Discussion.

The President moved a vote of thanks to the Author for his Paper. The President

Mr. C. O. Burge suggested that the amounts given in the Paper in dollars should be stated also in English money, so as to render them more readily comprehensible to English members. Mr. Burge.

Sir Maurice Fitzmaurice remarked that the Paper was rather different in many ways from some of the Papers which were brought forward at the Institution. A good deal of it referred to work carried out some time ago, which had already been described in the very interesting Papers of Messrs. Parsons and Jacobs; but, notwithstanding that, he thought The Institution was very fortunate in receiving Mr. Snyder's Paper, because it gave so complete a description of the transport facilities existing at the present time, or projected in the near future, in the four largest cities of the United States. One of the most striking points of the Paper, to his mind, was the immense sums of money which had been spent—particularly in New York and Boston, but also to a less extent in Philadelphia and Chicago—on either underground or overground lines; and still more striking was the vast amount of money which it was proposed to spend in the near future. Americans apparently took a much more far-sighted view than English people in regard to the requirements of the different cities in the near future; they made their plans many years ahead, and, what was equally important, they arranged that the money should be provided for carrying them out. The railways described in the Paper could not be compared altogether with the traffic facilities that existed in London, because tramway-traffic was not considered in the Paper at all, and the tramways in the four cities referred to represented a very large outlay, which had to be added to the huge sums mentioned in the Paper as having been spent on railways. Chicago was on rather a different basis from the other cities, because no underground railways existed there at the present time, although a very large scheme of underground railways had been projected. He thought hardly sufficient justice had been done in the Institution to the great work that had been carried out in Boston. Boston was the first city in the United States to have underground railways. He remembered very well going, in 1897, through the works then in Sir Maurice Fitzmaurice.

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progress in Tremont Street, Boston. He had been there several times since, and he had always been struck with the remarkable progress that had been made in the construction of the underground railways. *The Statist* of the previous Saturday (8th March, 1913) contained the following statement about the transport facilities in Boston:—

> "The city of Boston is provided with transportation facilities in a manner equalled by few and excelled by none. Not only is the centre of the city covered with means of transportation, but the various lines radiate in all directions out into the suburbs, connecting at the termini with the lines of other companies, so that it is possible to travel many miles on what would be called in England a tramway system."

He regarded that as a very just description of the transport position in Boston at present. In that connection he thought it should also be remembered that the type of underground railway now so common in the United States—constructed with roof and sides of steel girders surrounded with concrete—originated with Mr. H. A. Carson, M. Inst. C.E., in Boston. It was some years later that the same type was adopted in New York, as explained by Mr. Parsons in his Paper.[1] Mr. Parsons there stated that at a later stage reinforced concrete instead of a framed structure was used in New York; and on looking back to the Paper, he had found that Mr. Parsons gave the following reasons for using reinforced concrete in subway work, instead of a steel structure:—Economy in cost; rapidity of erection; use of unskilled labour; employment of small members readily handled; the ease with which the design might be modified. A large amount of work was carried out with reinforced concrete in New York in that way, but it was rather interesting to note that on p. 188 of the present Paper the Author stated that the latest designs in New York had reverted to the structural-steel frame embedded in concrete. He was not surprised at that, as he did not consider reinforced concrete at all suitable for this class of railway work. As he had often said in the Institution, he was not at all opposed to reinforced concrete; he had used a great deal of it, and he intended to use a great deal more; but he thought what the Author said must be borne in mind, namely, that the relative quantities of steel, concrete, and excavation required with reinforced concrete and with steel framing encased in concrete, were about the same, *if the same conditions of loading and unit-stresses were used.* He always found great difficulty in ascertaining, in the different systems of rein-

[1] Minutes of Proceedings Inst. C.E., vol. clxxiii, p. 83.

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forced concrete, whether the unit-stresses were the same, or whether the factor of safety adopted was the same. The particulars given in the Paper, such as the cost per mile of work, the unit costs, the stresses which had been adopted and had been found to be the best for different materials, ventilation, gradients, curves, running-costs, and signalling, would be extremely useful to the members when they wished to lay their hands on certain facts for future work; and he was sure they felt very much obliged to the Author for putting them forward so clearly in that way. The Paper was quite a mine of information, and he would have liked to go rather fully into many of the matters mentioned in it; but he would confine himself to a few remarks that he wished to make on London traffic. He was in a position of rather greater freedom than he had been for some time to speak of London in comparison with other cities. The conditions in London were very different from those met with in New York and Boston. Practically all the traffic in New York was north and south, whereas in London the traffic was in all directions. The existing traffic difficulties in London were due to surface traffic; some new tube railways were required, but the greatest trouble at the present time arose on account of the surface traffic. The principal requirements in London seemed to be street-widenings for the traffic, and particularly the widening, and the keeping wide, of the roads which led out of London. There were numerous roads leading out of London which were very little built on now, but they were being built on gradually, and being made extremely narrow. There were great difficulties in getting such matters put right in London, one of the principal reasons for the difficulties experienced being that the area under the control of the London County Council was a very small part of London. What was known as Greater London had an area of 700 square miles, whereas the area known as London County Council London had an area of only 121 square miles, the population of the former being 7 millions, against 5 millions in the latter. In the County Council area there were thirty local authorities, while in the outside area there were one hundred and fifty local authorities. Those various places could not be separated from the traffic point of view. It was impossible to differentiate West Ham from Poplar, Wimbledon from Wandsworth, Acton from Hammersmith, or Hampstead from Willesden. At the present time, trams, underground railways, and motor-omnibuses gave through traffic facilities between the outside and the inside areas. In many cases the drainage of outlying areas was taken into the London County Council area. With such a large number of local authorities, how-

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ever, it was quite impossible to take the broad view that was taken by the cities of the United States, where there was one authority dealing with a very large area. The Royal Commission of 1903 was supposed to settle all those matters, and to give a lead as to what should be done for the future. But, unfortunately, that Commission refused to tread on anybody's toes. They suggested the appointment of a Traffic Board, which, of course, was a very good thing in itself, but they proposed a Board without any power whatever. He had looked up the Royal Commission's report that morning, and found the following conclusions in it:—

"The creation of any authority with power to deal finally with all questions of London locomotion would involve intolerable interference with the existing local authorities and give rise to endless friction. . . . . The functions of such a Board as we recommend are of an advisory and semi-judicial character,"

they might almost have added "of a sentimental character"—

"and do not as outlined for the present include the exercise of Parliamentary or legislative authority; still less do they involve the Board in raising money by taxation in any form."

Even that was not good enough, and they therefore made the final recommendation:—

"The only course is to establish a central body limited in its powers and duties so as to avoid interference with the functions of existing local authorities."

His view of the matter was quite different from that. He thought that, far from limiting the powers of the Board so as not to interfere with the existing local authorities, the Royal Commission ought to have suggested the establishment of a Board whose powers would not be interfered with by any local authorities. He was afraid that, taking it all round, the Royal Commission of 1903 was very timid. He thought the only way was to have one authority in London which would deal with the whole question of the locomotion of Greater London, and would not only control, but also own, in the same way as the Metropolitan Water Board owned the water-supply, all the local railways, tramways, and motor-omnibuses; in fact, all passenger-vehicles except cabs. That Board, in his opinion, should not be an elected Board; it should be a Board of five persons, the members being chosen by the Government, and paid large salaries, so as to have no necessity to do anything but attend to their business. They ought to take no notice of what anybody else said so long as they had gone into a matter thoroughly and had made up their minds what was the right thing to do. One duty that he would

hand over to such a Board was that of dealing with improvements or widenings of roads and streets. He thought it was only right that the authority controlling the traffic in the streets should be the authority to deal with the provision of new streets and the widening of old streets to carry that traffic. The next point to be considered was how that authority was to get funds. In the first place it would have any profit there was from working the railways, trams, etc., which it ought not only to control but also to own. It ought to receive all the money which the Road Board now received from the area of Greater London, and it ought to get contributions from all the local authorities equal to the amounts they now contributed for improvements. Until a Board of that nature was instituted, which would do what it thought was right, without any interference from parliamentary or municipal people, no proper traffic-control would be obtained in London. Sir Maurice Fitzmaurice.

Dr. S. P. SMITH was particularly interested in that part of the Paper where the density of the traffic was referred to. It seemed that on some of the electrified sections the limit of the lines had now been reached, especially in New York, and that it was necessary to seek means of improving still further the traffic facilities on a given railway, to prevent overcrowding, which was always on the increase. That was a serious problem in London also, and he would like to know what acceleration and retardation were used on the trains in the United States, and also the relative amount of coasting. Those factors had probably to be pushed to their utmost limits, and it would be useful to know what those limits were. It appeared that the headway—which he presumed meant the time between successive trains—had been reduced to the minimum, so that the figures he had asked for should be of great interest. He also wished to make a suggestion, which might seem rather far-fetched. The trains had reached the limit of length, and the platforms could not be extended, and the question arose whether moving platforms, corresponding with moving staircases (escalators), could not be used, so arranged that as a train entered a station the passengers were allowed on to the moving platform, the speed of the trains being reduced to the speed of the platform, and the platform and train moving together for a certain distance, say 200 or 300 yards. In that way time would be saved through not having to stop the train. The suggestion might have been made many times previously, but it seemed to him it was only by adopting some such means that it would be possible to improve Dr. Smith.

Dr. Smith. the carrying-capacity of a given line by saving the few seconds which were requisite to stop and start a train. The only other point to which he wished to refer related to the third-rail and overhead systems. He noticed that the Americans used both, in connection with, he presumed, continuous current in all cases. He would like the Author to say which was really the better system, because much discussion was continually occurring on that point.

Mr. Lowcock. Mr. S. R. LOWCOCK remarked that he had not had the advantage of visiting any of the cities dealt with in the Paper, but from the diagrams exhibited it appeared to him that in each case there was an extraordinary absence of loops or connections outside the centre, which he thought was very largely responsible for a good deal of the congestion that took place, not only in those cities but in London as well. If, for instance, in Chicago a passenger desired to get from Stock Yards to South Fortieth Avenue, he had to go into the centre and go out again. Exactly the same thing occurred on many of the London tube railways. For instance, a passenger who desired to get from Kensington to Hampstead had to go in to Leicester Square station and then out again. The result was an immense rush of traffic to and from the centre, radiating in all directions. He could not conceive why that should be, unless it was that the Americans thought they were going to extend all their dead ends a good deal farther as their cities grew. At present they had not made any arrangements for circular traffic, which it appeared to him would very much relieve the congestion in the centres of the cities.

Mr. Ross. Mr. ALEXANDER ROSS remarked that, while the Paper referred to "City Passenger-Transportation in the United States," it was confined to New York, Boston, Chicago, and Philadelphia. The description was largely concerned with the traffic of railways which had been in existence for some time, and therefore it was valuable as relating to experience gained over several years. Many of the details given by the Author were to be found in Papers previously presented to The Institution by Mr. Barclay Parsons and Mr. C. M. Jacobs. He would therefore not refer to these. Taking the points of the Paper in the order in which they were set forth, "the general tendency for the urban population to increase faster than the rural population" was experienced on this side of the Atlantic also, but there were other forces at work, in addition to rapid and cheap transportation, to cause that. Again, "the effect of improved communications between large towns and the surrounding country in causing the city to become a centre for business, amusement, and

manufactures" was paralleled in this country. The City of London itself was almost denuded of its population at night, being left largely to caretakers. The tendency was for business people of almost all classes to find their homes in the suburbs, or even far outside the suburbs. It was undoubtedly correct, as the Author said, that with electric working and improved facilities the number of passengers increased ; and a good example of that was to be seen in London itself, where the underground services—the tubes, and metropolitan shallow lines—had increased year by year until in 1912 the four tube companies carried upwards of 175,000,000 people, and the shallow railways, namely, the Metropolitan and District Railways, carried more than 186,000,000, making a total of about 361,000,000. If further evidence were desired, it would be found in the results of the railways electrified by the large companies—the Midland, the North Eastern, the Lancashire and Yorkshire, and the London, Brighton and South Coast railways—whose experience had been communicated from time to time to The Institution. One notable example of facilities creating traffic—the most notable example that had come under his notice—was that afforded by the tube railway from Charing Cross underneath Hampstead Heath to the lower lands lying behind, which had been the means of creating two new towns—Golder's Green and the Hampstead Garden Suburb. When he visited New York in 1904, with the Institution party, he was not impressed with the desirability of having overhead railways along the streets with the rails on a level with the first-floor windows. It was not the sort of thing that would be countenanced in London, even when electrified, in which condition it must have been a great improvement on what it had been when worked by cables or locomotives. It was satisfactory to know that the New York authorities had prohibited any further extension of such railways. When the first elevated railway was built, in 1867, it met a great want. It was the form of railway which required least capital for its construction, and on the whole it had done excellent service, although, he supposed he might add, in a disagreeable manner. He agreed with the Author's enumeration of the advantages and disadvantages of an elevated and open-air service. When the party visited New York in 1904 the subway was very nearly completed at the northern end, but the contractors were still hard at work at the Battery end, in the more concentrated business part of the city. The members of the party were very much struck with the ample facilities given by the authorities for the construction of the line. Everything was upside down, but the public did not seem to mind as long

Mr. Ross.

Mr. Ross. as the work was proceeding as rapidly as possible towards completion, in the hope that when completed it would be of great service to them all. He could not help contrasting that state of affairs in New York with the view taken by the London authorities in regard to the construction of tubes and other railways. He thought that if the London authorities had had more sympathy with the tube railways, those railways would have been situated very differently, and arranged in a much better way, with fewer stairs, subways, and passages, and, possibly, fewer lifts. He did not see why railways should not be allowed in tunnels under the public parks and other open spaces, of which London had fortunately so many. If that were allowed, much compensation and a great deal of work would be spared, and greater facilities would be given for new lines through the town. In comparing New York with London in regard to traffic, consideration must be given to the difference in situation and in other circumstances. London was a huge area extending for miles all around, with the River Thames intersecting it; but the River Thames—like the river mentioned by the Author in his reference to Chicago—was crossed by numerous bridges and tunnels, and did not form a barrier to the development of the area as a whole. New York, on the other hand, was on a narrow strip of land with water on three sides. Again, London was situated on a soft substratum of London clay, gravel, and sometimes chalk, and almost invited the construction of shield-driven tunnels at such a depth as to cause as little disturbance as possible to existing underground works; whereas in New York the substratum was hard rock, making it almost imperative that the underground lines should be near the surface. Shallow railways offered many advantages, yet it was now known that, notwithstanding a great deal of adverse criticism, the tube lines were at the present time exceedingly popular. That was because they were well-managed, well-ventilated, clean, and always well-lighted. The passages were inevitable; but it must be remembered that, in designing the stations for the tube railways in London, very great care had been taken to provide a distinct passage for each stream of traffic, in order that people's paths should not cross. That necessitated longer passages. Having referred to tube railways, he might be allowed to give a few leading particulars of the tube railway system which he knew best—having constructed some miles of it—namely, the London electric lines. These particulars might be useful for comparison with those of the American lines to which the Author referred. The diameter of the running-tunnels was 11 feet 8 inches and of the station-tunnels 23 feet; all lines were of standard gauge,

4 feet 8½ inches; the railway permanent way consisted of bull- Mr. Ross.
headed rails with chairs and cross sleepers, which, he thought, was quite a departure from the American practice; trains were run constantly over the lines from 5.15 a.m. to 1.15 a.m. next day (18 hours out of the 24), the interval of time ranging from 1½ minute to 3 minutes. The stopping-time at stations was 15 seconds for ordinary stations, and perhaps double that for interchange stations; the scheduled speed ranged from 17 to 23 miles per hour. The most fully occupied section was between Camden Town and Charing Cross, on which 455 trains ran each way per day of 18 hours. The stations were island platforms 350 feet in length, and at each station there were lifts varying in number from two to four, each of which carried forty-five to fifty passengers. In the slack hours the trains were reduced to two carriages, while in the busy hours they were increased to seven and sometimes eight carriages. These long trains carried 350 to 400 passengers. Ventilation was effected by a fan at almost every station, and he considered that, on the whole, the London electric lines were very well ventilated; in fact, sometimes, on getting to the higher levels, as at Chalk Farm, one met with almost a gale. The indicating signals were of the usual semaphore type; but they were worked automatically on the electric track system, except at the stations, where a signal-box and interlocking were provided in the usual way. There was also a train-stop, by which a train passing a signal at danger was brought automatically to a standstill by the brakes being applied. It had now become almost usual to provide escalators instead of lifts. The first was that at Earl's Court which lifted 10,800 passengers and lowered an equal number per hour. The advantages of an escalator were that it worked continuously, and that, if a breakdown occurred in the machinery, it remained as a stairway. Indeed, young and active people were not only lifted by the escalator, but also ran up the stairs, thereby saving a good deal of time. With regard to the working of slow and express trains, they had adopted in America a plan which had not been followed in a general way in England, namely, the use of three lines, the inner line being used for traffic in the direction of the rush at busy times. He thought that was very ingenious, and he believed it was also very effective; at all events, he had never heard of any accident due to it. But personally—perhaps from some old-fashioned notion—he would like to see four lines. With regard to loops at terminal stations, where steam traction was being used, it was almost essential to have a loop line, so that the

Mr. Ross. engine had not to be reversed; but with multiple-unit trains, which could be driven from either end, a loop line was really not necessary. In the lines with which he had had to do, a double cross-over road in front of the station had been provided. That enabled the signalman to receive a train at either side of the platform, as might be convenient; and similarly he could dispatch a train from either side. In that respect he thought a cross-over road was quite as effective as a loop line, and it was much cheaper. The question of the time lost in loading and unloading trains at stations, and the provision of suitable carriage-doors, was carefully considered when the Piccadilly line was first opened. In the result, a central door was provided in each carriage, the intention being that incoming passengers should enter the carriage at the ends and move along towards the centre, while outgoing passengers should move towards the central door and leave by it. But the British public were not to be drilled in that way, and the result was that when a train arrived at a station, passengers on the platform crowded around the open central door, not only preventing people from alighting, but also preventing themselves from getting in. The outcome was that the central door had to be largely abandoned on the tubes—he did not say entirely, because it was sometimes used at the present time. Sir Maurice Fitzmaurice, in an excellent speech, had criticized adversely the Report of the Royal Commission on London Traffic of some years ago. Mr. Ross had not followed that Report so well as Sir Maurice must have done in his official capacity, but he must say that he thought at the time it was almost a colourless pronouncement. On the one positive recommendation made, namely, that a Traffic Board should be appointed to regulate the traffic of London, no action had been taken—why, he did not know. He thought this should not be a party question. There seemed to be an opportunity for many parties to take up the matter, but no action had ever been taken. Sir Maurice Fitzmaurice had not only offered what he might term destructive criticism, but had become constructive in the latter part of his speech, when he referred to the constitution of such a Commission as he thought ought to be established. According to Sir Maurice, the Board was to consist of five men with almost penal powers, and who were not to be interfered with by any other authority within London. Mr. Ross did not object to that, but Sir Maurice had said also that all the railways within the outer boundary of greater London should be handed over to the Board. As a railway man who had had a good deal to do with the building-up of the trunk lines of this country, Mr. Ross objected to that proposition. He could not agree that so absolute

a body should have the power to cut short all the trunk railways in this country at the boundary of London. [Sir MAURICE FITZMAURICE pointed out that he had referred to local railways.] Sir Maurice went farther, and courageously set up the ways and means, which was a difficult thing to do. Among other things, Sir Maurice had said—hesitatingly, Mr. Ross thought—that he would take the funds, or some of them, of the Road Board and apply them for the purpose. Mr. Ross's own recollection was that the taxes upon motors and petrol had been imposed to meet the complaint of the country districts of the way in which their roads were being torn up by heavy motors, mostly from London. Those roads never had a foundation fit to carry such heavy and fast traffic, and before Sir Maurice's proposed Board was given those funds, he certainly thought the country roads should be put in first-class order. He did not see why the funds should be applied in any way to wealthy London, which could look after itself and find its own means. The Author referred to what he termed the "riding habit." That was rather a new term to British engineers, but there was no doubt that the riding habit had come to stay. Everyone took advantage of the facilities now afforded to come into town, with the result that the streets were more congested than ever; and he considered that with motor-cars, motor-omnibuses, taxicabs, high and low vans hiding smaller vehicles, fast and slow traffic all mixed up, and the public trying to find their way along the streets, something would have to be done before long. He congratulated his friend, Sir Maurice Fitzmaurice, on having put forward a positive view which might be discussed. It was clear that London could not continue long in the way it was going now, and he thought that, even before a Traffic Commission was appointed, the traffic should be classified in some manner so as to divide the slow and bulky traffic from the fast and nimble. It was a very big question, and he was not prepared to say what should be done; but something ought to be done. Generally speaking, with regard to railways he would give the first place to open-air railways, whether on the surface or elevated above the streets; the second place he would give to subways; and for the third place he did not object, and he did not think the public need object, to well-constructed, well-ventilated, and well-lighted deep tunnels. He thought, on the whole, those who had been building tunnels could find many points in which they could improve in the future, and many mistakes committed in the past which might be avoided, and in that connection he would recommend that all future tube tunnels should be 12 feet 6 inches in diameter.

Mr. Ross.

Col. Sir Arthur Yorke.

Colonel Sir ARTHUR YORKE endorsed Sir Maurice Fitzmaurice's appreciation of the Paper, which seemed to him to be a complete encyclopædia of all that had been done in America up to the present time to provide passenger-transportation in the big cities. He would also like to express his agreement with Sir Maurice to a certain extent in the remarks he had made as to the Traffic Commission, and to a certain extent also with Mr. Ross's remarks on the same subject. He would not go quite so far as either of those gentlemen. In the Paper it was stated that originally the traffic of New York was controlled by a "Board of Rapid Transit Railroad Commissioners," who were subsequently superseded by "Public Service Commissioners," with somewhat enlarged powers. He believed a similar body, called the "Public Utility Commissioners," had been appointed in some Canadian cities. In his opinion it would be a good thing for London if the term "Traffic Board" were abandoned and something more comprehensive were adopted —such as "Public Service Commission"—because the Traffic Board suggested in the Report of the Royal Commission was not to control the street traffic, but merely to advise on the subject. It was to be an advisory board with no powers whatever of direct control or of initiation. To create a Traffic Board of that sort was, to his mind, simply superimposing another authority on all the existing authorities. At present there were the Borough Councils, the County Council, the Commissioner of Police, and the Board of Trade, and if on top of those numerous authorities a further authority was introduced, the position would only be made worse, and delay would be increased. He thought that if a Board were instituted at all for London, which was to control traffic and other matters, it should be a Public Service Board, with supreme powers in various matters. In order that it should possess those powers, certain powers would have to be taken from the existing authorities. They would have to yield their share of the control over the London street traffic, which would be vested in the one central Board. Again, in his judgment, the Public Service Commissioners should have authority also over gas-, water-, and electric-supply companies so far as the breaking-up of the streets was concerned. Nothing should be done to interfere with the streets in any way without the authority of the Public Service Commission. The Commission should also have certain powers of initiation. At the present time, for example, when the whole of the means of transportation were provided by private companies, there were undoubtedly certain connecting links which would be very useful, but which did not present an attractive appearance to financiers and

investors. In a case like that the Public Service Commission should have the power to construct those railways, as they had in New York at the present time. He did not suggest that the Commission should necessarily work the railways. In New York the Commissioners did not work them, but merely had the lines constructed, and leased them to certain contractors at a rental which would return interest on the capital invested, and which, by means of a sinking-fund, would wipe out that capital altogether at the end of 50 years. He thought, if ever a supreme Board were appointed for London, it ought to possess some of those powers, and not be confined to giving advice with regard to street-traffic. There were one or two small details in the Paper to which he would like to draw attention. The guard-railings shown in *Fig. 8a* (p. 184) seemed to be useful for people entering the train, although he did not quite follow their utility from the diagram, inasmuch as there was a gap between the railings, where the arrows curled round right and left, which led straight on to the door, and he did not see why a passenger who wanted to get on to the train should not go direct; instead of that, he was supposed to follow the arrow-heads and take a circuitous path somewhat resembling the maze at Hampton Court. But the objection to the guard-railings seemed to him to be that anybody getting out of the train, especially when it was on the move, would suddenly run the pit of his stomach against the guard-railing. The butt end of the railing being about 12 inches from the edge of the platform, it would just catch a man as he was alighting. On that account he thought that guard-railings used on platforms where passengers alighted from, as well as entered, a train, would be highly objectionable. He did not quite follow the Author's remark that, where the conditions were favourable, three tracks could be equal in capacity to four, as the trains could be run very closely together on the third track, which could thus feed the two other lines with trains so as to keep a full service of trains going upon them. The Author seemed to have overlooked the fact that each track was signalled for a certain number of trains running at a certain speed and with a certain headway; and the block sections, as fixed by the insulated joints of the track-circuit, and by the signals, would only allow a certain number of trains to pass over that track in a certain time. Sir Arthur Yorke did not see, therefore, how a single track could under any conditions feed two other tracks, because the third track would have to be signalled for ordinary passenger use in the morning, and, therefore, would have to be signalled in such a way that the number of trains passing over it was a fixed quantity, which

Col. Sir Arthur Yorke.

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quantity could not be increased. Further, each track would be signalled under the same conditions, and, therefore, it seemed to him that one track could only feed one track and not two. Mr. Ross had referred to the fact that third tracks were in existence in New York, and had seemed rather doubtful as to whether he cared for that arrangement. He would like to remind Mr. Ross that there was something analogous to that in London, on the London, Brighton and South Coast Railway, where there was a track which was used in one direction in the morning and in another direction in the evening. He had not heard of any difficulty or accident arising from it; at any rate, nothing of that nature had been reported to the department to which he had the honour to belong. He thought all would agree with the Author's remark that the lines at stations ought to be straight. He was sorry to say that in London there were cases on some of the earlier tube railways in which the lines at stations were not straight, and a good deal of trouble arose from time to time, owing to people falling between the side of the carriage and the edge of the platform. He imagined that the reason why the curved platforms were permitted in those early days was that the carriages in use in England at that time were much shorter than those now in use, and, of course, the longer the carriage, the more important it became that the platform should be straight. With regard to brakes, the Author mentioned that electro-pneumatic air-brakes were used upon American rolling stock. As far as Sir Arthur Yorke knew, the electro-pneumatic air-brake had never been tried anywhere in England, and he would much like to know a little more about it. It seemed to him that a brake of that kind would be exceedingly useful for trains running on such short headway as they did upon tube railways, inasmuch as instantaneous application of the brake upon every coach was obtained, however long the train might be. There was therefore no bunching-up of the trains, and he hoped there was not that jerk which was rather noticeable at present on the underground railways in London when a train stopped. Another interesting feature which had not been adopted so far in England was the speed-control signals, which were so arranged that the trains had to maintain a certain distance apart and therefore could not overrun one another. The device seemed to be exceedingly useful, and he would like to see it experimented with at any rate, if not installed, upon some of the London railways. The remark on p. 214, that with lower speeds the headway between trains could be shorter, might seem somewhat para-

doxical. At first sight it would be thought that the quicker the train got away and travelled, the sooner another train could be run after it; but the speed of a train settled the position of the signals and the amount of overlap which was necessary when a train reached a signal, or when it attempted to overrun a signal and was brought up by means of the train-stop. If the speed was high, there must be a longer distance in which the train could be brought to rest without overtaking the train in front of it. Therefore more headway was necessary with a high speed. It had to be settled, when a line was being signalled, what was the best speed, and what was, therefore, the best headway—the two things being interdependent—to give the best service to the public. If low speeds and short headways were adopted, the crowd on a platform could be cleared away fairly quickly, but each individual would be longer in getting to the end of his journey; on the other hand, with longer headway and higher speed, each individual might get to the end of his journey more quickly, but the crowd on the platform would not be cleared as rapidly. Col. Sir Arthur Yorke.

Mr. PHILIP DAWSON desired to emphasize certain points already referred to by Mr. Ross, because they showed that if similar traffic-facilities could be obtained in the large towns of this country, more or less similar results to those obtained in America might be expected. For instance, if the inner zone of the County of London were taken, it would be found that the population had decreased by 3 per cent. between 1901 and 1912; whereas the population of the outer zone of London had increased by 38 per cent. in the same period. What rapid transit and a frequent train-service could accomplish was shown, for instance, by Wimbledon. The population of Wimbledon in 1889 was about 20,000, in 1910 it was 58,000; and the fact that the increased transit-facilities caused people to travel more frequently—to acquire what had been referred to as "the riding habit"—was shown by the fact that, whereas the number of passengers carried from Wimbledon in 1890 was 1,100,000, in 1909 it was 5,460,000, or an increase of 396 per cent., while the population in that time had increased only a little over 190 per cent. In dealing with the question of rapid transit, there was a problem which had not been gone into in detail in the Paper, and to which he would like to refer. Mr. Ross had alluded to it in his reference to the suburban traffic of the trunk railways. Many of the main-line railways in large cities such as London had very large suburban traffics to deal with, whereas in American towns the main-line railways had, comparatively, a small purely suburban traffic to manage —with the possible exception of New York, where the New York Mr. Dawson.

Mr. Dawson. Central, and the New York, New Haven, and Hartford, had had to electrify certain portions of their lines. The latter railway indicated what English engineers had to look forward to in discussing the question of electrification of any main-line railway, even if it was only the suburban portion. Commencing by electrifying a small portion of its suburban system, the New York, New Haven, and Hartford Railway had continued for several years to extend, until it was just now completing the electrification of 75 miles of railway from its terminus, and was considering the electrification of the whole system as far as Boston, a distance of between 200 and 300 miles. As far as New Haven it was a six-track road, over which every class of goods- and passenger-traffic would be hauled electrically. There must be good financial reasons for that, particularly with a railway company such as the New York, New Haven, and Hartford, which was one of the oldest and best of the railways in the United States. If it had proved profitable for that railway to electrify its lines as far as 75 miles, and to consider the question of extension up to 250 or 300 miles, surely English engineers ought not to leave out of consideration the possibility of such extensions becoming advisable in the case of railways in this country. The railway with which he had the honour to be connected—the London, Brighton and South Coast Railway—had already electrified a portion of its suburban system, and was about to electrify in the near future the remainder of that system. When that suburban electrification had been completed, it would mean that practically one-third of the distance to Brighton was equipped electrically. There were already about forty trains per day running between London and Brighton, and over a considerable portion of the same line—as far as Wivelsfield Junction, where the branch to Eastbourne and Hastings diverged—there were another twenty trains daily, making a total of sixty trains daily for two-thirds of the distance. It could therefore easily be conceived that that line, at all events, was one which it might prove in the near future valuable and useful to electrify. With all deference to Sir Maurice Fitzmaurice, the question of electrification of English suburban railways was one in regard to which it was very difficult to draw the line where the suburban traffic ended and the long-distance traffic began. If the suburban end were under one authority, and that authority chose to interfere, or could easily interfere, with the handling of the long-distance traffic using an electrified road, the position of some English railways might become exceedingly difficult. The increase in traffic following electrification was clearly shown by the figures obtained on the Brighton

Railway, which he had had the honour to submit some time ago.[1] Some railway authorities believed that, in consequence of competition on purely local lines, such as those which were described in the Paper under discussion, and of motor-omnibuses and other methods of transport of that kind, it was better to face the loss of practically the whole of the suburban traffic, and to rely on the long-distance traffic alone. That might be the right course in the case of some railways, but it certainly was not so for all of them. Lord Bessborough, the chairman of the Brighton Railway, at the half-yearly meeting a few weeks previously, stated that the value of the suburban traffic of that line, excluding the traffic already handled by the electrified lines, was about £420,000 a year. If the electrified lines were included, Mr. Dawson imagined that the amount would certainly not fall far short of £500,000. If the Brighton Company had to face the possibility of losing half a million annually in receipts it would be a very serious thing. Fortunately their experience had shown that if they electrified they need not fear any such thing; because, not only had they gained back the traffic which they had lost owing to tramway, motor-omnibus, and other competition, but they had increased the number of passengers above what they had ever carried before, and that increase was still going steadily on. Electrification enabled another thing to be done, which for railways having termini in London was of the utmost importance. It enabled many more trains to be dealt with at a terminus than could possibly be handled by steam. As an example of what had been done already in that direction, he might mention that the figures given by Lord Bessborough showed that in Victoria Station before electrification 496 trains were dealt with daily, whereas at the present moment 739 trains were dealt with, and at London Bridge before electrification 663 trains were dealt with daily, whereas at the present time 901 trains were dealt with; and there was no doubt that by electrifying the remainder of the suburban system it would be easy to increase that number very considerably. The rolling stock adopted in the United States resembled closely the stock used on the underground electric railways in London. The most notable features were the short wheel-base and the small wheels; the former being about 5 feet, and the diameter of the latter 33, 35, and 36 inches. That, of course, was bad for the permanent way, and increased the cost of maintenance considerably. In tube lines, where the headroom was much restricted, the necessity for such dimensions was clear. On the other hand, the English

Mr. Dawson.

[1] Minutes of Proceedings Inst. C.E., vol. clxxxvi, p. 1.

Mr. Dawson. main-line railways which had electrified, such as the North Eastern, the Lancashire and Yorkshire, and the Brighton, had adopted stock in which the wheel-base of the bogies was 8 feet and the diameter of the wheels 4 feet 3½ inches, with exceedingly satisfactory results in the matter of wear and tear of the permanent way. The Author gave some figures as to the cost of working trains on some of the railways which he described, and Mr. Dawson would be glad if he would analyse those costs so as to show the locomotive part of the cost separate from the other parts. It would also be very interesting to those who were connected with the electrical side of the matter, if the Author could give the consumption of electrical energy, expressed, say, in watt-hours per ton-mile, or in units per car-mile generated at the power-stations. Another interesting point on which the Paper did not touch was the cost of sub-stations. Could the Author give that cost, say, per mile of track for the particular line to which he referred in the Paper? He hoped the Author would see his way to amplify, in the way suggested, his voluminous and exceedingly interesting summary of information.

Mr. Morgan. Mr. CHARLES L. MORGAN remarked that the three-line track referred to by Sir Arthur Yorke had been in use for about 3 or 4 years on the Brighton Railway between London Bridge and Bermondsey. There were originally two lines used wholly for the outgoing traffic and one for the incoming traffic, and the Company had now signalled one of the outgoing lines so that it was used for traffic in both directions. That system had been passed by the Board of Trade, and there had been no hitch of any kind whatever in working it. It had been a very great relief to the traffic. There was, however, no pretence, he thought, on the part of any person experienced in the working of railways, of saying that the three lines gave equal facilities to four lines. He did not agree with the Author at all in that respect; he would infinitely prefer to have four lines, so that the fast and slow traffic could be divided, and no question of reversible working involved. The great benefit which the Brighton Company had found from the reversibility of the third line was in relieving the pressure in the terminus. At night, when the outgoing traffic was the heavier, the incoming laden and empty trains could be brought into the station and be more promptly and speedily dealt with than the heavily-laden outgoing trains; so that during this period of pressure two lines were used for outgoing traffic and one for incoming, the reverse being the case in dealing with the morning traffic. It was really in the matter of terminal accommodation that the great relief occurred.

Mr. Morgan.

He fully endorsed what Sir Arthur Yorke had said with regard to the Paper, but he thought it was rather an historical record of the condition of things in four great cities of America than a theme which lent itself to a general discussion from an engineering point of view. There was much information in the Paper that would be exceedingly useful to the members, mainly statistics, and particulars of the cost of the various lines which had been carried out, but also—which was rather unusual in a Paper of this nature—information as to the loads that had been provided for and were permitted on the various materials used. Of course, the problem of dealing with traffic was a very pressing and difficult one in the four large cities mentioned in the Paper, but he thought London was well to the fore in that respect. On p. 169 the Author mentioned that the increase of the population of the United States in 1900–1910 was 21 per cent., and that during the same period the urban population increased by 34·8 per cent. But the urban population in the whole of the States was 46·3 per cent. of the total population. The population in the four cities was given as 12½ millions, or 13·5 per cent. of the total population. Greater London, with its population of 6,600,000, represented 16 per cent. of the population of England and Scotland. So that, as far as population was concerned, London alone had a far heavier problem to face in its traffic than the American cities referred to. Again, comparing London with New York, London, including the City, had an area of 78,491 acres, as against 183,555 acres in New York; and London's population was 60·16 per acre, against 26 per acre in New York. Then, outside the City, the population of New York was 4 per acre, whereas in London, outside the City boundary, it was 10·72 per acre. Taking both the inner and outer areas together, New York had a population of 10·5 per acre, whereas that of London was 24·62. He thought those figures in themselves showed impressively the extent of the problem which London now had to face, and which, as time went on, would become more difficult. Referring to the question of underground construction, the Metropolitan Railway had celebrated its jubilee, while the work in connection with the underground railways of New York and the other cities mentioned was much more recent. The first Chicago railway was constructed in 1892, the first Boston railway in 1897, and the first New York railway in 1904; and therefore, if there was anything at all between those cities and London to compare, he thought New York and the other cities ought to show some advance on this country. He did not think anybody present could admit that the English railways, especially the underground railways in

Mr. Morgan. London, had not made advances equal to anything in the new country. Referring to a point which Mr. Dawson had mentioned, namely, the increase of traffic by reason of electrification, he noticed (p. 174) that the first underground lines in New York were finished in 1904, and that in that year they carried 2,190,000 passengers per mile. During 1912 the number of passengers carried was 4,151,000 per mile. Now it was quite true that at first blush it might be said that that increase was due to electrification. So it was; but he would rather like to see those figures divided up per train-mile. If, for instance, in 1908 they were able to work thirty trains per hour, and in 1912, forty-five trains per hour, a very large increase in the number of passengers carried would naturally be expected. But with that increase the cost of working must also advance, because of the additional number of trains; and it would be interesting to know what was the commercial result of that increase in the number of passengers; that was to say, whether the additional passengers were being carried with the same margin of profit as the smaller number in 1908. As far as elevated lines were concerned, he thought they were out of the question in London—that was, overhead lines following the routes of streets. His experience in London was considerable, and he could say that if an engineer wanted to put up a column on a footway over a very awkward road, although the column would take up no more space on the footpath than a lamp-post, neither the County Council nor any local authority would allow it. He thought the authorities were exceedingly unreasonable in that respect, and if English railway-engineers could obtain the facilities which engineers in New York received in building structures over the streets, a great deal more could be done. But he did not advocate that system. As for lines near the surface, he had no doubt that if lines could be constructed in this country with the same amount of freedom as they were built in America—that was, by cut-and-cover work—very much better means of communication would be obtained from one side of London to another, because the main arteries of traffic could be followed. He did not think, however, that in this country, with the various interests which there were, and from what he knew of the fuss made about any little obstruction in the street, the cut-and-cover system would ever come into vogue. Imagine a steam-navvy working, as illustrated in the Paper, in Regent Street! He thought that even under Sir Maurice Fitzmaurice's independent, autocratic, and omnipotent authority the millennium would not have arrived, but rather the reverse. As to the question of terminal stations, the Author said that trains

left the station illustrated in Fig. 8, Plate 5, for nine different destinations. After looking at the Figure, Mr. Morgan had failed to follow the working of that station, and it would be interesting if the Author, when replying, would give further details. If it was a question of getting the train into the terminal station and discharging on both sides at the platforms, why was the overrun station there at all, and why could not the trains go out from the far end of the right-hand station on the illustration, without having, as he took it, first to discharge at the right-hand station and then to draw ahead to the other station—which was only about 100 feet distant—between the ends of the platforms of the two stations and so that the departing trains would cross the incoming traffic? He could not see the object of that at all, because if the first station was discharging on both sides, he took it they could load at that station; and if so they could discharge on one side, load from the other, and get away much more freely. He had no doubt, however, there was some satisfactory explanation of the working of the station, and he would be very glad if the Author would give it. The Author said that sixty-one trains per hour were being worked out of that particular station. That was quite a possible number, provided the nine trains to the nine different destinations got relief from the right-hand end of the station very quickly, in order to get fairly good headway between them. The Author referred to transfer-stations on the New York, Hudson and Manhattan Railway, where passengers paid as they entered. He presumed that the zone ticket system was in operation there. He was rather interested by the reference on p. 207 to the zone fares, and he noticed that a passenger could travel on the New York line a maximum distance of 17·82 miles for 2½*d.*, the average length of a journey being 5½ miles. It was not quite clear whether the 4 miles recommended by the Commission now sitting was intended to be the maximum or the average distance for a 5-cent fare, and it would be interesting if the Author would explain that point; evidently the New York lines had been carrying passengers at unremunerative rates. If that was so, it was calculated to bring about an artificial increase of traffic, and to that extent render it unsafe to accept the figures relating to that increase as indicating something which could be attained on this side of the Atlantic, where proper fares would be charged, making provision for profit and expenses. Like the Author, he did not agree with Mr. Wellman's suggestion for further increasing the capacity of the lines. It would mean practically a continuous train, platforms twice or three times the length of those shown

Mr. Morgan.

Mr. Morgan. in the Paper, and stations much farther apart. If movable platforms were installed, then, of course, the traffic might be worked. There was one peculiar feature of the permanent way of the Philadelphia subway, the advantage of which he did not really quite see, namely, that the rails were carried on longitudinal timbers resting on steel box girders embedded in concrete. If he had to put a rigid bottom of that sort under his longitudinal sleepers he would prefer to use concrete alone; he did not see the object of the box girders, nor did he see how the concrete could be filled in to the top flange of the box girder with any degree of accuracy. He also thought that for electric traction a rigid bottom, of the type shown, must be exceedingly bad for the motors; he would rather see a line with a little more spring in it. He noticed that the Hudson and Manhattan Railway had longitudinal timbers laid on concrete alone. In his opinion the crux of electrification was the signalling. Electrified underground lines were, of course, cleaner and pleasanter, and, where stops were frequent, much more speedy; but in his view their greatest advantage was the result of automatic signalling. In that direction there lay very great possibilities indeed, in allowing the short sections now being worked on the underground lines with perfect safety. There was the trip system, whereby if the signals were overrun the train was stopped within a given distance; and there was the method of automatic graduated speed-control, which was in use in America. If the latter was a practical working method—and it seemed to be so—he thought the maximum number of trains which could be worked over the underground railways had not yet been attained in England. At the present time forty-six trains per hour, and in some cases more, were being run with proper intervals—and being worked as trains, not as tram cars. Compared with what used to be the steam maximum, about twenty-four per hour, that was a great advance; but it had been brought about almost entirely, in his view, by the system of signalling. He did not think it could be put down solely to electrification. It was the result of shorter sections, greater control over the trains, and the control afforded by trip-cocks, and so forth, which automatically applied the brakes if one train overran into another section. He quite agreed with Sir Arthur Yorke's remarks as to curves at stations, but at many main-line stations curves existed, owing to topographical conditions and the necessity of avoiding particular property. There was a very important station not far from London which had a platform with a 15-chain curve, and with modern long coaches, and allowing for superelevation, there was a large space left between the plat-

form and the footboard: it was not altogether an uncommon thing to hear of people falling into that space. That, however, could not be avoided. It was stated in the Paper that on the elevated line in New York ninety trains per hour were run, that there were no signals—and, he presumed, no Board of Trade in New York—except at important curves and some important positions, and that very few accidents had resulted. If there were freedom of that kind in England, a much larger number of trains could be worked than at present, but what would happen on a foggy day he would not venture to say. It was not the sort of freedom he would ask for or wish to have, and he did not think any responsible railway man in England would take such a risk. He thought generally it might be said that the experience of American cities as to the growth of traffic owing to electrification should not be taken as necessarily indicating the results that might be obtained in England. Nearly all the lines shown in the illustrations in Plate 4 had been built under or over main arteries of traffic. The only line in London which was at all comparable with that state of things was the Central London, which ran under Oxford Street. If all the suburban lines which were being electrified could be placed under similar conditions, similar results to those obtained in America might be expected; but, unless that was the case, it was not safe to apply the experience of the railways of the United States to England. Mr. Morgan.

Mr. W. Willox had read the Paper in order to learn from it, and not to criticize it; but he thought that some very interesting comparisons might be drawn between the railways of the United States and those in England. It was stated in the Paper that, during the first year of working, the Rapid Transit Subway of New York carried about 2,000,000 passengers per mile of track per annum. He found that on the Metropolitan Railway last year the figure was also 2,000,000 per mile of track per annum; but, while in New York that figure had increased to more than double, on the Metropolitan the number had remained stationary. He thought perhaps a 5-cent fare would have a great effect on the advancement of underground railways in England. If the London underground railways could get $2\frac{1}{2}d.$ for every passenger instead of $1d.$ or $1\frac{1}{2}d.$—he thought the average on the Metropolitan was something over $1\frac{1}{4}d.$—the companies would have an incentive to do a great deal more than could be done at present, when they had to contend with vested interests, even in connection with the putting-up of a column. He had a grievance against the "tubes"—that it was necessary to walk a long distance in subways, mount many stairs, then Mr. Willox.

Mr. Willox. wait for a lift in order to rise a very short distance, and finally ascend another staircase to the street. For that reason he was very pleased to find that escalators were coming into fashion. One was about to be introduced to connect Baker Street station with the Baker Street and Waterloo tube, where there was a transfer every year of more than 1,500,000 passengers from platform to platform. There were many interesting problems which had to be dealt with by the underground railways of this country, for example, ventilation and noise. The tubes were exceedingly noisy. He supposed that could not be helped, because the wheels had to be made of iron, in order, he presumed, to prevent danger in case of fire. Otherwise Mansell wheels, with bonding, might very well be used. He found that brickwork in tunnels caused much less noise than concrete, but in the tubes he supposed the noise was due to the iron lining. As to ventilation, there was an excellent system in use on the Central London Railway. He desired to refer to the question of ventilation, because people seemed to have an idea that now steam trains had been taken off the underground railways very little attention need be paid to ventilation, and the cry was, "Build over all the open spaces, and let them for offices and shops." He had a visit, a short time ago, from the Chief Engineer of the Metropolitan Railway in Paris, who had come over specially to inquire how the Metropolitan railways of London had overcome the difficulties of ventilation, as that was a burning question in Paris. He had more or less to fight continually against having the whole of the Metropolitan Railway covered. He remembered hearing Sir Arthur Yorke, in the Institution, once advocate no signals at all—or perhaps he should rather say, hold such to be an ideal system. To run ninety-seven trains in an hour was a thing that could only be done without signals. Speaking for the Metropolitan Railway, the signalling was such that more than sixty trains per hour could be run, but they were not run, because the drivers would not run all at the same speed, and the stations were not equally spaced, while the worst difficulty of all was with passengers getting in and out at stations. There was really no need for control signals, although if the Board of Trade had not advanced—as it had done—with the march of electric signalling, his railway had been on the point of putting in control signals at a certain part of the line.

The Author. The AUTHOR, in reply, remarked that Mr. Burge's suggestion to express the costs in English money might easily have been done. While exchange fluctuated slightly and was normally at about $4·87

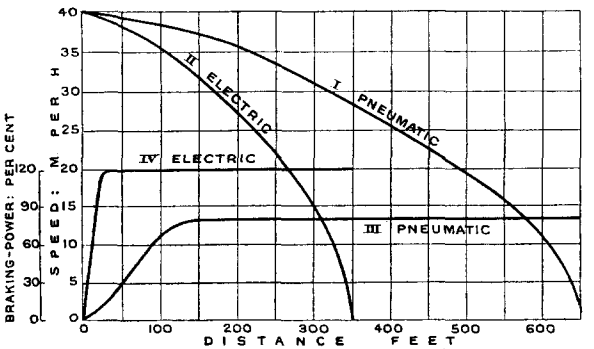
to £1, yet for all practical purposes it could be taken at $5·00 to the £1; four shillings to the dollar; or two cents to the penny; thus enabling the calculations to be made mentally. Sir Maurice Fitzmaurice's statement that Americans took a more far-sighted view than the English people as to their transit requirements would be questioned in America, as Boston was the only city where the transit development was consistently keeping pace with its requirements. New York's subway had been overcrowded from the start, and uniform development of the city was prevented by lack of facilities in some sections, retarding growth, while undue growth was going on along the line of the facilities, which were thus still further overcrowded. Further facilities were urgently needed in both Philadelphia and Chicago, but one thing or another had prevented them from being provided. The difficulties were not physical, but were largely financial, political, or legal. The older American cities also had their problems, due to the growth of the surface street traffic, and large sums were being expended in widening streets and cutting additional highways. The surface problem was largely influenced by the sub-surface and overhead facilities, as the tendency of business was to concentrate along the lines of these facilities and to materially increase the pedestrian traffic at certain hours. Conditions in Boston had been materially improved by placing the tramways underground or overhead on crowded streets. In reply to Dr. Smith's inquiry, the acceleration was on most lines at the rate of 1·25 mile per hour per second, although some trains would accelerate at the rate of 1·4 mile per hour per second. The usual braking retardation was also about 1·25 mile per hour per second, although with the electro-pneumatic brake a rate of retardation of 2 miles per hour per second had been obtained. The time spent in coasting varied greatly on the different lines and on the local and express tracks. Where the stations were close together, practically the whole time the train was in motion either the power was on or the brakes were on; while on express tracks and on the long falling gradients of the subaqueous tubes, a considerable portion of the run was made without power or without the application of brakes. The percentage of the run without power was given on p. 209 as 27·5 per cent. for the New York elevated lines, and as 30 to 50 per cent. for the Hudson and Manhattan Railroad; but, of course, this included the time the brakes were applied as well. Dr. Smith's suggestion of installing moving platforms at stations would probably be more expensive than lengthening the platforms, as owing to the practice of placing columns in the platforms near the tracks, extensive structural changes would be necessary.

The Author.

The Author. The lengths of the platforms on the New York subway had already been increased for the express tracks from eight to ten cars, and for the local tracks from five to six cars. It had been suggested that greater convenience and capacity would result if, instead of building a four-track line, moving platforms were installed in lieu of one pair of tracks, with express trains working on the other pair. In regard to the relative merits of overhead and third-rail contact there was some difference of opinion, although practically all elevated or underground lines using direct current at 500 to 600 volts used the third rail. The Brooklyn Rapid Transit Railroad, which operated over elevated structures in the city and which continued the same trains into the suburbs on surface lines on a private right of way, with numerous level road-crossings, used the third rail on the elevated lines and the overhead-contact wire on the surface lines. The New York Central Railroad, which used direct current, used the third rail, while the New York, New Haven and Hartford Railroad, worked by 11,000-volt alternating current, used the overhead contact, although the trains of both lines used the same terminus in new York. The New York, Westchester and Boston Railroad, a high-speed suburban passenger-line, also using 11,000-volt alternating current, used the overhead contact. As to the absence of provision of belt lines for circular traffic, there was not sufficient of this traffic to warrant the construction of underground or overhead lines, but reasonably good provision for it was made by the tramways. The guard-railings at Brooklyn Bridge (*Fig. 8a*), referred to by Sir Arthur Yorke, were used only at this terminal station. The trains were unloaded at another platform and arrived at this platform to be loaded for the return trip, so that no passengers left the train at this point. Before these railings were installed, indecent crowding and scrambling for seats occurred, and the object of the railings was to compel a double queue to form and enter the cars in order; the platform-guards preventing passengers from entering the trains direct. In regard to the relative capacity of three-track and four-track lines, the Author should have expressed himself more clearly. Of course, a three-track line could not have the same capacity as a four-track line, for the latter could be worked so as to transport the maximum number of passengers in both directions at the same time, which the former could not do. But, owing to the fact that at the time the traffic was heaviest in one direction it was lightest in the other, the ratio of up to the down traffic being often one to six, it was possible, by assigning two tracks to the heavy traffic, which was all that a four-track line could do, to carry on the remaining track all the traffic that was offered in the light direction, but

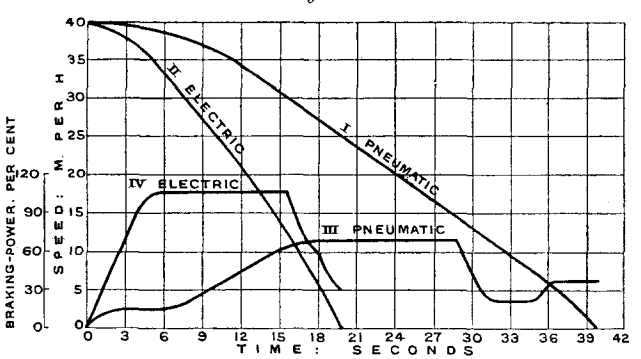
without the two speeds that were worked in the other direction. As to feeding two tracks with one, most of the lines worked in this way were elevated and did not have continuous automatic blocks, and the trains were run very slowly and very close together; The Author.

Fig. 16.



but even where they were signalled, more trains could be worked over the line in the light direction than in the heavy, owing to the shorter station-stop. With a line signalled for station-stops of 30 seconds, the actual station-stop in the direction

Fig. 17.



of light traffic was often 3 to 10 seconds, and with alternate trains running empty without stops, a considerably larger number of trains could be run over the line than the number for which it was signalled, while at the same time the station-stops in the direction

The Author. of heavy traffic were apt to be longer than normal, so that a few less trains were run than the usual number. These conditions, supplemented by ability to store a few extra trains at the end of the line, would enable the two tracks to be fed with trains during the 1½ to 2 hours of the heavy traffic. It was in the foregoing sense that the Author had stated that, under favourable conditions, the capacity of a three-track line would equal that of a four-track line. The electro-pneumatic brake had increased the safety of operation of trains of ten or more cars, and at the same time had enabled shorter headway to be maintained, by reducing the braking distance. This was indicated by some tests of an eight-car train with pneumatic control and a ten-car train with electro-pneumatic control, the results of which were illustrated in *Figs. 16* and *17*. It had other desirable features, in that, whenever the propulsive current was off the third rail, the brakes were applied automatically by the action of a triple valve and a pneumatic warning was sounded in the driver's cab. Also, the sudden release of brake-pressure at any point, either by operation of the track-trip or by a broken pipe, automatically applied the brakes instantaneously throughout the train. In response to Mr. Dawson's request, the following analysis of the cost of working the trains on the Interborough Rapid Transit Subway was given :—

	Cents per Car-Mile.
Maintenance of way and structures	1·32
,, ,, rolling stock and equipment	1·58
Power	2·26
Working of trains	3·41
Injuries and damages	0·29
General and miscellaneous	0·60
Total	9·46

The current-consumption per car-mile on several lines was :—

	Kilowatt-hours per Car-Mile.
Interborough Rapid Transit Company	3·0
Hudson and Manhattan Railroad Company	4·5
Brooklyn Rapid Transit Company	3·6

The Author had not accessible the cost of the electrical sub-stations on the Boston Elevated Railway. They cost, however, $30 to $40 per kilowatt. It would be noted that the cost of sub-stations and batteries was given in Table XXI at $1,753,458 for 185 miles of track, or about $9,500 per mile of track. In reply to Mr. Morgan, statistics as to the train-mileage were not available,

but the number of car-miles was published, so that the passengers per car-mile could be obtained, as well as the cost per passenger. These were given below for the Interborough Rapid Transit Subway:— The Author.

	Passengers per Car-Mile.	Cost per Passenger. Cents.
1905	3·84	2·55
1906	4·32	2·09
1907	4·47	2·34
1908	4·55	2·21
1909	5·16	1·91
1910	5·37	1·78
1911	4·83	2·14

With regard to the working of the Manhattan terminal of the Brooklyn Bridge (Fig. 8, Plate 5), the tracks on this bridge were originally worked by cable, and the passengers changed to elevated railway trains of various destinations at the Brooklyn end of the bridge, these latter trains being propelled by steam-locomotives. The overrun tracks at the left of the Figure were used to shunt the trains from the incoming tracks to a point on the outgoing track where the cable could be gripped, a steam-locomotive being used for this purpose. This method of working was continued for some time after the Brooklyn Elevated Railway lines were electrified, but finally the platforms were lengthened and the electric trains were run over the bridge; substantially, however, the same track layout was preserved, which provided two unloading tracks and four loading tracks. Incoming trains unloaded at the right-hand platform were then shunted to the left-hand platform, where they either loaded and ran past the right-hand platform, or, if they did not load, were shunted to the right-hand platform and then departed. It was only by alternating the loading at the two platforms that a uniform spacing of trains on the bridge could be obtained. The "Pay-as-you-enter" transfer-stations, mentioned on p. 185, referred to the fares of the tramway passengers, which were usually collected on the cars. The reference to "unremunerative fares" related to tramway lines in smaller cities, and did not refer to New York. The steel girders used in the permanent way in Philadelphia were intended to act as anchors and to prevent the wave-motion of rails and sleepers in advance of the wheels. The engineers were entirely satisfied with this form of construction, and they claimed that the cost of maintenance of the track was practically nothing, and the wear on the rail less than with sleepers and ballast, although this form of construction had not been used on other roads.