but because of the calm, cool way in which he disposed of the steam engine and the steam tramway as being out of the running altogether. Perhaps in this class of work he is quite right, but so far as he (the speaker) could judge it has never been practically demonstrated. The steam motor can do all that the author claims for the motor he advocates. It can practically go ahead or slacken in speed on the shortest notice; it is not dependent on a single wire or cable and a generating station which must have machinery in duplicate or triplicate. He knew that cables and electric motors could be run cheaper than steam trams are. The point he wished to take was a novel one. In the comparison of the efficiency of the cable with the electric car the former gives twenty-eight per cent. of the engine power, while the latter gives about double. It had often struck him that any motor that gave such small percentage of efficiency must contain some radical defect, looking at it from an engineer's point of view, and must have certain circumstances in connection with it to justify its adoption. But the fact remained that the efficiency of a steam motor is double that of a cable, and yet it does not pay to use it. He had no doubt if the Sydney trams had to be laid down again, and were so laid under the supervision of men who had the practical experience and the knowledge of what was required, they could be made to do the work much better than hitherto, and with a better financial return. It was not right to condemn a principle because that principle might have been carried out badly. For instance, we all know what gas engines had done. They have been very useful, especially for small powers. If we take one of Lenoir's early engines, we find it consumed ninety-five cubic feet of coal gas to get a horse power. If that had been a practical engine it ought to have consumed 3·77 to get a horse power. Since that time gas engines have been improved very much, and now, instead of something like ninety-five cubic feet of gas being required to get a horse power, we can get the same power with twenty-eight; dividing the one with the other we have raised the efficiency from four per cent. to thirteen, which is about the same as we get from our modern engine. Mr. Fischer says, in generating the current the

efficiency of his whole system, after the steam engine, is only ten per cent. of the value of the coal. So this efficiency, he claims, is only 55 per cent. of 10 per cent. — a result which is much inferior to our steam engine. With regard to copper wire one thing struck him, and that is in its power of conduction. The method of drawing wire seemed to him to contain an element which would reduce its conductivity to some considerable extent, because it would draw the molecules of the wire further apart. Whitworth, in making experiments with steel, found that its conductivity, when compressed, was much greater than that of steel made in the ordinary way. In a recent article by Ferranti, in charge of the Deptford installation, that gentleman had shown that a high tension of 10,000 volts was as safe as 500.

Mr. Elwell wished to say a word or two upon some remarks of Mr. Cruickshank's as to the efficiency of motors or dynamos, as he is under the impression it is much lower than it really is. There is no difficulty about making a motor or a dynamo return 95 per cent. of the power required to drive it, or the current put into it in the case of a motor; and there are dynamos and motors working at that rate of efficiency. There is another point in the case of storage battery traction which has not occurred to most people, and that is the great increase of the weight of the car caused by carrying the cells. That gives an extra loss of about 25 per cent., so that that rather tells against the battery system. Then about the locomotives. Mr. Cruickshank did not mention that when a car, or train of cars, is drawn by a locomotive you have to take along an extra weight of about 16 tons, which tells a good deal against the locomotive system. Then as regards the copper wire conductivity, it does not reduce it to any extent drawing it. Mr. Fischer's paper seems carefully written, but it is a little one-sided. For instance, he says our American cousins have long since put in the shade the more conservative countries of the Old World. He (the speaker) did not think there was anything in the States like the London and Southwark subway, which is now open, and which carries 150,000 people daily on only about three miles of line. There is a much larger

line under construction called the Central London line, where the trains intended to be driven will weigh 80 tons each. It must be borne in mind, that in England they have not had so much chance of putting down electric railways in consequence of the opposition of the municipal and local bodies. He might mention that a conduit is going to be made in Paris several miles long on the Lineff system. Mr. Fischer says it is to be hoped that eventually a successful storage battery will be invented. He (the speaker) had been making experiments for some time with an accumulator that had neither lead nor acid in it, and weight for weight was about half that of the lead battery. Mr. Fischer states that in case of an accidental cross between a railway and a telephone wire, which might lead to danger by fire, inexpensive and simple cut-outs are known, the use of which will make it an impossibility for a dangerous current to enter any premises. He (the speaker) did not think there was any safety cut-out which would prevent that, and the only way to prevent it was to use a completely insulated circuit. He says feeders should be put underground. Is it not better in that case to have everything underground? It makes it simpler, and everything is then out of sight.

Mr. Spruson, a visitor, said that Mr. Fischer's remarks concerning the Blackpool Tramway, wherein he would seem to consider Mr. Holroyd Smith's conduit as a typical one, and the fact of its practical financial failure a gauge of the possible success of conduits generally, can, however, hardly be accepted unreservedly. Whilst it must be admitted that, up to the present time, conduits have proved unequal to requirements, it cannot be said that it is beyond the range of possibility that a well-designed conduit would not prove a success in the Australian climate. Nevertheless, the great comparative cost of conduits and the few really practical advantages they offer relatively to the overhead system, would, under all ordinary circumstances, in his, the speaker's opinion, entirely preclude their successful competition with the latter system. There can hardly be a doubt that the storage battery cannot compete financially with direct contact systems. The reasons are manifold, and, it may safely be said, cannot be overcome

entirely, as proved by several arguments which have been put forward by Mr. Fischer; the chief reason is—as so clearly stated by Mr. F. J. Sprague at the late Kansas Convention, and quoted by Mr. Fitzmaurice—that energy cannot be converted three times at the same expense as that for which it can be converted once. Mr. Fischer has touched upon the question of danger. Now, the element of "danger," so-called, in an electric railway service is far less than it is in house-to-house lighting; but to the latter, for the year 1888, New York sacrificed only five lives, whilst gas and kerosene caused the loss of no less than 49 lives. As far as his knowledge went, there was not, up to date, the loss of a single life to charge against electricity used as a locomotive power. The objection to poles, upon the ground of obstruction, was one that existed mainly in the imagination of unpractical people. As to unsightliness, the American public may be said to have taken more kindly than otherwise to the use of overhead wires and mid-street and side-walk poles. He thought that he did not go too far when he said that he thought Mr. Fischer had not accorded the Sprague system its due meed of praise. Considering the question from a scientific point of view, that system should have been given as much prominence as any other; more so as it was daily coming to the front, and at the present time occupied a position just as exalted as its great rival, the Thomson-Houston system. As a proof of its success it might be mentioned that the Minneapolis 110 miles contract—spoken of by Mr. Fischer—had been obtained by it. The wholesale, unjustifiable condemnation of the Sprague governing system, enunciated by Mr. Whipple, and quoted in the paper under discussion, he could not pass without comment. The verdict was unfair, as it is unsupported by theory and by practical experience. The employment of feeders and sub-feeders to which Mr. Fischer refers, is claimed to be peculiar to the Sprague system. He could not understand that an electric motor could be prejudicially affected by reason of the controlling influence being brought to bear upon the motor itself, than he could understand that a steam engine could be injured by the employment of link motion. The practical experience of the present day, which was derived from

three and a half years actual electric railroad practice, with all sizes of motors and under all sorts of conditions, established the fact beyond the power of words to contradict, that Mr. Whipple's opinions on the question are merely speculative. The analogy drawn by Mr. Fischer between the commutated field and the loco-variable expansion gear does not hold. Applying to a steam engine for purposes of illustration, the equivalent of the Thomson-Houston rheostat system of controlling the motor would be to provide means whereby under all conditions of load the same amount of steam (pressure constant) is drawn from the boiler, but only sufficient used in the cylinder to do the actual work required. Such means would consist of a number of long coils of steam pipe, corresponding to the rheostat coils, through one or other of which the steam would pass from the boiler to the cylinder, and therein it would become reduced. The exact mechanical equivalent of the Sprague electrical method of governing by commutating the field was hard to conceive, because so free and perfect an action was not attainable in any mechanical combination. Roughly speaking, it was equivalent to substituting cylinders of varying diameter one for another (according to the work to be done) by the mere movement of a switch. But this analogy was very imperfect indeed. With fixed loads and grades the Thomson-Houston, or any other rheostat governed motor uses the same current with low speeds as with higher ones; the Sprague, or any other motor governed by commutating the fields under like circumstances uses current closely proportional to the speed developed. In a large installation this question of loss is very serious. The Sprague system offers special advantages in railway work where it is required to develop abnormal power in starting; the spires of wire in the field can be so joined up as to give about three times the effective turns of the spires in a rheostat governed machine when necessary, and thus, with a given current, develops a considerably greater torsional effort. The power of a motor depends upon the strengths of the fields, and these can be varied by altering either the current or the number of turns of wire. In the Thomson-Houston motor the current is

varied, but the number of turns of wire is kept constant; in the Sprague motor the number of turns of wire is varied, but the current is not interfered with. In the former, energy is lost in "throttling" the current; in the latter no such loss occurs. It might be mentioned that the commutation of dynamo fields is by no means a novel idea; if in connection with generators, practice has proved the safe applicability of the principle, there is no reason why it should fail when applied to motor construction; as a matter of fact, years of experience have shown that it does not fail when so used. In conclusion, he would like to refer briefly to a few remarks made by Mr. Cruickshank regarding the efficiency of an electric railroad system. That gentleman was evidently of opinion that in point of mechanical efficiency electric traction would not be a material improvement upon the present steam motor system. If it be allowed, as he thought it must, that the present motors consume ten pounds of coal per h.p., and that the efficiency of an electric system be as low as 60 per cent., and that a large stationary compound or triple expansion engine would consume say two pounds of coal per h.p., then the actual relative consumption would be—Electric system, about three and a half; steam motor system, ten per unit of work. Therefore, with the present fuel consumption, the amount of work done would be nearly tripled by the substitution, whilst the inconvenience and the expenses of wear and tear and operating would be reduced to a minimum.

Mr. Nixon: Mr. Fischer remarked that electricity is now being applied to mine traction. In the company that he had been connected with for some years there has been a discussion on the question of endless rope-traction. He sent Mr. Fischer's paper to the mine manager and he replies in this way: Can these cars do our work? Can they be erected at a cost as low as that we have been paying?

Mr. Kingsbury said there was one question he should like to ask Mr. Spruson. When he spoke just now of the tremendous amount of loss of energy in this resistance in the management of the cars does he know how much loss there is in that resistance?

Mr. Spruson: The loss that occurs is a regular quantity. Whether you are running the motor at full or slow speed you are using the same current.

Mr. Kingsbury: You do nothing of the kind. Respecting the overhead wire, we must expect to have some poles, and those are not the most ornamental things; but inasmuch as in America these subways have been tried and abandoned time after time, and overhead wires substituted, he thought we should profit by their experience. In regard to the cost, you can put up an overhead railway at half the cost of a subway. Then again, the cost of running an overhead tramway line is just one-third the cost of the cable line. In speaking about engines, Mr. Fitzmaurice was perfectly correct in saying it is absolutely necessary to have a perfect governor.

Mr. Howe said: Had he known that the subject of tramways was to be alluded to he could doubtless have collected a few notes together on the subject. As to the cost of working, and the outlay in construction, it was quite true, as suggested by Mr. Cruickshank, that the tramways in this city were very crudely laid down; the whole system was started badly and continued badly; and, doubtless, if the work had to be done over again under the supervision of experienced men, very different results would be seen. The cars were lumbering and unsightly, and excited prejudice against the trams from the very first. He had not the slightest doubt in his own mind that steam tramways could be worked in this city at one-third less cost than those worked at the present time. None of the engines that were used were adapted for the work—neither the Merewether, the Wilkinson, or the present American engines. These latter were constructed for the overhead tramways in New York; the Wilkinson was an utter failure, and so was the Merewether. Defective roads, too, had added considerably to the cost of maintenance. In Melbourne the cars weighed from 2½ to 3 tons, the dummy of the car not more than 2, running over a 94 lb. rail, while we were expected to carry a 12½ ton motor and a five-ton car, carrying sixty people over a rail of 41 lb., and badly laid at that, and with no attempt at

drainage. The rail itself was made the drain carrying the water and mud through the streets, and which by the centrifugal force of the wheel was carried up into the engine. Had the system been properly laid down, the cars and motors run into a proper central depôt where the cars could be properly washed, and the engines properly attended to, there would have been a considerable saving. Instead of that they drop their cars, some at one place, and some at another. One man at from 10s. to 11s. per day should be able to do what it takes a driver at 13s. and a fireman at 11s. to do.

Mr. Henson remarked that the question as to whether wires should be overhead or underground was one that would be very much debated before it was settled. He was inclined to the overhead. Mr. Fitzmaurice referred to the underground system. He did not think the sewers being constructed would get over the difficulty.

Mr. Fischer, in replying to the discussion on his paper, said he would do so as briefly as possible, considering that another very interesting paper was set down for reading this evening. The result of the discussion was highly gratifying to him, as there had actually nothing been advanced which would shake his belief in the conclusions at which he had arrived after a lengthy and careful study of this question. There were, however, a few remarks to which he might be permitted to reply in as few words as possible, lest it might lead to misunderstandings. Mr. Fitzmaurice's contribution was, on the whole, a supplement to his (the author's) paper; with the exception of governing the motor, and with which he would deal more in detail when replying to Mr. Spruson, he entirely agreed with him, and even here he (Mr. Fitzmaurice) came to the conclusion that the rheostat was undoubtedly the simplest and most easily repaired of the two. His remarks about the utilization of the Fitzroy Falls were highly interesting, and he hoped cordially that at some future time this tramway would be constructed, as there could be hardly any doubt but that it would be a remunerative undertaking. Mr. Dickinson's objection to the overhead conductor was merely sentimental, and could be answered perhaps

better in connection with Mr. Elwell's remarks. As his paper was intended to be descriptive of the electric appliances used in "Electric Traction," he trusted Mr. Cruickshank would pardon the passing treatment of the prime-mover, but as that gentleman was a much higher authority on steam engines than himself, he might be allowed to express a hope that Mr. Cruikshank would shortly favour us with a paper on that particular piece of mechanism, which would be highly acceptable to all of us. He thought Mr. Cruickshank might rest quite assured that a higher voltage than 500 would not be proposed by any engineer in connection with street railroading, where, as a rule, no very great distances have to be considered. When it came, however, to electric traction on main lines of railways, currents of higher E.M.F. would, no doubt, be used; but then the danger arising therefrom was reduced to a minimum, as none but employees had any need to come in close proximity to the conductors, and they would soon learn how to take care of themselves. Mr. Cruickshank, in common with Mr. Howe, was under the impression that he condemned the steam tramway motor as used in Sydney. He regretted this exceedingly, as, under the peculiar conditions, they were doing splendid service. This, however, was not the point at issue. What was required here was a three or five minutes' service to the various suburbs, as the public began to growl about having to hang about street corners from fifteen to twenty minutes before getting a tram to their destination, preferring reluctantly to make use of an omnibus, even if they did not reach their homes any quicker. What he wished to convey was—that a three to five minutes' service could not be given by steam motors with the same prospect of profit as with the electric system described in his paper. The question of consumption of fuel and efficiency had already been answered by Messrs. Elwell and Spruson. Regarding Mr. Elwell's statement that his paper was biassed in favour of American practice, this was not the case. The examples quoted by him of English practice were of very recent date, and up to the present had not had sufficient time to prove whether they were a practical success or not. The fact of an underground conduit being constructed in Paris on the Lineff

system was no proof of its turning out successfully, it being purely an experiment. Mr. Elwell was evidently in favour of the conduit system, but he could only repeat what had already been stated in the paper. The difficulties of draining such conduits efficiently, so as to prevent short circuits, under the most unfavourable conditions existing here, were very much greater than would appear without closer investigation. Besides this, the new system of sewerage under construction, not providing for the carrying off of storm water, it would necessitate a special drainage service for the tramways at an enormous cost. In the matter of safety cut-outs for telephone and other wires, Mr. Elwell appeared not to be well-informed on the latest inventions for preventing accidents. Mr. Elwell had his best wishes for the success of the accumulator with which he was now experimenting, and he hoped to hear soon of its having proved itself capable of withstanding the rough usage which tramway service called for. He did not dispute that the cable system could not be made a fair success where the streets were not too irregular, but even then it was his opinion that a good electric system would be more economical. In reply to Mr. Spruson's remarks, the only difference of opinion worth noting was the question of governing the motor. In his paper he had given credit to the Sprague system of showing a slightly higher electrical efficiency than the Thomson-Houston system, but even after Mr. Spruson's elaborate appeal his opinion remained unaltered. This opinion was based not only on the statements of Mr. Whipple and Sir John Fowler; many additional endorsements might be quoted; but he would only introduce one more, namely, the work of Messrs. T. C. Martin and J. Wetzler, "The Electric Motor," with which Mr. Spruson was no doubt acquainted. The authors of this book had been formerly the editors of the *Electrical World*, and were now the editors of the *Electrical Engineer* of New York, and had to be undoubtedly considered unbiassed authorities on this subject. On page 167 we found:—"In the larger type of motors, however, Mr. Sprague prefers to use a rheostat for throwing the machines into circuit, instead of winding the field coils in sections, because it is a much cheaper process of working, and, as in case a heavy machine should be damaged in the sectional

winding, it would be far more costly to make repairs to it than in the case where a rheostat is used. Of course this rheostat carries no current, except at the moment of starting the motor." Again, on page 196, it was stated:—"They are compound wound and provided with Professor Thomson's new winding, in which the main circuit field coils closely surround the armature and oppose the tendency to a change in the line of commutation under varying loads. The machines have, therefore, a constant lead, and require but casual attention when in operation. The efficiency of the motor *per se* is 90 per cent. The current strength employed is 7·5 ampères. The motor will stand thirty ampères indefinitely, and sixty ampères for half-an-hour. Speed is controlled by a coarse resistance in the main circuit composed of iron plates standing on edge. The motor is nearly self-regulating within the limits of its work, and the resistance comes but little into play. This method is preferred to that of changing the strength of the field magnet independently, since the latter necessitates also a change in the lead. The position of the brushes is never changed either for varying load or reversal." In the face of the above evidence the verdict that he had arrived at in favour of the Thomson-Houston motor might be safely claimed to be perfectly justified, and had not been reached without mature consideration. Mr. Nixon would no doubt obtain every information on the points of mining traction, by communicating with the representatives of the various manufacturers of this type of plant. In conclusion, he trusted to have proved to the satisfaction of the members of this Association the statements made in the paper, which would be, doubtless, ocularly demonstrated in a few months' time on the experimental line now in course of erection between Waverley and Randwick. An apology for bringing this question before the Association was hardly necessary, as it was one that had excited such a large amount of interest both privately and through the Press.