Discussion.

The Author showed a number of lantern-slides illustrating the works described in his Paper, and gave a sound-impression, by means of a gramophone-record, of the preparation for the first changeover.

Mr. Raymond Carpmael remarked that the Author, in indicating the necessity for the work described, said that only a bold scheme could solve the problems. There would be general agreement that a bold scheme had been evolved. Having indicated the problems, the Author proceeded to set out the obstacles, each of which presented many problems requiring the closest consideration. The principal concern of railway engineers when carrying out alterations to permanent way and stations was as a rule more or less confined to the maintenance of railway services, but the works described by the Author involved the maintenance of the continuity of the following services: the London Passenger Transport Board's own railway (with very brief occupations, generally of about 5 hours), the street-traffic overhead, including conduit-system trams, gas, water, drainage, electric power and light, and telegraphs and telephones, all in a very congested space. The work was also complicated, as had been stated, by the limitations imposed on interference with the business of traders. In fact, as the Author said, the methods of carrying out the work to overcome those difficulties really dominated the design; that had been brought out very clearly in the Paper.

Mr. Carpmael was very impressed by the models which had been made. They enabled the whole position to be visualized to an extent which could not have been possible by any other means. He could not improve on what the Author said about them in the section of the Paper headed "The Models" (p. 507). It would be of interest if the Author would say how many of the pipes had been located by the digging of exploratory trenches and how many had not been located at all until the work was actually in progress. It would appear that much information with regard to them was available, and in that respect the work differed from earlier works; the engineers responsible for the construction of the Central London Railway would envy the Author in that he could settle the progress-programmes for the works carried out with a certain degree of precision.

No details were given in the Paper of the plant employed in carrying out the excavations, which, in the circumstances described, was bound to have involved some difficulties. If any special types of plant peculiar to the job had been employed, details of them would be of interest.

The method adopted to avoid settlement-cracks of the main concrete walls was of interest, as being that adopted by the late Sir James Inglis,

Past-President Inst. C.E., in the construction of the parapet-wall of the breakwater of Fishguard harbour, although in that case the wall was built on a rubble base and the object was simply to allow the free settlement of each section independent of its neighbours. The same dimension, 25 feet, was selected, and the special V-jointed ends were thickly coated with putty mortar before adjoining lengths were cast.

The Author referred to the use of pre-cast concrete jack-arch centerings to avoid suspended timber centres. Mr. Carpmael had for some years used that type of jack arch, and had standardized it to suit various widths. In railway maintenance their use often simplified the work. It would be of interest to hear whether or not the Author had had any trouble with distortion or cracking of any of the girders due to the very unusual method of handling them.

Among the many difficult operations carried out, that of the lowering of some 1,400 feet of track was perhaps as difficult as any, in that it had to be carried out in a very short time. It was axiomatic in good railway engineering practice that the complete success of work of the character in question could be assured only by the efficiency of the preparatory arrangements, and the Author had emphasized that in presenting his Paper.

Mr. Arthur R. Cooper said that, having been Chief Engineer during about two-thirds of the work, there were a few matters which he would like to refer to.

In the initial stages, arrangements had been made for the engineers who were going to be actively engaged on the work on the site to take a part in the design, in the preparation of the drawings and specification, and in particular in getting out the various stages of the work. That gave them an intimate knowledge of what they had to construct and of the reasons why certain methods were being adopted. With an intricate work such as that in question, with unforeseen difficulties liable to arise at any time, great benefit had been found from adopting that policy and from bringing the men into the work at a very early stage.

The Author had referred to two contracts being let for the work. At the time when tenders were invited for the work it was very difficult to get steelwork promptly, and precedence was therefore given to finishing off the steelwork drawings at as early a date as possible. The contract for the steelwork was later made a sub-contract to the main contract. As would be seen from the Paper, the erection of that steelwork was a very complicated matter, and no little study was given to the method by which it should be carried out. Before that contract was let, all the firms who were going to be invited to tender for the main contract were seen and their general concurrence obtained with the methods of steel-erection proposed. He considered that that was a wise precaution, because it guaranteed that there would be no misunderstanding or difference of opinion between the main contractor and his steelwork sub-contractor.

Reference was also made in the Paper to various schemes having been

prepared. As early as 1913 powers had been obtained for the lengthening of the platforms at the old station. They were originally built for six-car trains only, and eight-car trains were running. The only precaution which it was possible to take at that time was to advise that only six cars could be used for passengers getting out or joining the train at that station, and horizontal ramps were put in in the tunnels at the end of the platforms, so that any one trying to get out would be protected. In 1920, other schemes were prepared on the basis of lengthening the platforms, but none of them embodied the bold policy of constructing a new station at a good traffic-centre and of doing away with two old stations which were not very well placed. The scheme which was eventually carried out also had the great advantage that it increased the factor of safety of traffic-working, as originally there were certain signal overlaps and arrangements which had not the factor of safety which was desired.

It was too early yet to give any particulars with regard to the effect on the traffic of doing away with the two old stations and building the new one. Naturally, during the construction-work the traffic fell at the two old stations, but he had been informed that during the last month the traffic at the new station had built up to the total of the two adjoining stations which had been closed down.

Reference had been made to the models. The making of models had always been a practice of the Underground railways. In the early days of the tube railways, Lord Ashfield had suggested that full-size models should be made of intricate passages and tube-work, and several such models were built and housed in a big hall which the railways owned at Earl's Court. That enabled the traffic officers to wander about the passages in those full-size models and to judge the actual requirements. That was of especial benefit so far as tube-work was concerned, because the difficulty and cost of making alterations in tube-construction after it had been completed would be appreciated.

The change-over had been rightly referred to by Mr. Carpmael as having been very carefully planned and very successfully carried out. It had been carried out under Mr. Cooper's successor, Mr. V. A. M. Robertson, M. Inst. C.E., who took a keen interest, with the Author, in working it out and making a great success of it. It might be mentioned that the whole of the intricate work which was done, and which covered a period of 2 years, was carried out without any mishap at all. That was a very great tribute to the engineers, the contractors, and all those associated with the work.

There was one incident which Mr. Cooper would recall. There were large gas-mains under the street which were being bagged off as a means of closing them, and unfortunately one of them caught alight. The fire brigade was called, but it was considered too risky to put the fire out; there were tunnels and cavities alongside where the gas might collect. It took 15 hours to bag off that supply, because four or five large mains had to be bagged off before the one concerned could be dealt with, and

during that time the fire-brigade continued to play water on the surrounding timber and excavation.

Mr. H. Alker Tripp observed that, as the Assistant Commissioner of Police, he was in charge of traffic-circulation in London. The Author had spoken lightly of street-occupation, but, in the case under discussion, traffic would have stopped unless drastic steps had been taken. Some of the traffic had to be accommodated elsewhere, and it might be of interest to refer to the arrangements made. During the time that the southern half of Whitechapel High street was occupied by hoardings and works, the traffic had been brought into a uni-directional flow by the Whitechapel High street westbound traffic being brought down Church lane (Fig. 2, Plate 1), turned right along Alie street, then right into Mansell street, and finally left into Aldgate High street. The eastbound traffic used the north side of Whitechapel High street. Pedestrians, being unsighted by the hoardings, were exposed to special dangers; barriers were therefore erected alongside the pavements and the tram-lines to prevent the promiscuous crossing of pedestrians, and gates in those barriers were provided at five points. At those points London Passenger Transport Board men were stationed in control of signal-lights, which they operated as the police stopped the traffic, thus enabling pedestrians to cross. Chains were drawn across to prevent pedestrians crossing when the lights were against them. That system came into operation when the hoardings were on the south side of Whitechapel High street; it was not in operation when the hoardings were on the north side. There was a 60-per-cent. reduction in pedestrian-casualties when those arrangements were in operation.

Mr. C. M. Norrie observed that when the works had been started, a very eminent engineer had said to him that works of that description should be carried out without interfering with the road surface at all. Mr. Norrie had been concerned with the work for 2 years, however, and his view was that if it had been possible to carry out such a work without disturbing the road surface, it would have been at enormous cost and would have involved a very great extension of the time taken for carrying it out. When his firm had tendered for the works, they had naturally found it very difficult to estimate the costs and to price their tender, and he would like to thank the railway company, and the railway engineers more especially, for allowing them to look at the wonderful models which were made before they tendered.

Another matter to which he would like to refer was the way in which the quantities were taken out. An engineer had generally to deal only with his own quantities, but contractors had to deal with the quantities of a variety of engineers, and that presented some difficulty at times. He would like to add—although that might not relate to the work described in the Paper—that there had been a growing tendency, no doubt on the part of employers, to insist on the quantities being got out by independent quantity surveyors, and that often gave the contractor a great deal of

additional work. The quantity surveyor was seldom able to visualize a heavy constructional work in the same way as an engineer, and the quantity surveyor's method of itemizing in too great or too little detail was often the cause of a great deal of extra work to contractors who were tendering; Mr. Norrie therefore considered that the engineer who had designed the works, and who knew how they were going to be carried out, should prepare the bill of quantities.

On behalf of his firm, he would like to mention and congratulate their agent, Mr. A. B. Gladwell, and his very able assistant, Mr. G. Ford, on their untiring efforts during the construction of the works, and to thank Mr. J. W. Carswell, the Resident Engineer, for his help.

Mr. T. H. Seaton had been concerned in the reconstruction under traffic of a number of stations, and agreed with Mr. Carpmael and the Author on the importance of making the most complete preliminary investigations, and also of preparing a complete programme in detail of works such as those described in the Paper. The models used were very instructive, as no drawings could show so clearly the works affected, and in particular public services such as sewers and water- and gas-mains and electric cables. In works of the character in question it could not be too strongly emphasized how important it was that the fullest information should be obtained of those public services before the works were actually designed, as otherwise it might be found necessary to redesign parts of them at a critical stage of their construction.

In carrying out railway works, the co-operation of the departments concerned was vital, and might be secured by frequent meetings of representatives at which the various stages of the work were discussed. From those meetings, a programme and stage plans could be prepared and circulated to all departments. That procedure had evidently been followed in the works described in the Paper, and had played no small part in ensuring the success which had been achieved.

A feature of note was the manner in which the sympathy of the public had been enlisted in connexion with any inconvenience to which they might be put. That had been achieved by pictorial posters describing the work which was being done by the engineers. Engineering works which affected the working of a railway were bound at times to cause delays, and the London & North Eastern Railway had found that, by taking the public into their confidence and explaining what was being done, complaints had been materially reduced.

A particularly valuable part of the Paper was the description and drawings of the temporary works, the character and extent of which were unique. Much consideration had evidently been given to their design, especially with regard to the rapidity of dismantling at the changeover periods, and the rehearsal carried out was an undoubted safeguard against any points in connexion with the work being overlooked. Apart from the description of the permanent works, the Paper was undoubtedly of par-

ticular value for the description of the changeover operations, and was to be recommended for careful perusal by railway engineers who might in the future have to carry out works of the character in question.

Mr. H. G. Follenfant remarked that it would be readily appreciated that from beginning to end a feature of the works was carefully planned organization. There were few operations which were unaffected by such considerations as the maintenance of road- and rail-traffic, pipes, mains, and sewers. Even such events as Christmas shopping and the illuminations at Southend had their effect upon the programme. The need for avoiding interference with local trade made some parts of the works very difficult. For example, special methods were necessary when shopkeepers had such keen business instinct that they sold meat during the night and such things as portmanteaux during the day in the same shop.

Those who had some share in the preparation of the contracts endeavoured to do all that was possible to present a picture of the works to the contractors, and to set out in narrative form a schedule of how it was visualized that the works would be carried out, although in some cases that had of necessity to be in outline. In the second contract, for instance, the condition and position of the foundations of some of the buildings were unknown until the ground was opened up, and the detailed design had to be done as the work progressed. A small drawing office was maintained in the Resident Engineer's office for that purpose.

It was, however, to the main contractors that the greatest credit was due for the way in which they organized in detail and carried through successfully the very complicated series of operations. The climax of their work was the big changeover from the old to the new station, and he would like to add a word or two to the description given in the Paper.

The broad outline of the scheme had been decided and set out in the specification. The date had to be fixed to suit the Traffic Department, not too near the summer holiday season and not too near Christmas. Progress was frequently reviewed in the earlier stages of the works, and the actual date had to be chosen in relation not only to the works at Aldgate but to changeovers on other lines where large gangs of the Board's staff were employed. It was difficult to decide the length of time to be allowed: as the time drew near, and especially after the rehearsal, everyone felt confident that from Saturday night to Monday morning was ample time, provided that there were no hitches, but that it would be unwise to make the widely advertised traffic-arrangements for a shorter occupation. The programme was accordingly drawn up on the basis of the maximum time that could be allowed for the demolition and removal of the trestles and the lowering of the tracks, allowing a minimum period of from midnight to 4.45 a.m. for completing the signalling and fettling of tracks.

After much consideration between the railway departments concerned and the contractors, a programme was agreed. Various methods of depicting the programme were considered, but the method found most

useful in the end was to set out on ordinary foolscap a series of typewritten statements covering every operation in chronological order. Opposite the statements in two columns were the limiting time to be allowed and the name of the assistant responsible for supervising the operation. All those in a supervisory capacity—foremen, inspectors, and charge-hands—had copies and were responsible for seeing that each individual man knew his job. The result was even better than had been hoped, and there was a noticeable atmosphere of enthusiasm, as if each man felt that upon him individually depended the success of the undertaking.

Mr. H. W. S. Husbands said that, as the Author had pointed out, none of the early schemes complied with all the requirements, and only a bold scheme sufficed to get rid of all the difficulties and to give the full advantage from the expense undertaken. The Board were also interested in traffic on the roads, and it seemed a pity that such a scheme could not have been combined with the provision of a fly-over junction for road traffic, which would have done away with congestion at that point. There was no doubt that traffic-congestion in London would never be eliminated unless fly-overs were provided at the main junctions. The roundabout would not solve the problem. At a level four-way road junction he estimated the lost capacity at three-quarters of the road capacity. There had been a proposal at Aldgate to construct a parallel road, but that would not get rid of the cross-traffic difficulty, and he did not think that much advantage would be obtained by diverting the traffic; in fact, it was impossible to divert traffic from central London. He hoped that when the Board were considering other schemes at important junctions they would at any rate see that when the designs were prepared the station was not sited in such a manner as to make it more difficult or more expensive to construct a fly-over junction at such a spot.

*** **Mr. R. H. Cunningham** observed that the gradient through the new station was not clear in Fig. 2, Plate 1; it was shown as level at the east end and 1 in 260 at the west. The new Metropolitan District Railway lines on the site of the old station were shown to be on gradients of 1 in 57·6 and 1 in 52, and probably an intermediate gradient-post had been omitted. With regard to the 1 in 40 gradient at the east end of the new station, the distance between the gradient-posts was 228 feet, giving a fall of 5·7 feet from the higher level to the station, as compared with the figure of 7 feet shown in Fig. 5, Plate 1.

He would like to obtain some information in regard to the vertical curves in the 1-in-40 gradient. In order to insert two equal vertical curves meeting at a point of reverse curvature half-way down the gradient, the radius of each curve would have to be about 9,000 feet, but probably in view of the proximity of the gradient to the platforms and the consequent

*** This and the succeeding contribution were submitted in writing.—SEC. INST. C.E.

low speeds the radius of each curve was considerably less. Was the gradient an arbitrary figure, or was it based on conditions of speed ?

Mr. H. G. Lloyd observed that in Figs. 7, Plate 1, was shown a height of some 16 feet of sandy ballast above invert-level, containing subsoil-water to a depth of about 7 feet. It would be of interest to know what proportion of the 500 gallons per hour pumped from the sump shown in Fig. 5, Plate 1, was subsoil water; experience had shown him that in general there was likely to be an increase of seepage, and some settlement, where the finest grains of sand were drawn away from the ballast by the flow of subsoil water.

The Author, in reply, observed that some 20 years before the work was commenced the London County Council had laid out very complicated tramway junctions at the intersection of Commercial street, Commercial road, and Whitechapel High street, and records were available of the positions of the shallow pipes, mains, etc., that were then uncovered. The depths of the larger and deeper mains and sewers were obtained from the service companies, or local authorities, to whom they belonged. Large sewers, say over 3 feet in diameter, were actually re-surveyed through the sewers from manhole to manhole. Where vital, the positions of mains were ascertained beforehand by trial-holes or headings. When the work was carried out some of the deeper mains were found some distance from the positions shown on the model and drawings. All the service undertakings and local authorities did their best to give accurate information, and on the whole the information was remarkably correct.

A large percentage of the excavating was carried out by the old method of hand-filling skips, which were then lifted by crane. Pneumatic spades were used to some extent in clay. A small short-jib mechanical excavator was used at the Minories junction, and afterwards for removing part of the dumpling in the new south curve. In the work under the shops in Aldgate and Whitchapel High streets a 2-foot gauge track was laid to hoisting bays.

Reference was made to possible distortion of the steelwork through the method of erection. No trouble, however, had been experienced from that cause, as the method of erection was known when each girder was designed, and the method of slinging and handling was carefully watched by the assistant responsible. A very close liaison existed between the steelwork sub-contractors and the Resident Engineer's staff, and all methods of erection and handling of steelwork were discussed and agreed beforehand.

Mr. Cooper referred to two contracts being let, and also to a steel contract. The Author would like to make it clear that there were two main contractors on the work and a steel contractor appointed by the Board, who afterwards acted as a sub-contractor to the two main contractors. The interrelation of the three contractors on the one job was carried through by the good will and enthusiasm of all concerned.

Mr. Tripp referred to the very useful experiment in pedestrian-control

that was carried out. The police authorities were very helpful and their diversion of the eastbound traffic made the works possible; the Board were glad to have been able to help them in return with their experiment. The experiment was being carried a step farther on the large works at present being undertaken at King's Cross, but members of the public had complained that the Board had interfered with the right of the public by the installation of some of the pedestrian-controls there. The Author was sure, however, that that pedestrian-control was far the best for all concerned.

In the Paper he had referred to the advantage of the Resident Engineer taking considerable responsibility in the office for the design before the contract was let, and he noted that Mr. Norrie strongly approved of the description of the works in the specification and the quantities being taken out in the same manner as the drawings were prepared by the engineers who would be responsible for the work. He agreed that the greatest possible technical information should be available for the contractors when works of the nature described were being tendered for. Mr. Norrie also referred to his agent and staff on the work, and the Author recognized the great help given by the agents and staff of the contractors and the initiative and ingenuity that they displayed in overcoming the many obstacles on a very restricted site for such large works.

Mr. Seaton referred to the close co-operation between the different departments of a railway company when traffic was interfered with. In that connexion meetings were held weekly (sometimes more often) throughout the duration of the works, when, if necessary, representatives of the departments concerned were invited to be present. The Traffic Department had a Liaison Assistant always in touch with the work. Mr. Follenfant gave further useful details of the organization in connexion with the final changeover, and rightly mentioned the enthusiasm of all concerned.

Mr. Husbands complained that the Board had not provided for fly-over junctions for road traffic, but he forgot that that was not the Board's function. He also suggested that all works carried out by the Board should be designed in a manner to facilitate future fly-under junctions; but the Author thought that he had overlooked the fact that at Aldgate East the Board had provided two fly-unders for pedestrian traffic crossing the congested Whitechapel High street, and by lowering their running tracks 7 feet it had made a valuable contribution to any scheme the Local Authorities might bring forward in the future for fly-overs for road traffic.

Mr. Cunningham asked for information about the track-gradients through the new station. Fig. 2, Plate 1, showing the general lay-out, was a reduction from the 20-feet-to-1-inch scale plan, and for clarity certain of the intermediate gradient-posts had been omitted. Those posts were: one immediately west of the east ticket-hall, showing a change from level to 1 in 260; the other was on the two tracks of the south curve between

the gradients of 1 in 52 and 1 in 57·6. With those additions the gradient-signs were complete. The Board's present practice, wherever possible, was to provide a vertical curve at changes of grade of a radius not less than 40 chains. That curvature had been adopted at Aldgate East.

In reply to Mr. Lloyd, the whole of the water pumped was subsoil water, but it was by no means wholly from within the area of the new works. The greater proportion was from the track-drains of the old tunnels, both east and west of the new works, which had been connected up to the new drains. The Author suggested that the amount from the new works would be something of the order of 100 gallons per hour. Although the volume mentioned might seem large, the wall- and invert-area was also large, and in no case was there more than a very slight trickle through any of the many joints in the concrete invert and lower parts of the walls, and there was nothing that should cause any apprehension regarding robbing the subsoil of its finer particles.

*** The Correspondence on the foregoing Paper will be published in the Institution Journal for October 1939.—SEC. INST. C.E.