Discussion.

Mr. W. W. GRIERSON observed that the Paper was of particular Mr. Grierson. interest, because the alterations described were consequent on the introduction of electric power, a subject which was very much to the fore at the present time. The problem was to introduce electric trains in addition to steam trains at Charing Cross and Cannon Street stations, which were situated on narrow sites, approached over limited accesses, neither of which could be enlarged either by widening or lengthening. Without full information as to the train-service aimed at, and without an intimate knowledge of the railways in the district, it would not be possible to express an opinion whether the best possible scheme had been devised, but it was apparent that the local conditions had been carefully considered and considerable ingenuity exercised, with the result that the effective capacity of the two stations must have been greatly increased. Some comments might be made on the length of the platforms, and for many terminal stations 600 to 800 feet would be adequate, but they could not have been extended further without encroaching on the circulating-areas, and it had also to be remembered that the Southern Railway had several terminal stations in London, and consequently a wide choice in allocating traffic to the different districts to be served. The Author mentioned that, although the original Hungerford bridge had been designed for a stress of 1 ton per linear foot of uniformly-distributed load, the electric trains which entered Charing Cross station caused a stress less than three-fourths of that caused by the light steam locomotives previously used, and barely more than one-third of what the modern heavy engine would produce. That fact had been taken advantage of to obviate the necessity of rebuilding or strengthening the bridge, and also to remove the restrictions that previously had existed as to the number of trains that could simultaneously enter and leave Charing Cross station. The latter result in itself must improve greatly the capacity of the station. A very important factor in carrying out works of that kind was the programme and methods adopted. The possible alternatives which had presented themselves in the case of Cannon Street station were given in the Paper, and he would only say that he thought the only alternative other than the one adopted that called for serious consideration was the closing of half the station at a time. The Author pointed out, quite rightly,

Mr. Grierson. that the longer period of interference with the ordinary traffic entering that station—and also presumably with the excluded traffic that would have had to be diverted to other stations—would have caused great inconvenience to both the railway operating staff and the public. It would be interesting to know if any opinion had been formed as to whether the method adopted had not proved as economical as any of the other schemes considered. The electrification of the two stations had been carried out to admit electric trains from the suburban areas, and the question naturally arose whether in course of time other terminal stations were likely to be dealt with in the same way, and even wholly converted; but that implied the electrification of main lines for through distant traffic. It was well recognized that one of the assets of electric traction was the higher rate of acceleration that was possible, and in densely-populated districts with stations at short intervals that factor, combined with suitable signalling, enabled a very much larger number of trains to be run. Electric trains could be made to travel as fast as steam trains, and an electric engine would haul quite as heavy, and perhaps heavier, loads. He did not know what was recognized at the present time as the average cost of converting a mile of road for electric traction, but he had had experience before the war, when it was considerable, and it could not be less now. He had had the opportunity a few years ago of examining some of the Swiss Government railways which were then being converted; and his recollection was that the Swiss engineer who accompanied him stated that the cost of equipping the way and works of the St. Gothard railways, including the strengthening and rebuilding of a considerable number of bridges, consequent on the heavier weight of the electric locomotive, had been £15,000 per mile. But whatever the cost might be at the present time, it was clear that it would constitute a large addition to the capital of a railway-company, and such cost would have to be compensated for by one of two methods: by either a substantial saving in other directions or an increase in revenue. It seemed to him that a substantial saving, taken as a whole, was not very evident, and it was clear that the mere fact of converting a line would not in itself produce more traffic or more revenue. There were, of course, places outside suburban areas where possibly the adoption of electric traction would be an advantage, such as, for instance, the congested colliery-districts of South Wales, where the gradients were heavy, and the railways were generally in valleys and hemmed in by colliery-plant and sidings—conditions which rendered widening both difficult and expensive. It was conceivable that in a case of that kind

the improved acceleration of electric traction would enable trains to be moved from one refuge siding to another in advance in a time that would not be possible with steam locomotives, thereby increasing the effective capacity of the railway; and consequently widening might be avoided. Comparing the practice in this country with that in countries such as Switzerland or North Italy, it should not be overlooked that Switzerland had plenty of water-power, but that all coal had to be imported; it was possible also that military considerations might have had some influence, seeing that in the event of access to Switzerland being closed, the railways, if steam-worked, would in course of time cease to function. In England water-power was limited, but there was plenty of coal, and he did not think military considerations applied. The advantages of electric power were evident in densely-populated districts, and also under other circumstances in some districts; but he suggested that the adoption of electric power for long-distance through traffic was still remote.

Mr. A. W. SZLUMPER remarked that all concerned, especially the executive, deserved praise for the manner in which the work had been carried out. In the Report of the Inspector of the Ministry of Transport it was stated: "The works constitute a remarkable achievement, not only from the engineering, but from the organization point of view, reflecting great credit upon all concerned." The difficulties encountered had not been insignificant: the strike, for instance, had occurred in May, but fortunately it had not delayed the completion of the work. There was no doubt that the possession of the vacant site at New Cross had been an important factor in the completion of the work in the time. The question of closing Cannon Street station had been given serious thought. The General Manager had naturally been very averse to it—he thought the public would complain; but having in view the experience at Charing Cross, where the station had been kept open with considerable trouble and at heavy expenditure upon temporary arrangements, the Company came to the conclusion that, if they took the public into their confidence and explained their difficulties, the public would be reasonable: they always were when they were fully informed. Consequently, the station had been closed; many of the trains had been worked from London Bridge, and others from Charing Cross. No complaints had been made, but instead compliments had been received. The system of signalling described was the first installation of its kind in the world. The choice of a system had been considered very carefully, and the conclusion reached had been that the system adopted would be very suitable.

Mr. Szlumper. for the position. A few months' experience had shown that that conclusion was right, and the system was a success in every way. It was costly to install, but its maintenance-cost would compare favourably with that of mechanical signalling. It had enabled nine signal-boxes to be closed between Charing Cross, Cannon Street, Ludgate Hill, and Blackfriars, and the Company would probably save several thousand pounds annually on that account. Another advantage was the increase in the capacity of the line, which was about 50 per cent. The Company had not been sure how the signalling would work in foggy weather, but he was glad to say that in the fogs that had occurred recently the success had been far beyond their expectations. The drivers liked the system ; they were able to see the signal-lights at a distance far greater than that from which they could see the semaphores in a fog. In consequence fewer fog-signalling men were required.

Mr. Brown. Mr. CHARLES J. BROWN observed that it was rather difficult for one who had not studied the works thoroughly to criticize the Paper, and therefore his remarks were intended rather to elicit information than to raise criticism. At Charing Cross the " up " and " down " tracks for main-line trains were on one side of the station, and those for local trains on the other side, but at Cannon Street the main-line trains occupied the two central roads. For the method of working that had to be adopted where steam and electric trains were dealt with separately the first was the better system. He supposed that the method adopted at Cannon Street was enforced by the layout of the lines in approaching the station. One of the platforms at Cannon Street was not accessible from all the lines ; that was, of course, rather a drawback from the point of view of traffic, as it was important to be able to run trains into and out of every platform at a terminal station such as this. It might be that the introduction of a facing crossover between the " up local " and the " up through " roads in front of the main access would overcome the difficulty, but there might be special reasons why that was impracticable. The rails were of high-carbon steel. In stations such as those under discussion, with intense traffic, the wear must be very heavy, and his experience had shown that, where point and crossing work would not stand for more than 4 years, the use of steel of a higher quality, such as manganese steel, was economical. The portion of the Paper dealing with signalling was interesting and instructive to those who were studying the matter on other railways, and he thought all engineers agreed that for lines used for both steam and electrical traction, where the steam trains might have to run at high speeds, up to

60 miles an hour and over, and the electric trains at lower speeds, Mr. Brown. the four-aspect light signals provided the best means of getting both kinds of trains over one set of metals without delay.

Mr. W. CHALLIS remarked that the electric power for signalling Mr. Challis. was alternating current supplied at 220 volts, 75 frequency, from three independent sets of feeders at Cannon Street, at Metropolitan Junction, and at Charing Cross, respectively, in order to prevent, if possible, a complete breakdown of the supply. Most of the signalling work in connection with Cannon Street station had been done at New Cross Gate, but imitation track-circuits and point-detectors had been connected to the frame, and sufficient work had been done at Cannon Street to enable the interior of the signal-box to be finished and tested before the station was closed. A single multiple-core cable was led to each group of signals and route-indicators. For a single four-aspect signal a five-core cable was used, and where there were two or more signals on one bridge, the number of conductors was correspondingly increased. Cables were laid to points shown on the engineer's plan and labelled; and, when the permanent way had been laid, they were taken across underneath the track trunking on the river bridge and in conduits and connected to the points and signals. A wrong connection had never occurred—which said much for the men who had carried out the work. The power frame at Cannon Street had not been delivered by the manufacturers until the 26th April. There were 365 alternating-current relays in that signal-box, and all the mechanism had been wired and tested in a period of 2 months. During that time the Borough Market–Charing Cross light signalling was also being installed, and on the 28th June the whole of the work from Charing Cross to Borough Market Junction, including the 100-lever power frame at Charing Cross, a 60-lever mechanical frame at Metropolitan Junction with electric signals, and a 20-lever mechanical frame with electric signals at Borough Market Junction, had been brought into use in 5½ hours, the old mechanical work being put out of service. Co-operation between the engineers' department and the operating department had helped the signal department to accomplish that task: the operating department decided that they could do without the lines between Charing Cross and Borough Market Junction for 6 hours, which period proved to be more than sufficient for the renewal of the signalling apparatus.

Sir E. OWEN WILLIAMS asked whether the live load of 1 ton per foot of track for which the old Hungerford bridge had been designed included impact; and, if not, what impact allowance had been

Sir E. Owen Williams.

Sir E. Owen Williams. made in estimating the stresses imposed by electric trains—which were stated to be less than those for which the bridge had been designed—particularly in view of the length of the top members of the girders. He would also appreciate information as to the stresses due to the dead load of the bridge itself, and as to what percentage was due to dead load and what percentage was due to live load.

Mr. Thorrowgood. Mr. W. J. THORROWGOOD observed that the electro-pneumatic type of signalling-frame had been described in the Institution several times, but he thought that those described in the Paper were the first which were operated solely by alternating current. Further, the electro-magnets and electric locks were all controlled by the same current. The signalling system that had been in use when he first took charge of the signalling of the South Eastern Railway at London Bridge was known as “intensified working”: the trains worked close together, and there were numerous short sections. The sections of the new all-electric system, paradoxical as it might appear, had been lengthened, eight sections now taking the place of nine, and trains ran better now than they had done with the intensified working. That was owing to two facts: firstly, that the four-aspect system of signalling gave the driver two warnings instead of one, and told him that three sections, two, or one section were clear before him; secondly, the trains moved faster because they had a longer section in which to run, and consequently the driver could maintain a higher speed. It did not follow, because there were short sections and trains were close together, that it was possible to get the trains over the lines more quickly than with longer sections. Another advantage was that it was not necessary to provide “overlaps”; in effect, by having longer sections and two warnings, and by getting rid of the “overlaps,” it was possible to increase the efficiency of sections that were available. When he had first advocated the use of light signalling for surface railways, the greatest difficulty he had had was to convince engineers that they could see a light in the daylight; and he had got over that difficulty by producing a beam of light which was much brighter than sunlight at mid-day in mid-summer. The next difficult question was what the aspects should be, some wanting four, some three, and a number even asking for five. However, four had been considered to be sufficient, and he thought that four had proved successful. The next question was what colours the lights should have, and it had been seriously proposed that they should be red, yellow, yellow-green, and green; but he had pointed out that it was not possible to have two aspects green and yellow-green, because, if the yellow light went out it would create a very dangerous condition. He

was glad that it was now agreed that a red light should mean "danger" in every case, that a yellow light or a double yellow light should mean "caution," and that a green light should mean "clear." He thought that the system described was not only the first four-aspect coloured light system, but also the first system under which a driver should not pass a red light or an equivalent danger signal in any circumstances. The red light was a definite signal for the driver to stop and could not be confused in any way. Most definite rules had, however, to be broken at times, and the exception in this case was that a driver might pass a red light in a shunt signal. He thought that most railwaymen had previously agreed that a running train should take no notice of a shunt signal. The point of a driver passing a red light had been raised, however, and it had been arranged on the Southern Railway that, where there was a ground signal referring to the line on which a train was running, that signal should be altered from red to green, so that the driver did not pass a red light under any circumstances. Many devices had been tried in the past to avoid necessity for a driver to pass a red light on a shunt signal, such as ringing a bell, but they were all subterfuges which did not obviate the fact that the driver had to pass a danger signal at certain times; but under the system now in use on the Southern Railway he did not. The changing of the red signal to green in the shunt signal rather upset the sequence, because only red and green lights were used there. The consequence was that a driver might pass one yellow light and come across a green aspect in a shunt signal, and immediately ahead he might encounter a red aspect in the running signal; but it had been thought better to suffer that anomaly than to let a driver pass a red light. The system was quite a revolution. Hitherto it had been thought, especially by railwaymen, that signals were intended to stop trains, but that was a false idea; signals were intended to keep the trains running, which was their particular function if they were properly designed and spaced. If the four-aspect system of signalling were carried out, especially in areas of intense traffic, it would not only solve a number of difficulties in connection with mixed traffic of heavy vehicles and light ones, but it would help in many other directions to increase the capacity of the line, so that more trains could be run over the same length of line than with any other system.

The AUTHOR, in reply, observed that complete plans had been prepared for the partial closing of Cannon Street station before coming to the final decision to close it wholly, and those plans had been carefully considered by the traffic and commercial departments; but they would have involved such serious interference with the working of both goods and passenger traffic, especially the latter,

Mr. Thorrow-
good.

The Author.

The Author. that they had been discarded. On the question of the economy of closing the station, there could be no doubt that it had been the cheaper course. The erection of the work temporarily at New Cross Gate had been done by men working in their ordinary time and paid at their ordinary rate. Although it had involved double-handling of the permanent-way material, it had avoided the payment of double rates necessary for permanent-way work on Sundays, which ordinarily would have been the only time when it could be done, with possibly a certain amount of night work that was also much more expensive. He was sorry he was not in a position to say anything about the cost of electrifying the railway, as the accounts were not yet completed. With regard to the point raised by Mr. Brown as to why at Cannon Street there were two "up" roads side by side and two "down" roads side by side, whereas at Charing Cross the "up" and "down" roads alternated, the reason was that London Bridge station was quite close to Cannon Street, and London Bridge was laid out for the working as it existed to-day. Schemes had been considered to alternate the working through London Bridge station, but it would have greatly increased the cost and resulted in serious disturbance to traffic—a good deal more than could possibly be contemplated—and the resultant advantages would not have been commensurate with the outlay. He quite agreed that if it had been possible to get access to the last platform road at Cannon Street from the "up" local it would have been a great improvement, and every effort had been made to do so. It could have been done at the expense of sharpening the curves, but the wear and tear of electric stock round sharp curves was very heavy; and within the limits of space in which the work had to be done it was not possible to get that connection, much as he would have liked to do so. He was aware that very much better results could be obtained from manganese-steel rails where there was very heavy wear, and that there were one or two other types of steel with which better results could be obtained than with high-carbon steel; but with the new layout and the new working it was not possible to predict exactly where the heaviest wear would take place; and, in view of the very heavy increased cost of manganese steel as compared with ordinary steel, it had been considered unwise to experiment by inserting haphazard manganese-steel points and crossings in places where the heaviest wear might not take place. The railway-company had been obliged to look very closely into the question of heavy wear on rails, because of the very large amount of electric traffic, and they were now experimenting with three or four different kinds of steel. There was one pair of points in Cannon Street—possibly a pair where excessive wear might

not have been expected—that had to be renewed regularly every 5 weeks. Such conditions gave an excellent opportunity to test the different classes of steel that they had in mind, with the object of seeing which would be the most economical in the long run. A Committee of Divisional Engineers, with himself, was studying the question very closely, and they had had some very interesting results up to the present, and were hoping later to get still more valuable results. He could assure Mr. Brown that they had not forgotten manganese steel and other steels which might give a better wearing result than was obtained from the high-carbon steel. With regard to Sir Owen Williams's point as to the original weight for which Charing Cross bridge had been calculated, he had had a little difficulty in finding out what it was, but a Paper¹ by Mr. Harrison Hayter, Past-President, which was read at the Institution about 60 years ago, gave several figures purporting to show what the bridge was designed for, and in one place gave 1 ton per foot as the original live load. He was sure that impact as impact had not been considered at that time, although the instinct the early engineers had in getting at the right result without the exact knowledge that existed to-day was extraordinary. That was shown by the way the bridge had done its work. Charing Cross bridge had been tested for impact—probably it was the first bridge that had been tested with the Fereday-Palmer instrument, which he considered the best instrument for the purpose. The maximum recorded impact amounted to 18 per cent. in the main girder booms, which was not large. Of course, with electric stock there was not the hammer-blow that was found with the steam locomotive. Although only electric stock was run ordinarily on the eastern portion of the bridge, it was possible in emergency to run steam locomotives, and therefore in designing the layout it had had to be borne in mind that steam locomotives might be required to pass over it.

Correspondence.

Mr. G. W. M. Boycott asked whether the Author could state, with reference to his remarks on p. 169 dealing with stresses in the foundations of Charing Cross bridge, what was the maximum loading per square foot of foundation which this bridge had at any time to carry under actual working conditions. The loading in text-books was always given as 8 tons per square foot, less support due to skin-friction. It was, however, not quite clear to him whether that

¹ Minutes of Proceedings Inst. C.E., vol. xxii (1863), p. 512.