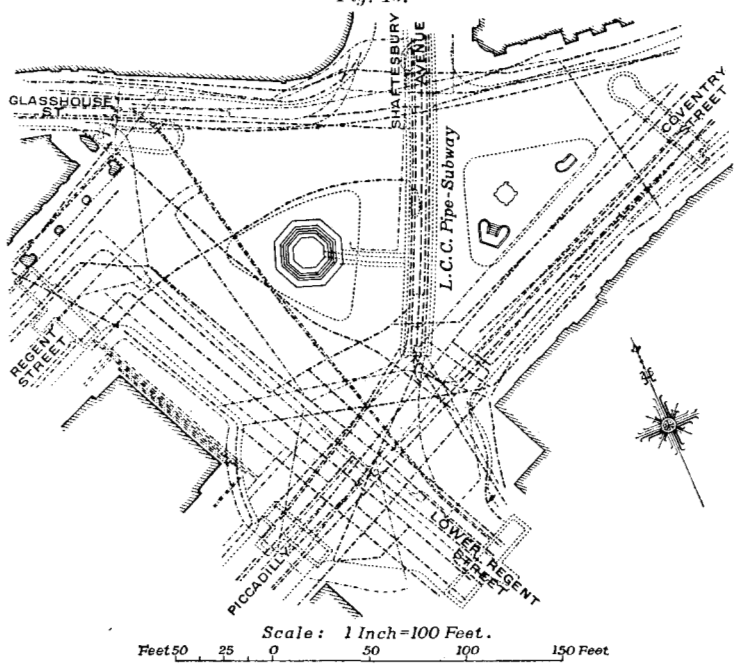
Discussion.

The PRESIDENT, in moving the vote of thanks, remarked that the members would all look with admiration on the work described—a work which had been carried out in what he thought one might call the centre of the Empire. It was a most complicated piece of work brought to a very successful issue. He much regretted the absence of Mr. Dalrymple-Hay, owing to illness. The President

Mr. J. S. WILSON exhibited, on behalf of Mr. Dalrymple-Hay, a plan (*Fig. 16*) which had been prepared to illustrate one of the Mr. Wilson.

Fig. 16.



CABLES, MAINS, SEWERS, ETC., DIVERTED BEFORE OR DURING THE CONSTRUCTION OF THE STATION.

early difficulties encountered in the work. It showed the network of buried cables and pipes which crossed the site of the station in every direction, and had to be diverted before the station excavations could be made. Those pipes and wires belonged to various bodies, and hardly anything had been known of their positions or

Mr. Wilson. depths, and, in order to discover everything that would have to be dug out or interfered with in the execution of the work, it was decided to make trenches across the ends of the roads opening on to the Circus and thus to intercept every pipe and wire it would be necessary to provide for. From the trenches the wires and water-pipes were led into the pipe-subway constructed round, and partly under, the booking-hall area. The pipes and cables belonged to a large number of authorities; there were telegraph- and telephone-wires and pneumatic tubes belonging to the Post Office; water-pipes belonging to the Metropolitan Water Board; and hydraulic pipes and electric cables belonging to three public-supply companies, in addition to surface-water drains. It was decided that a 12-foot diameter subway could accommodate all the cables and pipes, but in fixing this size it was not easy to estimate what might be the requirements of the various bodies. The gas-pipes were not put inside the subway. In addition to the parties, already referred to, owning the pipes and cables, several other bodies were interested in the Piccadilly works, for instance, the Crown, the Ministry of Transport, the London County Council, the Westminster City Council, and last, but not least, the London Electric Railway Company itself. Gratitude and congratulations were due to the railway-company for their vision and inspiration in providing such magnificent travelling facilities at that central spot, and also for having chosen such an able engineer as Mr. Dalrymple-Hay. As the President had said, the station occupied what might be called the centre of the Empire. Other places were known as "the hub of the universe," but Piccadilly Circus was nearer the heart of far more people than any other place; and to have had anything to do with the work at such a spot was something for those concerned to be proud of. The elliptical plan of the booking-hall was very pleasing and effective, and those who had been responsible for the plan and lay-out of the work were to be congratulated. The evolution and planning of such underground works in London were always very difficult, and Piccadilly station was no exception; for having to satisfy several parties and, at the same time, fit all in with the exigencies of the site necessitated the working-out of an unusually large number of preliminary and more or less completed plans. He regretted that the Author, when exhibiting his slides, had not described more fully how some of the girders over the booking-hall had been erected. The precautions which had had to be taken emphasized the difficulties of the work. Practically all the girder-work had been got into place by way of the shaft; the exception, however, was the key girder, G. 8, referred to on p. 174. That had

had to be put down through an opening in the road, where week-day traffic could not be interrupted. To avoid the possibility of holding up traffic as a result of difficulty with that heavy girder, which might have got jammed half-way out above the road, the operation was rehearsed with a wooden dummy girder. On the first Sunday trial that stuck, but on the second trial, a week later, after the hole had been enlarged, the rehearsal was successful, and the girder itself was got under ground on the third Sunday. Before reaching its final position, however, the girder had to be turned and moved about in a very restricted space. It had been instructive to estimate what that girder had cost to erect; the figure was very high, as would be expected. The difficult conditions under which the erection of the steelwork had to be carried out had rendered it essential that there should be no error in the dimensions or fitting together of the parts, and he had had charge of that part of the work for Mr. Dalrymple-Hay. For purposes of manufacture and erection, he had calculated the exact distances between intersection-points, in both a normal and a diagonal sense, for a great many pairs of points, distributed over the elliptical plan, and when the whole of the girder-work had been erected complete in the manufacturers' yard at Millwall, it had been checked to those dimensions and found to be very accurate. There had been no room to store anything at Piccadilly, and to be able to bring the steel quickly from Millwall had been of great advantage. The difficult operation of setting out column-positions and girder centre-lines, under cramped conditions in the headings underground, had been carried out by Messrs. F. Gregory and H. J. B. Harding, Assoc. M. Inst. C.E., acting for the engineer and the contractors respectively, and the accurate fitting together of all that work without interruption was highly to their credit. In Piccadilly station so much had been done with so little interference with traffic and surface conditions that he thought all would admire the forethought and skill of the consulting engineer responsible. To carry the work through and deal on the site with all the interests involved had required special temperamental qualifications, which the Author had, and he congratulated him on his success. Following Mr. Ogilvie, Mr. J. C. Martin had been resident engineer for an intervening period. In recording his admiration for the work of those engineers, he wished to include also that of the very able representatives of the contractors—Mr. I. J. Jones, M. Inst. C.E., and the late Mr. William Rowell.

Mr. Wilson.

Mr. ARTHUR R. COOPER remarked that it was particularly unfortunate that Mr. Dalrymple-Hay was prevented from being present; otherwise, he felt sure, Mr. Dalrymple-Hay would have been able

Mr. Cooper.

Mr. Cooper. to add many interesting details, which would have made the Paper more complete—particularly as a Paper for reference. The Author had referred to the reason for constructing a new station at Piccadilly, and had mentioned that the traffic had grown to an extent with which the old station had been quite incapable of dealing. The railway-company had had to consider to what extent development should be carried out, and, quite apart from the natural development of the railways, which could be estimated to some extent for the following few years, it had had to be borne in mind that extensions were under review for the various lines, which certainly made it necessary to look well ahead. Therefore it had been thought best to make the new station as large as was possible in that particular place. The Author mentioned that the floor-area of the booking-hall was 16,000 square feet. To start with it had been smaller; every opportunity during the progress of the work had been taken to extend the outer walls, as it was realized that to enlarge at some later date would be almost impossible. He desired especially to emphasize one matter which had already been referred to by Mr. Wilson, namely, the number of schemes that had been prepared. One feature of the work that was somewhat new was the use made of full-size models. An ordinary small model gave only a general impression of what was being considered; and even engineers found difficulty in reading drawings in such a way as to appreciate exactly how the work would look when it was completed. It was still more difficult for the railway operating staff to judge from a drawing whether a certain structure was going to give them what they wanted; and it had therefore been decided, in the case under discussion, to have full-size models of many features of the work. The Empress Hall at the old Earl's Court Exhibition had been available, and had been used for building full-size models of, for instance, such booking-hall and subway layouts as it was imagined at that time would best meet requirements. Those models had been constructed of wood framing and millboard, with adequate electric lighting inside. One particular model represented the top station with the five escalators leading down towards the half-way landing. One could walk along the length of the escalator, actually in a horizontal plane, and then enter the full-size model of the half-way landing chambers and passage-ways, including the tops of the escalators, at one end leading down to the Bakerloo Railway, and at the other end of these half-way chambers leading down to the Piccadilly Railway. Those models had been of very great value, and all those concerned with the proposals had made use of them. The Operating Manager and his staff had decided

whether sufficient room was provided or whether additional room was required; the engineers, who had also been present, had decided whether the additional facilities desired could be provided or not. By that means a scheme had been arrived at which as nearly as possible met the requirements; in fact it was due to the use of those full-size models that the station to-day existed in a form in which little or no improvement could be desired. A few figures with regard to the cost of the station might be of interest. It had been stated in the Press that the station had cost about £500,000, and, whilst the accounts with regard to the work were not yet complete, it was probable that the final cost would be about £550,000. The main engineering works, including the pipe-subway, represented 60 to 65 per cent. of the total cost—£340,000; the escalator equipment, which consisted of eleven machines, their installation, and the electrical connections and fitments, represented about 14 per cent. —£75,000. The architectural finish of the station (and in mentioning that he would like to record the railway-company's opinion that Mr. Holden, the consulting architect, had obtained a very satisfactory and artistic result) represented about 9 per cent.—£45,000; that figure covered the show-cases, the special column work, marble, bronze, and so on. Then there was the large item of expenditure incurred by outside bodies, such as the Metropolitan Water Board, the Post Office, the gas and electric companies, and other companies, who had carried out their own work; that had meant about 11 per cent., or £60,000. As indicating the amount of work to be carried out, he might mention that about 60,000 telephone-lines had had to be removed. It was usually difficult in a work of such a kind to say whether the expenditure had been justified—whether it had brought in a sufficient return, or whether it had not; but in the present case it was perhaps not quite so difficult. The railway-company had been surprised at the increase in the traffic since the opening of the new station; it was difficult to make a direct comparison, but so far as could be judged after 2 months of operation the traffic in the station had increased by 25 per cent., and there had been an increase of takings at the station of, say, £500 a week. One naturally asked what had brought about that result, because the train facilities had remained practically constant: the additional traffic had been induced, so far as could be judged, merely by the facilities afforded by the new station. It was thought in the first place that the five entrances had provided facilities to which the public responded. When it was considered that those new entrances were all round the Circus, as compared with the old station which used to be in one corner, there was some reason,

Mr. Cooper.

Mr. Cooper. particularly with regard to short-distance journeys, for saying that such an arrangement induced traffic; there had to be borne in mind the difficulty of crossing from one side to the other of a place like Piccadilly Circus. Again, the new station was certainly attractive; it had a cheerful and roomy aspect which undoubtedly attracted the public. There was also the feature that the new station had escalators as opposed to lifts. Mr. Dalrymple-Hay had been able, in re-arranging the lower passages, to do away with long passages that had existed at the old station, particularly on the Piccadilly line. All those features had undoubtedly conduced to the present very satisfactory result. In referring to escalators it was perhaps well to mention that in a station which had the depth of the Piccadilly station double-flight escalators were not as speedy as one would wish; they did not compare in vertical speed with lifts. The original escalators on the railways had run at 90 feet per minute; they had been speeded up now to 100 feet per minute, and those concerned were engaged in seeing whether some higher speed could be adopted—a speed which could only be judged by trying it with the public. If that higher speed could be brought about, still deeper stations could be satisfactorily worked with escalators. The ventilation of a tube line was very important, and at Piccadilly there were three separate fan-installations. A fan with a capacity of 45,000 cubic feet per minute drew air from the top of the old station and pumped it direct into the lower tunnels. A smaller plant of 15,000 cubic feet per minute drew air from the top of the old station also, and by means of ducts delivered it all round the booking-hall at about 2 feet above the level of the floor. There was a third ventilating-plant for drawing air out of the various machine-chambers both immediately below the booking-hall and in the mid-way level, so as to prevent any smell of oil or machinery in the station. He desired to draw attention to the spirit of co-operation with the railway-company that had existed amongst all the authorities concerned in the endeavour to make the station a success, to which Lord Ashfield had specially referred at the opening of the station. The goodwill and co-operation that had existed were among the reasons why the work had been brought to such a successful conclusion. The Author and Mr. Ogilvie had every reason to feel proud of the part they had played in carrying out the work, and they would always be able to look back with satisfaction to having been the resident engineers for this important work.

Mr. Segrave. Mr. J. H. SEGRAVE observed that the burdens and anxieties entailed in the carrying out of a work like that described in the Paper were by no means light. He could say that with conviction,

Mr. Segrave.

because he had spent more than 3 years on the work, as second in command on behalf of the contractors. The rail-grids gave a remarkable sense of security in the tunnels under the roadway. They were very easy to lay in narrow widths; and after 3 days a motor-'bus could run over them safely. The reinstatement of the roadway, however, was not quite so easy, and that had to be taken into consideration when rail-grids were laid. The large openings between the escalator-tunnels on the middle landing had entailed very heavy work. It would be seen from Figs. 6 and 8, Plate 3, that the junction-chamber No. 2 of the pipe-subway was only 3 feet above one of the very big double openings in the middle landing. It was natural to ask why the openings had not been made before the building of the junction-chamber, which was of concrete with a steel roof. The answer was that the pipe-subway had been urgently required so that the numerous undertakers could lay their water-pipes, cables, etc., to permit the construction of the booking-hall to be proceeded with. Therefore those concerned had been forced to build the junction-chamber first and to make a very big opening immediately underneath it. They had had to be very careful, and the care exercised had been repaid, because in the junction-chamber there was not even a hair crack. The method of executing those junction-chambers had been devised by Mr. Dalrymple-Hay. It would be noticed from Figs. 6 that there had been what was called a floating beam from which the roof-beams were propped. That expedient had been adopted because it was necessary to excavate actually behind the props, which were 1 foot 6 inches apart from centre to centre, and room had to be made behind so as to get the men in and the excavated material out. The floating beam could be propped wherever it was convenient, and plenty of room was left for the work behind. Such a work could not be carried out without the hearty support of the workmen. He thought there had been a remarkable advance in the character of the workman in the last 25 years. He was cleaner and more careful, and his work was better. Those characteristics had been shown in the work under discussion by the comparative immunity from accidents that there had been. Although it had been a rule that every accident, from a cut finger upwards, should be reported, there had been only fifty-five cases of accident in more than 3 years, the most serious of which had been the fracture of a small ankle-bone. Even when there had been a minor mishap with a gas-main, which was thought to be dead, but which was charged, and nine men were slightly burned, none of them lost more than one shift. He would like to say a word in praise of the specification and bills of quantities. Mr. Dalrymple-Hay told a

Mr. Segrave. contractor exactly what he wanted done: he specified everything and took out his quantities very carefully. Mr. Cooper had mentioned that the cost of the engineering work was well over £250,000. So carefully had Mr. Dalrymple-Hay's quantities been got out that the difference between the estimate and the amount of money certified by measurement was less than 0·2 per cent. He wondered why engineers still adhered to three columns when they made out a bill of quantities—one column headed "yards," another "feet," and the third, not headed, in which was written "super" or "cube" or "linear," as the case might be. There was no place for tons, or hundredweight, or gallons, etc. He had worked with the Author very intimately ever since he had been appointed to succeed Mr. Ogilvie, and he was glad to record his admiration of the manner in which the Author had surmounted the many difficulties presented.

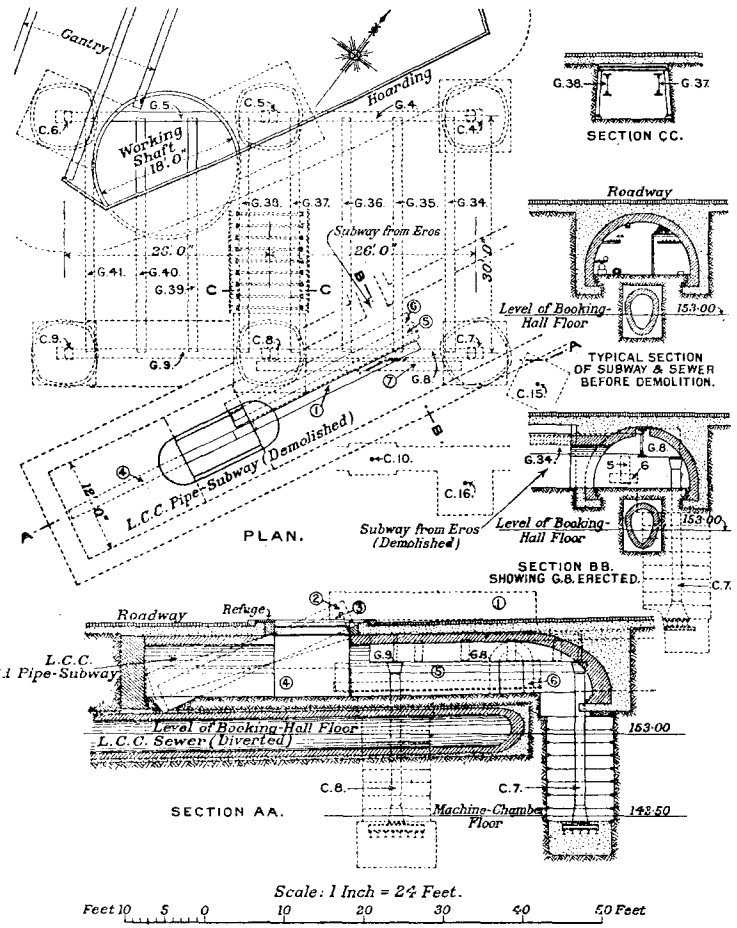
Dr. Lowe-Brown. Dr. W. L. LOWE-BROWN remarked that he desired to consider Piccadilly Circus station from a rather different point of view from that of the previous speakers. For anybody who had had to deal with the commercial side of underground railways, this station must have a very special interest. When the most important station of an urban railway was situated in the middle of its length, that railway was very much cheaper to operate than one in which the bulk of the traffic was concentrated at a terminal station. Piccadilly Circus station was equivalent to four terminal stations concentrated at one point where no shunting-operations of any kind were necessary. At such a point it was of the utmost importance to provide every facility for the rapid removal of passengers from the platforms and approaches, because each incoming train from all four directions would usually not only set down but also take up passengers, and it was only by avoiding congestion that the prompt dispatch of trains could be secured. Large expenditure in providing adequate facilities was therefore justified. He supposed that every engineer who had to do with underground railways had for many years longed to reconstruct Piccadilly Circus station, and he thought that those who had had that opportunity were to be congratulated on the way in which they had done the work. They had followed conventional lines. There was nothing new; but looked at from a broad point of view it was an excellent job and one of which everybody concerned should be justly proud. It was a pity that the Author had not given some of the reasons why this particular arrangement, of the several that were possible, had been adopted. A large underground booking-hall, similar to that at the Bank station, was inevitable, so were pipe-subways and escalators. But the Author did not say why that particular arrangement had been

given preference over some of the other solutions which would readily occur to anybody who thought out the problem. He thought it was a pity that the expression " novelty heading " had been used in the Paper, because a very similar form of cross section had been used 50 years ago in a tunnel of great historical importance. The first tunnel in which compressed air was used was driven in Antwerp in 1879, and there the form of cross section was almost exactly the same as that used in the " novelty heading " except that the plates had been specially designed for the purpose. The outstanding feature of the work described in the Paper, and one which deserved the greatest praise, was the careful way in which the construction had been carried out and the scrupulous care taken to avoid subsidence. As anyone who had had charge of that class of work must know, both the resident engineer and the contractor must have spent many anxious days and nights, and they were to be heartily congratulated on the result. Dr. Lowe-Brown.

The AUTHOR, in reply, thanked the members for the way in which they had received the Paper. With regard to the question how the oval form of booking-hall had been arrived at, he was sorry he was unable to give any information. Mr. Dalrymple-Hay had worked out numerous schemes, and had apparently concluded that the one eventually adopted appeared to be the most convenient. He desired to commend the contractors' representatives who had had charge of the work, and to thank Mr. Segrave for his kind remarks. He desired, too, to endorse Mr. Wilson's commendation of the work of Mr. Harding and Mr. Gregory. *Figs. 17* had been prepared to make clearer the difficulties encountered in getting girders G 8 and G 9 down from the road-surface, where they had been delivered, into position on top of the caps of stanchions C 7, C 8, and C 9, referred to on p. 174. The working-shaft indicated in *Figs. 17* had been sunk, as already stated, for getting away excavated material from the various underground works, and for lowering and distributing materials to be used in their construction, including the steelwork for supporting the booking-hall roof. When, however, it was time to excavate over the booking-hall area for the purpose of erecting the steelwork supporting the booking-hall roof, it was considered desirable to erect a line of primary main girders to form a base from which the remainder of the steelwork could be set out. Girders G 8 and G 9 formed a convenient line for setting out from when erected, as the site of their erection was readily accessible from the London County Council pipe-subway. Further, there was an aperture in a refuge on the road-surface near the western end of the subway which had been covered with a large The Author.

The Author. iron-bar grating, forming one of the subway ventilators, and through which the two girders could be lowered. As this refuge

Figs. 17.



ERECTION OF MAIN GIRDERS G8 AND G9. (TIMBERING NOT SHOWN.)

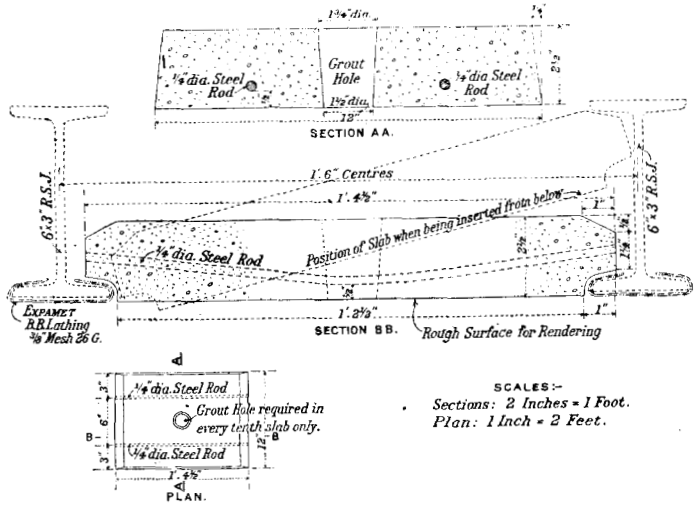
Order in which Stanchions were Erected.			Order in which Girders were Erected.					
1.	Stanchion	C9	1.	Girder	G9	7.	Girder	G5
2.	,,	C8	2.	,,	G39	8.	,,	G37
3.	,,	C4	3.	,,	G40	9.	,,	G36
4.	,,	C5	4.	,,	G41	10.	,,	G35
5.	,,	C6	5.	,,	G38	11.	,,	G34
6.	,,	C7	6.	,,	G4	12.	,,	G8

The Author

was situated in a busy thoroughfare, where week-day traffic must not be interrupted, the necessary preparations for lowering had to be carried on at nights and on Sunday. A longitudinal section AA of the subway was first plotted, as shown in *Figs. 17*, and a piece of cardboard representing one of the two girders (each having the same dimensions, namely 26 feet long, 3 feet 9 inches deep over rivet-heads, and 1 foot 2 inches wide, and weighing $4\frac{1}{4}$ tons) was manœuvred to see how it could be got through the aperture into the subway with as little alteration to the subway structure as possible. The extent of the cutting away of the stone curb and brick arch of the subway as at first considered necessary was indicated on section AA. A full-sized model of a girder was then constructed of light timber framework, weighing about 2 cwt., and attempts were made to lower it into the subway through the enlarged aperture in the refuge. After further cutting away of the subway curb and arch and excavating a portion of the floor of the subway, as shown on section AA, the model was successfully lowered on to the subway-floor. The foundation of stanchion C 8 was situated partly in the heading extending from stanchion C 8 to C 9 and partly in an opening made in the western side wall of the old subway, the head of the opening being supported by heavy steel joists as needles. Stanchion C 8 actually stood in the opening in the subway-wall, as shown on the plan in *Figs. 17*. The foundation of stanchion C 7 was situated just inside the subway, near the eastern side of it, as shown on the plan and section BB, *Figs. 17*. The foundations of stanchions C 7, C 8, and C 9 having been completed, girder G 9 was lowered through the aperture in the refuge in the manner indicated on section AA. The girder was halted at various stages, some of the positions being shown and numbered 1 to 5 and 7. The girder was taken through the opening in the western side wall of the subway which had, as already remarked, been made for sinking the foundation of stanchion C 8, and it was then laid along one side of the heading connecting the foundations of stanchions C 8 and C 9. Stanchions C 8 and C 9 were then erected, and girder G 9 was hoisted on top of them and secured. The secondary main girders G 39, G 40, G 41, and G 38 were then erected in the order mentioned in headings driven parallel to and of similar construction to the main heading from C 2 to C 8, of which a section was shown in *Figs. 10* (p. 169). Stanchion C 7 was then erected. Girder G 8, which had in the meantime been lowered into the subway and had occupied various positions, of which those numbered 1 to 6 in *Figs. 17* were examples, was left in position 6, that was, lying on its side, for some considerable time while excavated material from the foundations of

The Author. columns C 10, C 16, etc., was brought out through headings broken into the eastern side wall of the subway and carried away over the girder and through headings to the working-shaft. In the reverse direction and from the working-shaft materials such as concrete, steel grillages, etc., were brought along and carried over the girder to the sites of columns C 10, C 16, etc., for constructing their foundations. Finally, after girder G 8 had been shifted into the upright position 7 alongside stanchions C 7 and C 8, the roof of the old subway was horseheaded, wedged, and cut away in a skew direction across

Figs. 18.



REINFORCED CONCRETE SLABS BETWEEN 6-INCH BY 3-INCH ROOF-BEAMS.

the semi-circular arch and backing, as shown on section BB and the plan, *Figs. 17*. Girder G 8 was then hoisted into position, fixed on the tops of stanchions C 7 and C 8, and attached to the secondary main girders G 37, G 36, G 35, and G 34 already fixed to the primary main girder G 4 (between stanchions C 4 and C 5) and protruding through holes in the subway arch ready to receive it. The order in which the stanchions and girders were erected was tabulated in *Figs. 17*. *Figs. 18* showed details of one of the precast-concrete slabs mentioned on p. 176.