remembered that it had been

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adopted at Blackpool in the early days. He had designed and constructed that plant in 1883–4, and was associated with it as consulting engineer to the company for seven years. The economy of running on that line would compare with anything since achieved. There were special difficulties at Blackpool—the sea would run over the line and bring the sand with it; but notwithstanding these difficulties good results were obtained. Since then 4 miles or 5 miles had been laid in Madras on a conduit system. Financial difficulties had occurred in connection with it; but he thought it would be interesting to the members to have the particulars before them. In Blackpool it would be remembered that the slot was in the middle of the road, introducing a great number of mechanical and obstructional difficulties. In Madras that had been dispensed with. The underground conductors were so laid that little difficulty was experienced from the point which had generally proved a stumbling-block to their adoption. He had recently heard from one of the directors of the company that the 4 miles or 5 miles of tramway laid before the financial difficulties had worked well. The slot was in the side of the road as in the case at Buda-Pesth, but it did not exceed $\frac{3}{4}$ inch in width anywhere. The difficulty of the working of the points had been very successfully overcome. These were questions which should be thoroughly considered in view of the application of tramways to English cities. He had designed and constructed an overhead tramway in South Staffordshire, and he thought it was perhaps as successful as anything of the kind in England. The economies obtained were, he believed, equal to the best obtained in America. The cost of the Madras system was about £2,500 per mile as originally laid down. The corrosion of gas-pipes and water-pipes was an electrical problem which was not insurmountable and was a question of cost, and all such difficulties would be overcome. Mr. Parker.

Mr. W. H. Preece said that the phenomenal growth of the electrical tramway system in the United States had been referred to, not only in the Paper, but in the course of the discussion; and as one who had visited the United States in 1884, and found there only one railway, at Cleveland, it was to him a matter of great surprise to find that in the short space of twelve years one railway of about 2 miles in length had grown to 10,363 miles of railway worked by electricity. But it should not be forgotten that tramways, whether worked by electricity or horse-power, were a necessity in the United States; they were not such a necessity in this country but rather a luxury. In the United States there were not Mr. Preece.

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Mr. Preece. the conveniences of locomotion existing in England. There were great variations of climate, and many reasons why the introduction of electricity as a motive power for working the lines had proved so great a financial success. Unquestionably the working of those tram lines had been far more economical by means of electricity than by means of horses. The Paper was extremely valuable, since, as mentioned by Mr. Parker, the Author had given the cost of working. He was not quite sure that the expenditure could be followed exactly, or even checked; but the Author had brought out the fact that while the total cost of working the lines in Montreal amounted to $5\frac{1}{3}d.$ per car-mile, the cost of the power expended was only $\frac{3}{4}d.$ per car-mile. In England, and he thought in the United States, it was considered that there was an expenditure of one Board of Trade unit for every car-mile run; and that was verified by what he had recently heard in Rome, where the cost amounted to 620 watts per car-kilometre, which compared almost exactly with 1,000 watts per car-mile. From the Paper, however, it appeared that the mean expenditure of watt-hours per car-mile in Montreal amounted to 1,560. It was surprising to find that there should be such a difference as that between 1,000 and 1,560 in working the tramways in Montreal as compared with the United States and with England. But he thought it was fully explained in the Paper, where it was shown that the tramways had very heavy gradients. Montreal was very hilly, and with gradients of 1 to 10, or 1 to 8, it was not surprising that there was an expenditure of energy far beyond that experienced in this country, in Europe, and in America generally. The point he wished to urge was that, if in Montreal it was possible to move the trams with an expenditure of $\frac{3}{4}d.$ per car-mile, and with an expenditure of $1\frac{1}{2}$ Board of Trade unit, it meant that it had been possible to produce and supply a Board of Trade unit to the working of the cars which was equivalent to $\frac{1}{2}d.$ per Board of Trade unit. He had in that room on several occasions pointed out as a fact that could not be too strongly urged and accepted, that if electrical energy was generated and applied for any purpose so as to use continuously the machinery at its full efficiency, and for the whole twenty-four hours of the day, electrical energy could be produced at an expenditure less than $\frac{1}{2}d.$ per unit. That was done in all cases of electro-chemical industry, and it could be done on tramways if the machinery was worked for the twenty-four hours. That it could be done was proved by the facts that the Author had brought before them. He had shown that with a load-curve for less than twenty-four hours per day the electrical energy could

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be applied for an expenditure equivalent to $\frac{1}{2}d.$ per unit. That was the fact of the greatest importance to all local authorities and local industries that were now establishing in their midst installations for the purpose of generating light. An installation for the purpose of generating light was practically only used at its maximum figure for two hours during the day. But tramways were worked from early daylight till late in the evening; the maximum load of the tramway system was in the morning and in the afternoon. Now if machinery could be applied primarily to the production of electric-light at night, and secondarily to the production of electrical energy for power during the day, it could not only be produced at the figure given by the Author, about $\frac{1}{2}d.$ per unit, but in such a way as to bring down the price of electric-light at night so low as to make the cost of light comparatively insignificant, and it could be applied during the day at a price equally low so as to compare most favourably with that of horseflesh. The result was that by the application of electrical energy in towns for both working tramways and producing light the greatest possible benefit could be given to the ratepayers who supplied the funds. He had recently visited Rome, where there was in use quite a novel system. The energy that lighted 60,000 glow-lamps and 1,000 arc-lamps, and performed much other work besides, was produced primarily by water-power at Tivoli, 18 miles away, and was brought by high-pressure currents, at a pressure of 5,000 volts to 6,000 volts, to Rome. But, in addition to that, within the last twelve months Professor Mengarini had during the day applied the energy from Tivoli to charging batteries and working the tramways. The tramway hours and the electric-light hours overlapped each other for about two hours during the day. In the early hours the currents worked the trams direct, but during the overlapping hours they were worked by the batteries and the currents gave the electric-light. The result was that energy could be supplied to work tramways during the day and to maintain the lighting of the glow-lamps and the arc-lamps at night by precisely the same power. That was a thing likely to come into use in this country, for it meant economy. It was quite a novelty to find that without any apparent loss of energy, and practically with the greatest ease, alternating currents were used to charge batteries. A visitor to Rome could not spend the time better than by going to see how a purely scientific man, with the deepest insight, had developed practical instincts and sound engineering, and had utilized the immense water-power, hitherto running to waste, to light Rome and to work the tramways in that charming city.

Mr. Preece.

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Major-General Webber.

Major-General WEBBER assumed that Mr. Preece, in speaking of consumption, took it at the terminals of the generators per car as 1 kilowatt. At the speed given of $7\frac{1}{2}$ miles per hour, the Author's figure in July gave 13 kilowatts per hour. Perhaps Mr. Preece would state, with regard to the Tivoli lighting, whether the batteries took the whole of the overlapping load? It was a common thing on the Continent for stations to generate both for lighting and traction. He should be glad to know if the cars were supplied entirely by the reserve in the batteries during the overlapping hours.

Mr. Preece.

Mr. W. H. PREECE said he did not think there was anything in the Paper which could possibly indicate that 13 kilowatts per hour were consumed in moving a car. Experience in the working of tramways showed that 1 car-mile absorbed 1 Board of Trade unit when run at the normal velocity of between 7 miles and 8 miles per hour, and the Paper showed distinctly that at the same speed, $7\frac{1}{2}$ miles per hour, 1·56 unit had been so absorbed. With regard to what had been done in Rome, it was quite true that during the time of full load, from four to about six o'clock, the trams were worked by batteries. There were three hundred and four very large cells of the Tudor type, having 1,200 ampere-hours' capacity, and those from day to day, without any trouble, maintained constant the voltage of the trolley-wire (550 volts) which supplied the current required by the tramway.

Mr. Parker.

Mr. THOMAS PARKER wished the Author would give curves or figures showing the actual power in amperes and volts used upon the various gradients, together with the speed. The total amount of energy used per car-mile or per ton-mile did not fully state the conditions under which the tramway worked as to gradients, speeds, &c.

Dr. Kennedy.

Dr. A. B. W. KENNEDY had calculated the figures as Mr. Preece had read them—$1\frac{1}{2}$ unit per car-mile, so that if the cost of producing a car-mile was $\frac{3}{4}d.$, the cost of producing a unit was $\frac{1}{2}d.$ He had not drawn exactly the same inference as Mr. Preece, but hoped that the Author would justify Mr. Preece's inference. There was in England a most salutary institution called the Board of Trade, which compelled accounts of many electrical undertakings to be issued in a form which could be understood by all who took the trouble to read them, and which practically, so far as concerned the technical part of the works, placed the cost beyond question. Although there was, of course, no Board of Trade connection with the present matter, he had no doubt that the Author would give some details as to the cost, made out in a similar form to that

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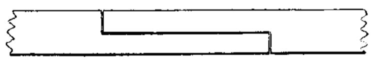
now familiar to all engineers in England. When he stated that the total cost was $5\frac{1}{2}d.$, and that the cost of power was $\frac{3}{4}d.$, it was very difficult to understand what these figures represented, or what the difference of $4\frac{3}{4}d.$ was composed of. The total cost included a great many matters which were peculiar to electrical street-railway working. If the Author would analyse those costs for a month, or for twelve months, in something like Board of Trade form, it would add very much to the usefulness of the Paper. Dr. Kennedy.

Major-General WEBBER asked whether the Author had used a bond for the rails, which was now coming into considerable use on the other side of the St. George's Channel, and shown diagramatically in *Fig. 6*. It necessitated a thicker flange and a heavier rail. It gave excellent electrical connection, and almost entirely avoided any vibration of the car, in passing over the joint. It was ingenious and only costly in the respect which he had mentioned. He thought it added 12 lbs. or 13 lbs. to the rail, the flange being also thickened. Major-General Webber.

Fig. 6.



Mr. LLEWELYN B. ATKINSON said it would add to the usefulness of the Paper if information were given as to the cost of the permanent way. In recently examining some figures relating to American street-railways, and comparing them with the cost of English street-railways, for horse or steam traction, it appeared that one of the great difficulties in the capital outlay, and therefore the probable earnings in England, was that the local authorities and others insisted on a road-bed of a class which was not required in America. As had been suggested in the Paper, and mentioned by one or two of the speakers, many of the roads in America were simply sleeper roads laid on the surface, or just buried into the road, and very inexpensive. He had calculated the cost of some of those roads with concrete beds, suitable for carrying the load to be dealt with and paved as they were required to be paved in England, and it appeared to him that it was useless to compare (except in some towns) the cost of American roads with the cost which would be incurred in English roads, not only on the electrical part, but on the actual permanent way. Mr. Atkinson.

Mr. JEREMIAH HEAD remarked that in the United States the mileage of electrical tramways was equal to between one-third and one-fourth of the total single-line mileage in England, whereas he doubted if a hundred miles of electrical tramway, all told, could be found in the United Kingdom. Five years ago there were five systems Mr. Head.

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Mr. Head. in the United States in very keen competition with one another: horse-cars, steam-locomotive cars, trolley-cars, accumulator-cars, and cable-cars. All had now virtually given way to trolley-cars. That had not been done without good reason, for it should be remembered that electric railways had very great advantages. It had been stated in the Paper that they were working on gradients as steep as 1 in 8. That, so far as he knew, was quite unprecedented in any other type of adhesion railways whatever. The trolley-cars were so well under control that if the road was obstructed ahead the motor man could go along as gently as he liked, whereas if it was entirely unobstructed he could go along as quickly as 26 or 28 miles an hour. He had himself been in trolley-cars with a clear road and had timed them up to that speed. In the City of Cleveland the average speed, including stops, was 9 miles per hour, which involved a maximum between stops of about 18 miles per hour. They could stop and start with the utmost celerity; they could go round sharp curves, such as round any street corner, and they could carry a much larger number of passengers than any two-horse car or omnibus. In the United States the cars were often full, the platforms crammed front and back, with people hanging on to the side-boards on both sides. There were frequently in busy times as many as fifty or sixty passengers. By means of the electrical current the car was driven and lighted and heated; and in some cases, as in the Chicago overhead railway, a special motor worked an air-pump which was used to brake the car. He believed a little of the electrical current was also taken for working the bells. When the cars were very crowded it was difficult to indicate to the conductor a desire to stop. There were little buttons behind all the seats, and when one of them was pressed, a bell rang, and the conductor behind (who could not be seen) rang another to the motor man, and at the next street corner the car was stopped. All those were very great conveniences which were not found in any other system. He did not think there was much chance in the United States of the electrical tram-cars being superseded; there was every probability that it would extend very largely. In Philadelphia they were developing so quickly that the main-line railways were feeling the effect on their suburban traffic. A man residing in the outskirts of the city could jump into the trolley-car, at 5-minute intervals and get out at his place of business, without the loss of time that he had been accustomed to expend in walking to the railway-station, waiting for his train, and then walking from the station to his office. Although the cars did not travel quite so quickly as the main-line trains, they

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Mr. Head.

were infinitely more convenient for that sort of traffic. With regard to stopping-places, the plan at present adopted was to stop at street corners and on the near side of the principal cross streets. The cars formerly stopped on the far side, but that was found to be productive of accidents on account of crossing the traffic, but now they stopped at the near side. They did not stop at intermediate places for every person who hailed them. There were, as stated by Mr. Preece, proper boards indicating the stopping places. Allusion had been made to the fact that the ordinary street traffic tended to make a rut on the inner side of the rail and cut away the concrete. The great bulk of the trolley-car rails now being made in the United States were of a different section to that shown; the lip on the upper part of the rail, instead of being hooked up as shown in the diagram, was made perfectly flat. He believed that about 75 per cent. of all the rails now made were of that form. Most of the City Councils stipulated that it should be so. The ordinary car-traffic ran on the flat place inside the rail, and that being the same gauge as that of an ordinary wagon or carriage, it facilitated the ordinary traffic, and saved the road surface generally from wear and tear. When a trolley-car was approaching carts and carriages were usually occupying the rails to some extent. The motor man sounded his gong, and the traffic cleared off before he came up to it. It had been said that tramways were not a necessity in England. He thought that that could hardly be decided till there had been a little more experience. Improved communication in any country was sure to lead to benefit. If facilities for travel were afforded they were sure to be used, and if in Great Britain electric tramways were made in populous districts, giving the people facilities to which they were at present strangers, it was quite certain that they would use them. The point with regard to cost of traction alone would prove their advantage. The London omnibus with its two horses accomplished no more than 12 miles a day per horse, and cost at least 18*s.* a week each to keep; the cost of the two horses was something like 6*d.* per mile. In the case under discussion it was stated that the cost was $\frac{3}{4}d.$ a mile for power only; that would give some idea of the saving that might be expected in places that were suitable for such a system. The great argument used in this country by persons who knew nothing about electric tramways, which he was sorry to think included the major part of the population, was that overhead wires were ugly, that the posts were ugly, and that they would never be allowed because people would not permit the disfigurement of the streets and the like. He

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Mr. Head. thought, however, that it would always be found that questions of beauty and ugliness were very much what people were or were not accustomed to. Exactly the same thing had been said of the overhead electric telegraph and telephone wires in the past; but now no one took the slightest notice of them. So far, with regard to the tramway wires, certainly they might be put up in an ugly way with rough wooden poles and the like, but where they were erected artistically and the poles were made ornamental, whether placed in the middle of the street with brackets on each side, or in a line with the lamp-posts, or whether the suspending wires were stretched from house to house, nobody elsewhere took any notice of them. He only wished that some of the Town Councillors and others who had been on deputations to Bristol and a few other places in the country, would go on the other side of the Atlantic and stay there six months; nothing more would then be heard of the puerile objections to so great and successful a product of civilization, nor would any other system, such as cable-cars, be entertained for a moment in comparison with it, where there was sufficient width of street and where the locality was generally suitable.

Mr. Hedges. Mr. KILLINGWORTH HEDGES desired to supplement the remarks of Mr. Head as to the great progress of electrical traction in America. It had been remarked that some of the roads were sleeper-roads. There were, no doubt, a great number of what would be called, in England, light railways, running from point to point, occasionally on the main roads; very often the land was acquired by the company, and naturally they made the road-bed in the cheapest manner. A few years ago, when he went from one side of America to the other, and visited many installations in the principal towns, he found that the principal object of the engineers was to construct the road-bed in the streets of cities in a good manner. Great pains were always taken in putting down a permanent road-bed, and using rails of very heavy section. In the early days, light-section rails were used, but that was found to be a great mistake. Many engineers had told him that the secret of their success was in putting down a rail which would not have to be taken up for a long time, or require to be examined. The rail-bonds had to be more carefully designed and proportioned than was at first expected. Light bonds were used on the early roads and found to give great trouble; but with heavy bonding and heavy rails there was much less trouble, and electrolytic action of pipes almost entirely disappeared. Overhead insulated copper wires has been referred to by the Author. He had not been in the United States for two years,

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and was not, therefore, up to date, but he had thought that that system was being done away with altogether, because it was very unsightly. If it was going to be used in this country it would be an additional objection to many people who would stand a single trolley-wire, and perhaps some feeder-wires, but they would not wish to have return-wires also carried overhead. He observed that at Montreal steam power-stations were used. When he was in Canada there was a talk of employing water-power. He should like to ask if any scheme was brought forward for using the immense water-power in the neighbourhood of Montreal for generating electricity, and, if so, why it was not adopted for working the tramways mentioned in the Paper. Mr. Hedges.

Mr. G. C. Cuningham in reply to the discussion said, with regard to the tee-rail with a plank laid alongside, that when ordinary vehicles followed on the tramway line the horse naturally trotted midway between the rails, and the wheels of the vehicle in consequence ran on the plank laid alongside the rail. This prevented the rut from forming. Very little care, however, on the part of the road repairers would prevent the rut from forming, even where no plank was laid, especially where the traffic was light in suburban districts. In the suburban parts of Montreal, on the macadam roads, there was a good deal of line of the ordinary sleeper construction. The sleepers were laid at about $2\frac{1}{2}$ feet, centre to centre, and filled in with macadam to the level of the surface of the rail; the ordinary Sandberg pattern, or tee-rail, was used. In some instances a 4-inch plank was spiked down alongside the rail, so as to prevent as much as possible the cutting away of the macadam close inside the rail. That construction had been very satisfactory so far, but no doubt the more satisfactory construction was that laid with concrete. A very large amount of the street mileage of Montreal was so laid. The plan that he adopted there was to use a moderately heavy section of rail, not a very heavy section, because he relied upon the concrete to give rigidity. It was necessary to have a rail rigid, because if there was undulatory action in the rail it would act upon the paving blocks on either side, and in the winter particularly it would have a bad effect in pumping any moisture, and sudden and violent frosts would heave the paving and split it to pieces. It was considered better to rely upon the concrete to make the rail rigid rather than to have a very heavy section of rail. He was aware that in many places in the United States a very heavy section of rail was used, laid in most places upon a gravel foundation, which he thought was not as good as the plan adopted, because in the case of concrete Mr. Cuningham.

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Mr. Cuningham. there was a solid foundation bearing the whole length of the rail, and it was impossible for any spring to take place.

In reply to the various remarks that had been made as to the power used on the system, he submitted a Table (p. 305) showing in detail a summary of the working of the power-house for the year ending 30th September, 1895. The amount of power used could best be derived from the number of watt-hours used per motor-car hour. The average was 14,851 watt-hours, or almost exactly 20 HP.-hours. This power would be affected by the weight of the motor-cars and the weight of passengers and trailers which they conveyed; and therefore, to reduce this to a proper basis for comparison with other systems, it would be necessary to know what this power corresponded to in watts or watt-hours per ton-mile. The Table showed that the number of watt-hours per ton-mile was 282 (= 0·38 HP.), and the number of watts 2,290 (= 3·07 HP.), the speed of the car being 8·12 minutes to a mile. This was the power recorded at the terminals of the generators, and included all losses on the line. In other words, in order to move a ton a mile on the Montreal system the power-house had to exert a force of 3·07 HP. On other systems where the gradients were less severe and where the obstructions of winter were not so serious, the power used would naturally be less. In Toronto, for instance, where the streets were very level, about 30 per cent. less power was used than in Montreal. The power in Montreal varied between a maximum of 2,716 watts per ton-mile in winter and a minimum of 2,048 watts in summer.

From the "watts per ton" had been estimated the average draw-bar pull per ton. This was found to be 19·2 lbs. Instead of working from this draw-bar pull as the basis and deriving the total power of the station, the process had been reversed, and from the total power exerted in the station worked down to the average draw-bar pull. In this was included whatever power might be lost in transmission. Great care had been taken during the past year, and covering the period dealt with by the Paper, to perfect the feed-wire and return-wire system and to improve the bonding, so as to reduce losses as much as possible. The loss from leakage was absolutely nil, the whole system having been recently (1896) carefully tested with the most delicate instruments by the city electrician with a view to determining leakage. The consequence of this was that the power now generated in the power-house per ton-mile was less than in 1894–5, and though the cost of haulage for that year (less than $\frac{3}{4}d.$ per car-mile) seemed to be particularly small, the cost for the present year (1895–6) would be lower still.

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With reference to the unsightliness of the overhead trolley system, he might mention that he had seen that day in Edinburgh, the system adopted there for the electric-lighting of that city. Large iron poles had been erected on either side of the street with brackets projecting, from which the arc-lamps depended. It would Mr. Cuningham.

TABLE SHOWING WORK DEVELOPED AND COAL CONSUMED ON MONTREAL STREET-RAILWAY SYSTEM DURING YEAR ENDING 30TH SEPTEMBER, 1895.

	Motor car-miles	5,677,581
	Trailer car-miles	654,057
	Total car-miles	6,331,638
	Motor[1] ton-miles[2]	36,900,873
	Trailer[3] ton-miles	1,645,140
	Passenger[4] ton-miles	1,810,033
	Total ton-miles	40,356,046
	Passengers carried	25,857,758
	,, ,, per car-mile	4·10
	Coal consumed	19,171·60 tons.
	,, ,, per car-mile	6·80 lbs.
	,, ,, ,, motor car-mile	7·50 ,,
	,, ,, ,, ton-mile	1·06 ,,
	,, ,, ,, passenger-mile	1·66 ,,
	,, ,, ,, E.HP.-hour	2·80 ,,
	Engine-hours	25,183
	Electrical output	15,305,254 HP.-hours.
	,, ,, per engine-hour	608 ,,
	,, ,, ,, motor car-mile	2,011 watt-hours.
	,, ,, ,, ton-mile	282 ,,
	,, ,, ,, lb. of coal	266 ,,
Motor Cars.	Total on road	43,822·00
	Average per day	120·07
	Car-hours	68,837·00
	Speed	7·39 miles per hour.
	,,	8·12 minutes per mile.
	Watt-hours per car-hour	14,851·00
	,, ,, mile	2,011·00
	Watts per mile	16,329·00
	,, ton	2,290·00
	Ton-miles per car-mile	7·11
	Effort per ton per mile	101,316·00 foot-lbs.

be the simplest thing in the world to erect similar poles on the opposite side of the street and span a wire across; then they would have all that was necessary for overhead wires. The iron poles erected in Edinburgh were by no means unsightly. Electric

[1] Weight, 6 tons.
[2] 2,000 lbs. to 1 ton.
[3] Weight, $2\frac{1}{2}$ tons.
[4] 140 lbs. each.

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Mr. Cuningham. light enormously improved the appearance of the city, and it was in every way satisfactory. Certainly no one complained of the unsightliness of the poles. He was well aware that in this country there was a strong objection to overhead wires. So there was in Canada, but within a fortnight after they had been erected there was not a man in the city who wished to have them taken down, the benefit of the system being so apparent. Reference had been made to insulated return-wires. It would be a simple matter to bring back the return-wires underground just as the feed-wires might be taken underground, but in Montreal that refinement had not been considered necessary.

A question had been asked as to the use of water-power in Montreal. Great progress had been made with the use of water-power there, but considerable difficulty was felt with regard to it on account of the ice in winter. The ice jammed in the river in the winter and raised the level of the water so that the head available in the summer was much reduced. It was doubtful if the power could be used all the year round, and consequently the Street-Railway Company had been forced to rely upon steam-plant. Even if water-power were installed, it would not be prudent to throw away the steam-plant until it had been tested for some years. The ice-jam did not form every year in the way of raising the water.

Correspondence.

Mr. Moss. Mr. LINCOLN MOSS, of New York, thought the Paper described an excellent example of modern electric railway construction, although it was to be regretted that the direct-coupled type of multipolar generator and engine had not been used in place of belted machines. He differed from the Author as to the waste of energy in the steam locomotive. On American elevated roads, a passenger ton-mile was covered with a consumption of between 4 ozs. and 8 ozs. of coal, including braking and all losses, with trains weighing between 80 tons and 130 tons, moving at an average speed of 15 miles per hour, stopping four times per mile, and over gradients of as much as 2 per cent. If more elevated roads should be built, it was probable that the steam locomotive must give way to the electric-motor car, in view of the recent successes of heavy electric traction. In elevated service electric-motor cars would reduce the train weight, decrease the live load on the structures, and greatly increase the available draw-bar pull, which will give a decided increase in speed, reduce the number of coaches required, and the number of train-

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