

Discussion.

The President. THE PRESIDENT said that the members owed a cordial vote of thanks to the Authors for their interesting Paper. The details of construction of the great goods warehouse and passenger station were highly interesting, and were well illustrated by the diagrams on the wall. Having seen the warehouse in course of construction and also in its completed state, he could hardly consider it a thing of beauty, but no doubt it was well adapted to the purpose for which it had been built. The Paper afforded ample material for discussion by the many representative railway engineers present.

Mr. Hobson. Mr. G. A. HOBSON, having shown a number of lantern-slides, illustrating various features of the work, said he wished to express his colleague's satisfaction and his own with the Council's decision that the Paper should be discussed. At the present time several important stations were about to be built or reconstructed, and probably a discussion upon Marylebone would be of some use and interest to those engaged in designing similar works. Of course when such extensive works as those described were completed, it could be seen that many things might have been done differently. Those who came after, however, would have the advantage of their predecessors' experience, and would probably benefit by avoiding some of their mistakes. It would be very useful to obtain the opinions of experts upon some simple questions. For instance, it was mentioned in the Paper that the question of the load which London clay would bear was a matter upon which opinions differed widely, and if a definite statement on that subject could be obtained, it would no doubt tend to the saving of a considerable amount of money in extensive operations. There were many other points upon which reliable data were much wanted, such as the weight which brickwork and concrete would carry, and the strength and form of ferro-concrete.

Mr. Fox. Mr. FRANCIS FOX desired to bear testimony to the able manner in which the Authors of the Paper had carried out their work. With regard to the station, the first thing noticeable on entering it was the fact that the rails were at the level of the street. That was entirely due to the grasp of the situation taken by Mr. (now Sir William) Pollitt. He believed there was no other place in

London where at the present day a large terminal station could ^{Mr. Fox.} have been brought through the heart of the great metropolis actually to the level of the roadway. With regard to the span of the roof, his family had been associated with the design and construction of many roofs of long span. His father, being at the time on the staff of the late Mr. Robert Stephenson, had assisted in the design of the roof of Euston Station, and had erected that of New Street Station, Birmingham, which had a span of 212 feet, and also that of Paddington Station. Another member of the family had erected, under Mr. Barlow, the roof of St. Pancras Station, with a span of 240 feet. But, after consideration of all those instances, he had come to the conclusion that very large spans were undesirable, and that smaller spans were quite as efficient and less costly. Large spans were difficult to clean and repair, and costly to erect in the first instance, whereas small roofs involved none of those disadvantages. He had recently seen a large station which had just been constructed in Boston, U.S.A. There the engineers had gone in for large spans—680 feet of arched roof, divided into three sections; but he thought those who were designing a new station should bear in mind that a column caused no greater obstruction on a platform, than did a passenger's hand-bag or a seat, and that the conveniences in other ways of reducing the span to moderate dimensions were far greater than the drawbacks. In demolishing a large number of houses for the purposes of the railway, 5,000 chimneys had been removed, and to that extent, he claimed, they had added to the lungs of London. Thirty years had elapsed since the last addition of a terminus (St. Pancras) to London had taken place, and, during that time, two million people had been added to the metropolis. Therefore, it seemed necessary that a fresh station should be provided. Although the traffic up to the present time was not as good as could be wished, that was due in a great measure to the restrictions which had been placed upon the Company by Parliament and by other companies. No doubt time would mend that. He would mention a curious coincidence which he thought would be interesting to the members. In the year 1835 Mr. Robert Stephenson had written to his father, the late Sir Charles Fox, stating that he had received instructions to proceed with the plans of the extension of the station at Euston Grove, now Euston Station, and continuing in the following terms: "Having now received instructions to proceed with this work, I shall be glad if you will come in about a fortnight's time and bring with you

Mr. Fox. comparative estimates for a double and quadruple line of railway from Camden Town to Euston Grove, including a bridge over the Canal" (the Regent's Canal). Exactly 60 years later, in 1895, Sir William Pollitt had written a letter to him in almost identical terms in regard to the plans for the line from Finchley Road to Marylebone, including a bridge over the Regent's Canal; and thus history repeated itself. He had looked through the original contract for the London and Birmingham Railway in order to see the prices of work and material then (1835) as compared with the present time. The amounts per cubic yard were as follows: Excavation for the whole length of the line, 1s. 3d.; ashlar, 3s. 6d.; timber, 4s.; brickwork in lime, £1; brickwork in Roman cement, £1 7s.; concrete in lime, 7s. Then came an item at which an engineer at the present day stood aghast, "ironwork in girders, £36 per ton." With regard to future stations, it was difficult to say how the traffic of this great metropolis was going to be dealt with. At Boston a new idea had been tried. The main lines, which were parallel, had been brought up to a promenade, and the suburban lines had been taken round a semi-circle on a lower platform, so as to make the station practically a way-side station; the result being that the engine was always at the right end of the train, which came in and went round and out again, without any delay in shunting. If that could be done at Waterloo and elsewhere, the trouble to the staff and delay on the part of travellers would be largely reduced.

Mr. Johnson. Mr. RICHARD JOHNSON understood from the Authors' statements that there was something new in a station being at the street-level, as in the Great Central Station at Marylebone. If he remembered rightly both King's Cross and Euston were on a level with the street, so that there was nothing new in that feature of the work. At King's Cross he had had to do with a goods warehouse very like the old-fashioned one described in the Paper; and he was very sorry to see that a warehouse had been constructed on that plan in the year 1900. With a fan-shaped piece of land he would have expected the engineers to build a modern shed. Trouble had arisen at King's Cross for at least 30 years past with the old-fashioned shed there, and the engineers had been at their wits' ends from time to time to know what to do to make it more workable. The end of the shed had been cut off, a cart-road had been made across, and additional platforms had been formed, so that trucks could be put into position and not be moved until the trucks were loaded. Mr. J. A. McDonald had built, a few years ago, a fine shed at the Somers Town Station of the Midland Railway.

Mr. Johnson.

He had placed on the wall a plan (Fig. 26) of the warehouse in question, which gave standing room for about 180 wagons, and it appeared to him the principle was that those wagons, being put into position, could be loaded from the main platform without any one of them being removed until they were all loaded. That was a very important element in the working of a goods warehouse. Mr. Alexander Ross had built recently, at the King's Cross Station of the Great Northern Railway, a modern shed, although a comparatively small one. Mr. Ross had kindly allowed him to make an enlarged drawing (Figs. 27) of that shed, which he had placed upon the wall. It would be noticed that there was a roadway round the end of the shed, and a road alongside. Trucks could be placed in the six roads, worked out by engines and made up into trains. Each of the lines would hold, on the average, about fifteen trucks. In the Midland shed there was an average of about eight. He thought that since Mr. Ross had designed the Marylebone shed he had benefited by experience of London traffic, and, therefore, in designing the Great Northern shed he had adopted what might be called an "end-on" arrangement, which he thought was very good. The London and North Western Railway Company had had to alter their shed at Camden Town many years ago, and

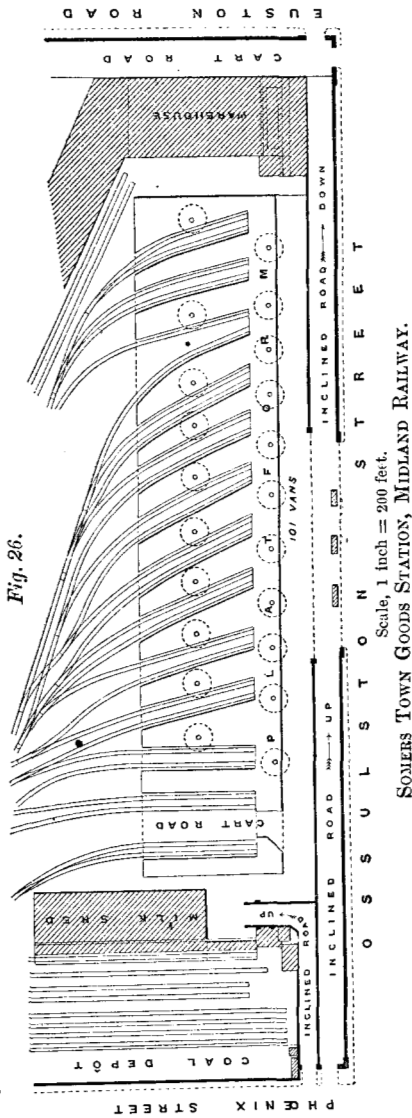


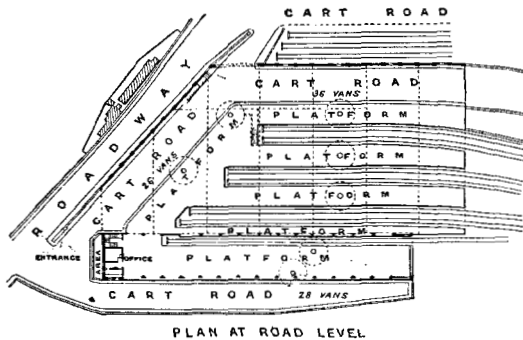
Fig. 26.

Scale, 1 inch = 200 feet.

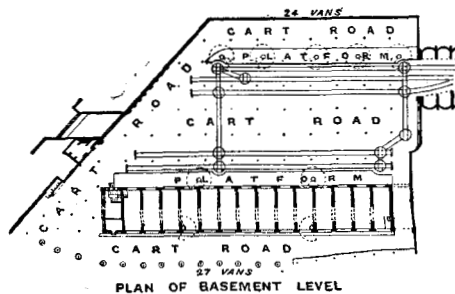
SOMERS TOWN GOODS STATION, MIDLAND RAILWAY.

Mr. Johnson, to make the cart-road across the end of the shed, with many platforms, so that trains could be formed almost ready for starting. The Authors had built a fine shed, but he ventured to say that it was wrong in plan and that the ground-floor was not properly laid out. With such a broad piece of land a shed could have been built which, in his opinion, would have been much more workable than the one so well described in the Paper.

Figs. 27.



PLAN AT ROAD LEVEL



PLAN OF BASEMENT LEVEL

Scale, 1 inch = 200 feet.

KING'S CROSS NEW GOODS STATION, GREAT NORTHERN RAILWAY.

Sir John Wolfe Barry.

Sir JOHN WOLFE BARRY, K.C.B., Past-President, remarked that the Paper was more descriptive than argumentative, but there were one or two things to which he might allude. With regard to the columns, he did not quite understand why the great spread of the base should be given in one direction and not in the other. That the base should be spread was undoubtedly necessary, but he thought that if it was desirable to spread the base in the longitudinal direction it was equally desirable to spread it in the

transverse direction. The supporting power of London clay was a matter of which he had had some little experience. In speaking of the supporting power it was necessary to define clearly what was meant. The ultimate power of support of London clay was no doubt high, but it was also true that London clay would show signs of subsidence under moderate loads. He had had some careful experiments made on the subject, in the building of the Tower Bridge, and he had found that from about 1 ton per square foot every increment of load produced a more or less observable subsidence. It was perfectly regular and not at all alarming, but still the fact remained that as the load on a plastic material was increased from a comparatively small amount there was a certain increment of subsidence as weights were added. The load on the Tower Bridge foundations was nearly 4 tons per square foot, and with that load the subsidence had gradually increased up to $3\frac{3}{4}$ inches as weight had been added in building the structure. The Charing Cross Bridge, with which he had had something to do in his early days under his master, Sir John Hawkshaw, carried a heavier load. He thought he was right in saying it was about 8 tons per square foot, neglecting the large relief due to skin friction of the gravel and earth surrounding the cylinders for a depth of about 35 feet. But he did not think the total subsidence had been carefully observed, except in the case of two cylinders where, under the full load, it had been noted as about 4 inches. The additional subsidence due to putting the loaded trains on the bridge had been carefully noted by himself and had amounted to something like 2 inches, and this had been due to an additional load of about $2\frac{1}{2}$ tons per square foot. He had little doubt that during the whole course of the construction of the bridge a general and gradual subsidence had taken place as the load on the London clay had increased. He thought very little attention was generally given to observation of subsidence until the ultimate load had to be placed on the structure, and that the effect of the weight of the structure itself was frequently not observed at all. In his experience in the building of viaducts, he had noticed that very little care was taken in the early stages of the loading of the foundations, and it was not until a pier attained a considerable height that engineers began to observe the effects of additional permanent and moving loads. His own impression was that nearly every foundation subsided to some extent. Probably the subsidence of rock could not be observed, but still it was reasonable to suppose that if the load on a foundation, particularly a plastic foundation, was increased, every increment

Sir John
Wolfe Barry.

Sir John Wolfe Barry. of load would produce some result in the way of subsidence. He did not think such subsidence as he had mentioned need have the least influence on the safety of the structure under consideration. He would imagine, from observation of the traffic on the railway, that hitherto the large warehouse had never received anything like its full load; and it would be interesting to know whether any and, if so, what, subsidence had been observed when any of the columns had been fully loaded. The question of the span of station-roofs was one on which wide differences of opinion existed, and he thought that the circumstances of each case ought to be taken into account. It was impossible to generalize on a matter of that kind, because the conditions of individual cases, such as width of site, cost of land, etc., were entirely different. He could not conceive that it would be prudent to put columns in Charing Cross Station, as the platforms were quite narrow enough already. Every possible consideration had been given to the question of gaining there the maximum number of platforms by reducing their width to the narrowest dimensions admissible, and some of the platforms were not more than about 10 feet wide. In Cannon Street Station some of the principal platforms were only 12 feet 6 inches wide, with trains on both sides, and to put a row of columns down the middle of those platforms was a very different thing indeed from putting columns down the middle of a 25-foot or 30-foot platform.

Mr. Blyth. Mr. B. H. BLYTH wished to endorse what Sir John Wolfe Barry had said as to the impossibility of generalizing on the question of having roof-columns in stations. To the reasons which had been advanced for preferring low roofs, he thought another might be added, namely, that sometimes Parliament did not allow high roofs to be constructed. He had just finished building the Waverley Station roof at Edinburgh, where Parliament had insisted on the roof being kept down to a height of 42 feet above the rail-level. With such a height as that it was of course quite impossible to adopt large spans. He had also built the Glasgow Central Station, where the span of the roof was 211 feet 6 inches. Comparing one with the other, and other things being equal, he would certainly adopt the wide span where possible. Low roofs and columns were adopted because it was not possible to do otherwise, but he thought every engineer who had the desire to accommodate the traffic to the best of his ability, would adopt, if he had the choice, a wide span with as low a roof as possible. Probably such high roofs as those of Charing Cross and Cannon Street stations would never be repeated, but something inter-

mediate between roofs of that sort and the low roof which had Mr. Blyth. been adopted at Marylebone would be built, and the compromise would be of general advantage.

Mr. J. A. McDONALD remarked that when he had read the Paper Mr. McDonald. his feeling had been one of envy, for the engineers of the station had had an opportunity of designing a goods shed in London, beginning with a clean sheet of paper. That was an experience he had never had. He had built three or four depôts in London, but had always been hampered by having to suit the shape and design of the building to the available area of land, as had been the case with the shed at Somers Town to which Mr. Johnson had alluded (*Fig. 26*). He had had there a piece of land in the shape of an isosceles triangle, with the angle between the equal sides cut off. The natural railway access to this land had been from one corner at the base. The only way of building a shed on this site large enough for the purposes of the railway had been to put it on the long side of the triangle, but it had been impossible to enter it so as to bring the roads square with the building. He had adopted a plan, which he did not think had been used before, of bringing the roads into the warehouse diagonally, at an angle of about 60° with the outside wall of the shed. At first it had been thought that this might cause difficulty in working, but since the shed had been finished it had been worked most satisfactorily, in fact he thought the men who had to deal with the goods traffic almost preferred the roads lying in that way to having them come in square. He had been rather surprised to see that turn-tables were still used in the Marylebone shed. He had spent a great deal of money for the Midland Railway Company in order to avoid the use of turn-tables. The shed of which he had been speaking had no turn-tables whatever; it was about 770 feet long, and 180 feet wide, with twenty-six roads running into it, each road holding about seven wagons. Consequently, when once the trucks were in position they never had to be moved until they were filled and ready to go away. Adjacent lines were kept for traffic to a particular point, and the seven trucks were drawn out and backed on to others until the complement of twenty-five wagons was obtained, when the train was ready to start. He thought there was very little question that nowadays turn-tables were a mistake in working goods traffic, especially in London or other large towns. With regard to the retaining-wall at Wellington Road, if he understood the Authors' description of it correctly, the wall had been first of all built in a trench down to the bottom of the 5-foot bed of concrete, and after the material between the walls had

Mr. McDonald. been removed, the ground had been excavated for the concrete toe, the wall being undercut for this purpose as shown on the section. In that case he would much like to know if the wall had been carefully watched whilst it was being undercut and the concrete was being put in; and if it had been carefully watched he would be glad if the Authors would state whether any movement had been observed in it. Looking at the cross section, the operation certainly appeared to him to be rather risky, and one which he would prefer not to undertake if it could be avoided. With regard to the load on the London clay, for some years past the loading which he had ventured on had been an increased load of about $1\frac{3}{4}$ ton. He did not think it was enough simply to state the weight put on the clay irrespective of what had been taken away. He preferred to deal with the increase in the load, deducting from the gross load on the clay the weight of the material which had been excavated for the foundation below the level at which the ground was to be left permanently.

Mr. Galbraith. Mr. W. R. GALBRAITH had been one of the committee of inhabitants which had opposed the extension of the Manchester Sheffield and Lincolnshire Company's line into London, mainly on the ground of the annoyance anticipated during a great many years from the work of construction and from the goods traffic after the opening of the railway. In the first year, when the opposition had been strongest, the railway had been laid out for four lines, and it had been thought that the carting, and the work going on for a long time, would cause great annoyance to the inhabitants of the district. The opposition had been successful in the first year, but in the second year the Bill for the railway had been passed. Possibly the inhabitants had been wrong and the Parliamentary Committee right; he supposed the idea had been that, having regard to the growth of London, another trunk line, approaching the Metropolis through fresh country, was desirable. The clauses inserted in the Bill at the instance of the Eyre Trustees, prohibiting carting through the streets had, however, had considerable effect, and the annoyance anticipated by the inhabitants had been realized in but a very slight degree. The Authors had stated that the conditions thus laid down had made it necessary to run a large heading right through the covered way and the tunnel. His own feeling was that, while benefiting the inhabitants, that course had been of great advantage to the Company itself and to the contractor. In constructing a tunnel a large heading ought to be run at once through the works, and he always specified that the contractor should run a heading

right through the tunnel and the adjacent cuttings, so that big **Mr. Galbraith.** wagons might come in in order to remove the excavation and to bring in materials. He thought that was the best, cheapest, and most expeditious way of constructing a tunnel. Tinkering with top headings was a great mistake, and led to much delay and additional expense. He noticed that the time occupied, from the commencement of the excavation, in completing each 12-foot length of brickwork in the tunnels, varied between 15 days and 30 days. That seemed to be a very slow rate of progress. Probably nothing would be done immediately adjacent to the face for a week or 10 days after the brickwork was set, so that nearly a month had elapsed at each face before another length had been started. He was constructing two tunnels in Hampshire through the chalk in 18-foot lengths, and the good progress of a length per face per fortnight was accomplished. He did not suppose that could be done in heavy ground or in London clay, but he thought the rate of construction on the Great Central Railway might have been greater. He had been wondering what would have been the result of constructing the tunnel in iron by means of a shield. No particulars of cost had been given in the Paper, but he had no doubt the expense would be greater than with the method adopted. The progress of the work, however, would certainly have been more rapid, for a large shield could be driven through the London clay at the rate of 6 feet per day without trouble, so that if expedition was required it might pay an engineer or a company to adopt an iron tunnel, at all events for a short length. With regard to the station, as it was one of the latest constructed, something new and good was expected. The first thing that had struck him in looking at the goods station was that, unfortunately, the sidings leading to the goods shed were short. Possibly that could not have been avoided, owing to the disposition of the available ground and to the proximity of that sacred enclosure, Lord's Cricket Ground, which prevented the widening out of the approach. It was a pity that it had not been possible to arrange the sidings and the goods warehouse so as to make the former longer, and he thought the existing arrangement would be found disadvantageous in working. St. John's Wood had been relieved by the placing of the coal-depot farther to the west, in a place where there were poor streets and the approaches were not used for rapid traffic to the district. The approach was chiefly from Lisson Grove and the Grove End Road, so that the main approach to the district had been only slightly affected by the construction of the station. With regard to the span of

Mr. Galbraith. station-roofs, he did not agree with Sir John Wolfe Barry that it was not possible to generalize on a question of that kind. It was not possible to lay down a hard and fast rule that there were to be no large roofs, but he thought it was possible to say that roofs of moderate span and height ought generally to be adopted. Large spans like those at Charing Cross, at Cannon Street and at St. Pancras, were to be avoided. When those roofs had been built, the idea had been that a station should be free from columns or similar obstructions, but advantage had not been taken of the freedom which the mode of construction had been intended to secure. At Charing Cross Station he had noticed in the middle of the most important platform an automatic sweet-meat-machine, a book-stall, a number of seats, and, last but not least, a row of standard lamps. It seemed to him that those standard lamps might just as well have been columns carrying the roof. The diameter would have been very little greater; whilst the roof would have been much less costly, and would not have been so difficult to enlarge as the existing one would be found to be when the South Eastern Company took the matter in hand, as he supposed they would have to do ere long. Two spans of 50 feet and one of 66 feet could easily have been laid out as the station stood, and this arrangement might have been still further modified at the time the rails and platforms had been arranged. St. Pancras could have been built with one span of 70 feet, one of 80 feet, and one of 90 feet. The saving in cost would have been considerable, and he did not see any advantage in the great height of the roof and the heavy expenditure that it must have entailed. Speaking of roofs of moderate span he might mention the roof of Victoria Station, consisting of two spans of 120 feet each, as an instance. It was an excellent roof, and he believed it had been much less costly than Cannon Street; he thought the latter had cost about 50 per cent. more than the roof at Victoria. A prominent feature of the works under discussion was the goods shed, for which he thought a more appropriate name was "goods warehouse." Only the ground-floor was in use for carts and wagons; there was a basement that would come into use hereafter, and the three upper floors were warehouses for the storage of goods. Rather a strong attack had been made upon it, but he did not quite see where the constructors had erred to any extent. It seemed to him that one disadvantage of the way in which it was laid out was that the cart-roads were too narrow. The carts came in entirely at one end, turned in the shed and came out again. If the cart-roads had been given more width or the

carts had been brought in at one end of the shed and out by another, the arrangement would have worked much better than it did. The working of goods stations, however, was a question in which the manager certainly ought to have the chief voice, and he believed the shed had been laid out by the engineers in accordance with the instructions they had received, so that if the shed were not satisfactory the blame would not rest upon them. The question had been asked whether it was possible to form some estimate of the weight that London clay would carry. That was a point on which generalization was more difficult than on the span of a station-roof, owing to the variations in the nature of London clay. The upper brown clay was very plastic and would not carry nearly as much as the hard blue clay at a deeper level. Sir John Wolfe Barry had made some experiments at Southampton, where the clay much resembled London clay, and he thought Sir John had found that it would carry about 5 tons per square foot. It had been recorded in the "Proceedings" that when the spans of the Charing Cross bridge were fully loaded the weight on the foundations was about 8 tons per square foot.¹ It was not possible to put as much as that on the brown clay. Looking down the shaft at Piccadilly of the Baker Street and Waterloo Railway, clay might be seen on which an engineer could put any load without going to bed in an uncomfortable state of mind. He was afraid the Great Central Railway Company had not yet been recouped for their expenditure, nor were they likely to be for some years, but the work was highly interesting. Living in the neighbourhood, he had seen it carried out and he thought the workmanship and the materials reflected great credit both on the engineers and on the contractors. As it was the latest trunk line, everything ought to be of the latest pattern, and he would much like to hear something about the rolling stock, not on that railway only but on railways generally. In particular he would like to hear what could be said in favour of that abomination—corridor carriages. He thought their adoption had been the greatest mistake railway managers had ever made, and he believed many of them now were coming to that conclusion.

Mr. F. E. ROBERTSON remarked that, although the Paper was a record of one of the most important works that had been carried out in London of late years, it did not seem to afford much scope for discussion, as the work was well designed and executed. He

¹ Minutes of Proceedings Inst. C.E., vol. xxii. p. 516.

Mr. Robertson. would like, however, to make a remark with regard to Sir John Wolfe Barry's comment on the columns, that there did not appear to be any reason why the base should not be spread in both directions. The diagrams, however, showed the reason. The gussets in the longitudinal direction were required to transmit the load to the several joists which formed the base, but the gussets in the transverse direction could only distribute the load over one joist, which itself was capable of carrying it. He thought the designer had been right in adopting the base shown. With regard to the span of roofs, he quite admitted the force of the observation that it was unwise to generalize on an engineering subject, but he would like to record his advocacy of roofs of moderate span. He did not think it was possible to have a more satisfactory roof than that described in the Paper. Monumental roofs like that at St. Pancras were excessively costly; they were extremely ugly externally, although perhaps they might be majestic from the inside; they did not light well; and he could not see that there was any real reason for them. Charing Cross Station had been mentioned in the discussion, and he agreed with what Mr. Galbraith had said about it. The platforms were encumbered with all sorts of obstacles, the place of which could just as well have been filled by slender steel columns carrying a roof of moderate span. If columns could be admitted at Charing Cross they could be admitted anywhere. With regard to the goods warehouse, it would of course have been preferable not to have to deal with turn-tables and traversers if possible, but he did not see how, in the space at the engineers' disposal, they could have arranged it better than had been done.

Mr. Parkinson. Mr. R. M. PARKINSON observed, with reference to Mr. Francis Fox's remark that a column was no more obstruction on a platform than a hand-bag, that it was rather more expensive to move the column than to move the bag. If the passenger traffic became large, considerable alterations would have to be made. He noticed that there were only two lines between the main platforms, and he thought there ought to have been four. If two more were added it meant a space of 12 feet between the roads where the columns stood, and if the roads were connected by scissors crossings it meant a loss of a further 50 feet in the length of the platform. Therefore he thought some larger span would have been better. He would not suggest anything like St. Pancras, but he thought such a roof as at the joint station at Bristol was an ideal one, not only for convenience of arrangement in the station, but also because a new railway coming into London should

have something to show for itself, and he did not think the Mr. Parkinson. elevation of the station was quite what was to be expected from an important railway. Shops were often built with expensive frontages, notably in Edinburgh, and he did not see why the same should not obtain for a station as for a shop. What he meant by the scissors crossings was that there should be room for two trains one after the other. The front train, having come in, should be able to clear out of the way without disturbing the second train, so that trains might be continually arriving and departing without interfering with each other. He understood that the railway had been brought into London partly for the benefit of the Great Central Company and partly for the benefit of the Metropolitan Company, but the station was situated 500 yards or 600 yards from the Metropolitan station. In Glasgow the suburban line was brought right into the middle of the station. He did not suppose it would have been possible to do that at Marylebone, as it would have meant lowering the Metropolitan Railway at considerable expense. He thought, however, the line might have been brought up to the Marylebone Road, putting the hotel over the line and the station-buildings below, or putting the station-buildings farther away at the side—practically buildings were only wanted for the departure platforms—as at Paddington, and in that case to have made a new station on the Metropolitan Railway, so that any one arriving without luggage could get on to that railway at once. With regard to what had been said about the goods shed, he thought there was one thing that had not been mentioned, viz., that a goods manager ought to have sufficient room in his goods shed for a whole train, so that he could load his whole train at once and send it right away. As a rule a goods manager might want, say, seven wagons for Liverpool, three wagons for Manchester, five wagons for Birmingham, and so on, and he might perhaps have to clear one wagon and load it again, although that was unusual. In many cases he sent a whole train to one place. There was one point in which he believed the station was superior to any other London station, viz., that it had a crane which would transfer anything from a railway truck to the canal. He was told that there were no cranes at any of the London stations capable of loading 25 tons into a barge. He noticed that Fletton bricks had been largely used in the construction of the railway, and he would like to know if any such trouble as had been brought to his notice had ever been experienced with those bricks. About a fortnight after they had been laid, some bricks had separated from the cement

Mr. Parkinson. owing to chemical action, the brick being forced away from the cement. This had not been due to the cement, or the sand, or the water, because the same cement, sand and water had been used with blue bricks and common red bricks; but in two cases where the bricks had been laid in cement they had stood all right for nearly a fortnight, and then some chemical action had been set up and they had been forced apart.

Mr. Inglis. Mr. J. C. INGLIS agreed with previous speakers as to the excellence of the work generally. He thought the principal and really interesting feature of the Paper was that it was a description of a modern terminus in London. London was suffering from the terminus question at the present time, and that, no doubt, gave considerable importance to the discussion. It was to be regretted somewhat that more had not been heard of the business side of the question, but it was for those in charge of the traffic department to speak about that. Both the goods shed and the passenger station had been criticized, but railway engineers were largely subject to the opinions of the traffic officials of the company, who really laid down the lines on which the engineers had to carry out the work. One of the questions was the disposition of the platforms and the arrangement of a large goods station. His first impression had been that the one described in the Paper was more or less a luxury in the way of goods sheds, that was to say, comparing the space it covered and the amount of roadway with the number of wagons it would accommodate, it was rather a luxurious arrangement, only justified if there had been plenty of room about the site. Circumstances had driven his company, the Great Western, to the same arrangement in goods sheds as that which Mr. Johnson had described as being typified to a large extent by the new shed which the Midland Railway Company had built. Paddington goods shed was an old one, and it had resolved itself very much into the character of the second shed mentioned by Mr. Johnson, namely, a number of goods lines with comparatively narrow platforms between them butting up against an end roadway, where the goods had to be wheeled a short distance to the wagons. That was a condition imposed by the great value of land at sites where goods sheds had to be built. Looking at the general plan of the goods terminus, the first observation that would be made was that it was a pity there was not more room in front of the goods shed. He thought the accommodation required for manipulating the wagons, notwithstanding all the array of turn-tables there, was too restricted, and no doubt additional accommodation would have to be provided by giving more lines in front of the shed. At any rate, at

Paddington it had been a very real difficulty indeed to get room enough in front of the shed to operate and re-dress the platforms as the wagons were dealt with. With regard to the turn-tables, they were a feature for which he had not been quite prepared, chiefly perhaps on account of the expense. In 1881, Paddington Station had had exactly the same number of turn-tables as there were at Marylebone, but all except three had been taken out, those three being on a high level, quite out of the way, where a long strip of land by the canal had to be utilized. He did not mention that fact as condemning turn-tables, but as showing the great pressure there must have been to effect the removal of every one of them. Not a turn-table now remained in the working-lines, the last having disappeared three years ago. The principal reason for this was the great restriction put by the presence of a turn-table upon the movement of trucks by locomotives, and it might also be said that prevention of cruelty to animals was a factor. At any rate, they were all gone, and the result was that the traffic was more quickly handled. In case it might be said that he was hardly comparing like with like, he might mention that the row of turn-tables had been right across the goods shed at Paddington in the way shown on the diagram of Marylebone. Maintenance, of course, was a serious item. In connection with the turn-tables at coal-depots, the very same point had had to be met at Reading, where a large coal-trade was done by many different coal-merchants, each wanting his own dock; and there the accommodation had been provided at great sacrifice without turn-tables. He had rather strong ideas on the matter of columns. It was a dangerous thing to generalize, but that might safely be done to the extent of saying that every column in a railway station was more or less a nuisance. Many nuisances had to be put up with, such as sweetmeat-boxes, but still he held strongly that columns at busy places must be reduced to a minimum. He had carried out that idea to a large extent in his own Company's works, and the freedom resulting from the absence of columns had been abundantly appreciated by the traffic officials. He noticed that the 30-foot departure platform at Marylebone was divided by the columns in the middle into two 15-foot widths. Deducting, say, 2 feet for keeping away from the edge, this did not give sufficient freedom for moving about with large boxes and other impedimenta which people carried in travelling, especially on a trunk line. The question was a different one for different stations. At a station having largely metropolitan traffic—"handbag traffic"—where the passengers simply walked

Mr. Inglis. out of the station, the question of columns was not so important as at great termini—Charing Cross included—where heavy boxes had to be dealt with. Without pushing the column question too far, he was inclined to think that towards the ends of the platforms it was wise, if columns could not be avoided, to have the spans longer, so as to minimise obstruction at points where the traffic was busiest. He could only emphasise Mr. Galbraith's remarks as to the desirability of driving headings through tunnels of considerable length. That was quite in accord with his own views, but he had not gone quite so far as to specify that it should be done in every contract, because he took up the position of leaving the contractor to judge for himself as to the best way of carrying out the work. He believed it was the best way if the ground and the drainage permitted it, but he thought it was not necessary to predicate too much in a specification, unless there was a particular object in view. As to the supporting power of London clay, that was a very variable quantity; but his practice in ordinary clay had been to adopt a maximum load of 4 tons per square foot. In some cases, however, he had had to allow less than that.

Mr. Myers-
Beswick.

Mr. W. B. MYERS-BESWICK considered that there were one or two points of detail on which it might be interesting to have further information. With regard to the bridge at Loudoun Road, no plan was given, but he gathered it was of the ordinary cross-girder type with outside girders for the roadsides. Those would be rather difficult to put in without in any way interfering with the surface of the road. He did not know whether the description in the Paper meant that the traffic was not interfered with, inasmuch as they were put in at night when there was little or no traffic. He had had a case in which he had been very much limited in headway, and he had had to make special arrangements to avoid any interference whatever with the road-surface. Allusion was made in the Paper to the heading which had been driven, and to the great pressure which had been found to be exerted on the timbers. In constructing a tunnel in clay somewhat of the same nature, he had found, after attempting to make a heading, that it was almost impossible, the pressure on the timber being so great that 12-inch or 15-inch baulks had been twisted like matchwood. In the end the heading had been abandoned altogether, and the tunnel had been constructed to full dimensions for each length, without a heading. He would have thought that the pressure which had been noticed in the heading might have been attended by damage to house-property, and he was not quite

sure whether the Authors meant that there had been no damage at all over the surface where the headings had been driven. With regard to the Lodge Road Bridge, it was stated that box-girders had been used. It was some years since he had used girders of that type, and he thought it was generally recognised that they were very liable to serious rust in the inside, which was inaccessible. It had been stated that large quantities of rust had been found in thick flakes on the inside of the iron plates of Lambeth Bridge. He considered that must be always more or less the case after some period had elapsed, and he would like to know if any provision had been made for it, or whether arrangements could not have been made for boxing in the girders with timber, or something of that kind, which could easily be removed so that the girders might be got at for scraping and painting. He noticed that hydraulic travelling cranes, capable of lifting 25 tons, had been placed near the canal, and that there was also a 25-ton electric overhead traveller for the goods yard. It would be very interesting to hear from the engineers which they had found the more effective and useful. He was rather surprised that some heavier crane had not been required. In the north of England he had recently had to put up a hydraulic crane which lifted 40 tons with a radius of 20 feet, and there was a large derricking beam 50 feet long which would carry 10 tons. That crane covered a very large area indeed for ordinary purposes, about 500 square yards of cart-space and 12 trucks on the roads adjacent; the 40-ton crane would cover one or two trucks. It had worked in a very satisfactory manner, but he did not think it covered so much ground as the 25-ton electric crane at Marylebone. He noticed also that the capstans were placed 120 feet apart. He had recently had to put up a great number in a large yard where there was heavy goods traffic, but they had not been put quite so close together over a large portion of the yard. He thought capstans would be found to work satisfactorily at distances ranging between 140 feet and 150 feet, and, after all, a difference of that sort made a great deal of difference in the number of capstans required. Care had no doubt been taken to provide for the maximum probable load on the floors of the goods warehouse, but he had found it necessary to considerably increase the allowance mentioned in the Paper, viz., 3 cwt. per square foot, and in the last warehouse he had put up for goods traffic he had provided for a weight of 5 cwt. per square foot. In fact it was almost impossible to assign a limit to the load put on some warehouse-floors. When grain was piled up almost to the roof the weight was some-

Mr. Myers-
Beswick.

times enormous. There was supposed to be a limit, but in practice excessive loads were frequently put on the floors. With regard to the passenger station, the refreshment-rooms and offices were placed at the extreme end, at the entrance to the station, whilst almost every other London terminus, he thought, had a large number of buildings at the side of the main departure-platform, with refreshment-rooms, waiting-rooms, booking-offices, and every convenience. Passengers frequently arrived rather early for long-distance journeys, and liked to have these conveniences close to the train. If a passenger had to run down a long platform, and then perhaps arrived at the wrong place, not seeing where he was going to, he would be put to more inconvenience than by the ordinary system. With regard to the angle of the crossings, he thought 1 in 8 was the best practical angle to have in a yard; but it seemed to him that with the sharp curves that angle must be frequently exceeded. He did not think the cross-over roads could be taken round those sharp curves with that angle. The platforms in the warehouse were said to be edged with beech, and fenders of elm were used on the carting side. He did not see mention of angle-bars, or iron of any sort, to protect them, but he had found in practice that oak for the carting side and red-wood for the railway side was sufficient, if an angle-bar was run along the edge. He had found that to last better than any other form of construction. He had also frequently faced the platform with a flat iron plate about 10 inches or 1 foot wide for the wagon-doors, when let down, to rub against, and that preserved the platform for many years.

Mr. Cooper. Mr. R. ELLIOTT COOPER thought it would be allowed that the chief interest of the Paper centred in the question of arrangements for passengers and goods, and in dealing with that subject he thought those who had had experience in that particular line knew that engineers were subject, to a large extent, to the control of the general managers and the goods managers; so that really, in designing a great central terminus for London, the engineer was much in the position of an architect who was designing a house for a client. He had to bear in mind what were the requirements of the traffic department just in the same way as the architect had to bear in mind the special requirements of his client. In cases of new lines, where there was no general manager or traffic superintendent, a great deal of responsibility for the future working of the line necessarily fell upon the engineer, and sometimes that was not found to be the most satisfactory plan. He knew of one case where a new railway had been designed and

nearly completed before the general manager had been appointed. Mr. Cooper. Looking into the drawings of the various stations, that general manager had wanted to make alterations and increase the accommodation; and Mr. Cooper had been told by one of the directors that the alterations had cost something like £50,000. That gentleman had happened to be also a director of a railway of which Mr. Cooper had lately completed a considerable length, costing about £2,000,000, so that he had at once seen the desirability of appointing the general manager before the stations were commenced; and personally Mr. Cooper was very glad that that had been done, because, after all, the man who was responsible for the working was really the man whose opinion ought to be asked before any large expenditure was incurred. Very often an engineer was criticised when the criticism really ought to rest on the general manager or the traffic department, and if the accommodation provided was more than eventually appeared to be necessary, he did not think the engineer ought to be blamed for undue extravagance, when probably he had merely been carrying out the requirements of the traffic department. Most of the members probably knew cases of that kind, and he himself knew many where a station was pointed to as being an example of the extravagance of the engineer, when it had been the general manager who had considered that the increase of traffic at that particular place within a few years would be such as to fully justify the large expenditure. That, to a certain extent, bore upon the questions under discussion, and therefore the comments made did not, in his opinion, reflect in the least degree upon the engineers, because so long as they had carried out their work well, and had met the requirements put before them, he did not see that, if there were any small points, or even important points, which engineers considered could have been improved, it necessarily followed there was any reflection on the engineers who designed the work. The chief difference of opinion appeared to be on the question of the relative advantages of large-span roofs and small-span roofs for passenger stations; but he thought much depended upon the individual circumstances of each case. Those acquainted with large continental stations, such as Frankfort and Cologne, would allow that it would be unreasonable to find fault with those stations from a monumental point of view. Frankfort was probably the most beautiful station that could well be imagined, and formed a very imposing feature in the town; and yet the span of its roof was not anything approaching the span of the St. Pancras roof. It had three curved roofs, and was ended by a façade, which was not a hotel but merely

Mr. Cooper. a group of offices. That, of course, was the difference between the continental mode of dealing with stations and the system which was adopted in this country. As a rule, stations in this country, unless finished by a hotel, looked as if the funds of the company had come to an end just on the point of completing the station ; as for instance, Victoria Station, or the Central Station in Manchester, and the Central Station in Liverpool. The two latter were fine stations, with roofs of large span, and must have cost considerable sums of money, but the appearance from the outside was about as bad as could be conceived. The ends were filled up with glass and boards, so that it looked as though when that portion of the station had been completed, there had been no money left to put a finish to the outside. The plan generally adopted in England had been to put a hotel at the end of a station. He did not at all agree that that was desirable. He thought that when a hotel simply formed the finish of a station it was bad for the station, and exceedingly disagreeable for the hotel. In that respect the designers of the station at Marylebone had really hit upon a very happy medium. The hotel was kept apart from the station, so that its back rooms were nearly as pleasant as the front rooms, and it was possible to dine in the great dining-hall and look out upon the station buildings at the back with just as much comfort as if the outlook were into the street. The station itself was finished by offices, which formed a natural façade much more in keeping with it than any hotel could be. Another feature of Marylebone, and a great improvement upon the majority of stations, was that the approach to the station and to the back of the hotel was one continuous road quite separate from the main entrance to the hotel. It was possible to go all round the hotel, or out of the hotel into the station, without necessarily passing through or under the hotel to get to the station, as in the case of Charing Cross and Cannon Street. If, on the other hand, it had been decided to make the hotel the finish of the station, he did not think the roof that had been designed would have been at all in keeping. However, he thought it was impossible to generalize upon any question of the particular size of a roof, because it must necessarily be in proportion to the buildings with which it was associated. Personally he thought the roof of the new station was a little low, although he quite agreed that there would have been no justification for the large expense that would have been incurred in having a roof anything approaching in span that of St. Pancras Station. If the columns had been a little higher, and the roof of somewhat

greater span, it might have been an improvement. But Mr. Cooper. that again was largely a question of expense, and in all these matters so many points had to be considered that any criticism almost appeared to be carping at something the facts in connection with which were not properly understood. So far as the columns were concerned, the chief point was that when those columns were surrounded with a seat, as had been done at this station, and when people sat there, with an array of portmanteaus in front of them, which they kept in view until their train came up, it really left only a comparatively small space between the luggage and the edge of a 15-foot platform; so that he thought those seats would have to be removed. At present the station was not crowded, and therefore that particular inconvenience had not been felt; when it did arise it would be time enough to think how more space could be given. It was manifest that, if the traffic increased, some extension would be required in order to get the trains out of the station after discharging their load. There were two lines between the platforms, with a scissors crossing, and it was quite clear that in order to get a train out one of the lines alongside the platforms must be clear in front of it. With the great length of platform at Marylebone, if two or three trains were run in one after the other, as was often the case at King's Cross (where the same difficulty was experienced), it would be necessary to wait for a favourable opportunity for clearing out all the trains together. At King's Cross he had seen five or six engines imprisoned in the station, blocking all ingress of trains, because there were no means of utilizing any independent line for getting the empty trains away. He had always adopted the plan of having three lines between the platforms, the centre line being kept clear for the return of empty trains, and the two lines adjoining the platforms being available for the discharge and loading of the trains. Of course all that could be altered when the station was enlarged, as it must be when the traffic increased. With regard to the goods warehouse, a good many points had been cleared up in the discussion, but the chief point was the apparently small amount of what he would call truck-space and carting-space in proportion to the floor-area. It might be that the upper floors were only intended to be used as warehouses, in which goods would remain for long periods without requiring to be removed, although the tendency of traffic nowadays was for goods to be cleared out much more rapidly than in former times. When he had been designing the stations on the Lancashire, Derbyshire and East Coast line, a railway manager had told him he considered that, to a very large extent,

Mr. Cooper. the goods sheds in the local yards might be dispensed with. As a matter of fact, the goods were removed from the wagons direct to the local warehouses and shops, and were not left in the sheds to any extent. That was probably not the case in London, and might be the reason why so large a floor-space was provided at Marylebone for such a comparatively small amount of truck-space and carting-space. He had recently been at the goods shed of the Great Northern Railway in Manchester which he thought was one of the most modern sheds. It had appeared to him to be a very excellent one from a working point of view. In that warehouse there were lines running in all directions, with turn-tables at all intersections. Not only was the warehouse fairly full of trucks, but the carting-space, which was very large in proportion to the floor-space, was almost blocked. That showed that a warehouse with ample carting-space and ample truck-space really was a very great advantage. In Manchester there were two floors on which there were rails. Lines came in on the high-level, and the low-level was served by a line with a fairly steep gradient to the ground floor. There were practically two warehouses working at the same time, which of course facilitated the working of the shed. With reference to the question of turn-tables, he really could not see how they could be avoided, because it was quite clear that in the short space which, both at Marylebone and at Manchester, was allowed, it was not possible to get in points and crossings. Where trucks could be turned round, and got away from a particular platform by means of a turn-table, it was really a most convenient mode of dealing with the traffic. The capstans in Manchester were all hydraulic, so that any question of difficulty with horses did not occur. He had always maintained that where there was very small space there was really little objection to a turn-table. In Manchester and at Marylebone, and at all stations where it was not intended to run the engines over the turn-tables, he did not see any practical disadvantage whatever. With regard to the question of the tunnels, he had constructed a good many, and he had always specified what Mr. Galbraith said he specified, namely, that a bottom heading should be driven right through the tunnel. But lately he had come to the conclusion that it by no means followed that that was the best plan. He had constructed a tunnel about 2 miles long two or three years ago, and it had been found that the material, when exposed to the air before the bricking in of the arch overtook the heading, caused great difficulties to arise in securing the heading during the long intervening period. If he had to build that tunnel, again he would

carry the brickwork on simultaneously with the heading, and Mr. Cooper would not drive a bottom heading right through. In a tunnel where there were no difficulties of ground to contend with there were many advantages in getting a wagon-road right through in the first instance, and then working by break-ups, but in many cases it was better, particularly in heavy ground, to make the complete tunnel at once, and not carry a bottom heading through much in advance of the brickwork.

Mr. ALEXANDER ROSS said he had been connected with the work in Mr. Ross. the early stages, and he might be allowed to supplement the communication that had been submitted to the Institution by giving a short historical sketch of what had occurred. The first Bill had been promoted in 1891, the late Mr. Charles Liddell being the Parliamentary Engineer, Mr. Edward Richards and Mr. Edward Parry, M. Inst. C.E., acting with him. The Bill had gone smoothly through its first stages, and had been eventually referred to a Commons Committee, of which Mr. William Woodall, M.P., had been the chairman. The hearing had occupied 29 days, 17 days for the promoters, and 12 days for the opponents, and the momentous decision had been given on the 16th June, 1891, the decision being that the preamble had not been proved. The Bill had, therefore, been shelved for that year, but the promoters, with true British pluck, had put it forward again for the session of 1892, Mr. Charles Liddell still being Engineer, and it had been referred to a Commons Committee again, Sir Richard Paget, M.P., being the chairman. After 17 days' hearing the preamble had been found proved, and the clauses had been gone into on the 29th April, 1892. It had happened that he had been appointed engineer of the Company some time before the inquiry of 1891, and he had taken an active part in the proceedings before the Committees; but what he wanted particularly to point out at that stage was, that when counsel for the promoters had met, preliminary to the arduous undertaking before them in 1892, they had decided that the local opposition was of such a nature, headed as it was by Mr. Boulnois, M.P., that it would not be advisable simply to fight the Bill on centre lines and limits of deviations only, and it had been decided that a detailed plan should be prepared showing their full intentions. He had been appointed to draw up that plan, in the preparation of which he had been ably assisted by Mr. D. C. Rattray, Assoc. M. Inst. C.E., now Assistant Engineer, Lancashire and Yorkshire Railway, and the plan was represented substantially by the one on the wall (Fig. 3, Plate 2). On the plan prepared by him most of the buildings had been

Mr. Ross. shown as on that drawing, but the hydraulic-power station on his plan had been in the corner between Grove Road and North Road, and the coal-yard had been formed in straight lines instead of with turn-tables. Dealing with the passenger station, the question of the span of the roof did not concern the public, but the rise in the air of a large roof like St. Pancras had been strongly opposed, and an undertaking had been given before the Committee that the roof should only be of a certain height. He had prepared at the time a sketch which had been handed in to the Committee, and in point of fact the roof had been carried out in that way. The hotel was in the same place as in his plan, as were the other matters, with the exceptions stated, and he thought Sir Douglas Fox would bear him out that, between the plan on the wall and that referred to, along with the enlarged drawings which he had sent Sir Douglas afterwards in a friendly way, there was very little difference. With regard to the carriage-shed, it had been undertaken in Committee to build a screen-wall between the boundary-wall of the station and Park Road, and that screen-wall seemed to indicate the place where the carriage-shed should be built. The wharf had been built on the canal because there had been no direct communication with the docks and the East of London, and it had been decided to have the wharf so as to get the traffic on to the canal. Before the Bill had left the Commons Committee, the plan before them had been signed by the chairman and appended to the Bill. It had passed on in due course to the Lords Committee, Lord Baring being chairman, and had been considered for a further 9 days, finally passing the Committee stages on the 22nd June, 1892. Then it had passed the third reading in both Houses; but a dissolution taking place, it had been hung up and had not received the Royal Assent until the 28th March, 1893. The central point of criticism appeared to be the warehouse, and the warehouse in outline had been shown on his plan in the position in which it had been built; but eventually it had been found, on going into the matter, that the lines of rails would have to be altered, and the chief goods manager of the company, Mr. Charles Smith, and himself had visited a large number of warehouses, and had finally decided how the warehouse should be laid out. As far as he could gather the criticism had been made on wrong assumptions. This building was not simply a warehouse, but a warehouse plus an "inwards" and an "outwards" goods depot and an underground station. The criticism had been based entirely upon the subject of an outwards depot. The King's Cross shed, to which Mr. Johnson

had referred (Figs. 27) was entirely an outwards depot, no inwards Mr. Ross. goods coming there; consequently that building was really in operation only at one part of the 24 hours, the full tide of work being between 5 P.M. and 2 A.M. After the goods had been dispatched that warehouse—and he presumed also the Somers Town warehouse—was swept clean ready for the next day. The warehouse at Marylebone was of a different type; it dealt with inwards goods and with outwards goods, one part being for the outwards and one part for the inwards. The work in connection with the outwards goods in London went on between 5 P.M. and 2 A.M., whereas the inwards goods were dealt with between 2 A.M. and 12 noon. It was obviously a desirable thing to have the two side by side, because, when the one department was overwhelmed with work, the empty one could come to its aid. It had so happened that in the new ground at Marylebone this could be arranged in the way shown. The King's Cross building was comparatively a small one, accommodating 51 road vans in the basement at platforms at the same time, and on the ground floor 141. The Somers Town shed held 101, and Marylebone 224, but that was for both the inwards and outwards goods—in other words, 112 each way. It would be seen at once that the Marylebone warehouse was not by any means an antiquated warehouse, but was up-to-date in every way, and he believed the company could pass a large volume of traffic through it in both directions with facility. On the bottom floor there was a large area where general goods could be dealt with by means of hoists. In the upper part of the building there were three floors used merely as a warehouse. Mr. Johnson's experience was so large that every one must respect it, but he thought Mr. Johnson's point about the cross road at the end did not quite apply to this particular warehouse. The cross road at the end was very desirable, but if it were made in this instance it would to a certain extent shorten the platforms. It would be seen from the plan that the effect of a cross road to end-on platforms was to shorten the run of the barrows, but in the Marylebone case the barrow-runs were crosswise on the platform, and the wagons were never farther away from a van than the width of the platforms. It was a great mistake to say that the warehouse was worked by turn-tables. The turn-tables were auxiliary to the warehouse, and the warehouse was worked in the usual way by shunting-engines. The warehouse-yard had a shunting-siding all to itself: trains came in on the two main-line sidings, the engines went round the train and broke it up, and the wagons were placed inside the warehouse. A merchant might want his goods at once, and those

Mr. Ross. goods could be picked out, carried across one of the traversers in the warehouse, along a siding and over the turn-tables to the place where he wanted them. There was constantly a little interchange between the sides of a warehouse. On the other hand, the turn-tables had to work the lower level with the hoists, and were chiefly designed for that level. There were two wagon-hoists to get the wagons to and from the low level. The wagons were manipulated on the top by the turn-tables, and it would thus be seen that the turn-tables were auxiliary to the working of the warehouse, the main working being by engines. He could not conceive that a warehouse would work well if there was no opportunity of doing odds and ends without moving a whole train to get at a wagon. He believed the works were very well designed. They were works of great magnitude, and, like all such works, were not the result of one man's brain, but the result of a good many brains and a good deal of thought. With the design the officials at the northern end of the line had had a great deal to do; but the execution had been carried out at the southern end of the line by such engineers as Sir Douglas Fox and his brother, and therefore no exception could be taken to the work on the score of execution. In conclusion, he wished the Paper had been more ample, and had entered into the historical part of the work a little more fully. There was one defect in the plan of which he thought some explanation ought to be given—namely, the entire disappearance from it of railway No. 12, the connection with the Metropolitan Railway.

Mr. Sadler. Mr. H. W. SADLER wished to call attention to one point of construction—the jack arches used at the Loudoun Road and Rossmore Road bridges, which were described as being of “the ordinary girder and jack-arch construction,” and to hint a doubt as to the wisdom of that method of construction with steel girders. The objections he took to it were two: first, the unnecessary dead load put on the girders, and, secondly, the difficulty of painting and examining them. He had gone into the question of the dead load, and he found that at Loudoun Road the excess of dead weight of the jack arches over ordinary flooring amounted to as much as 278 tons. The girders varied in span between 48 feet and 70 feet and were 7 feet apart. On the 70-foot span there was an unnecessary load of 32 tons, and on the smaller span of 22 tons. The Authors had rather corroborated his view by stating, in their description of Rossmore Road Bridge, that the roadway of certain spans was supported by “steel flooring housed under the top flange of the main girders, the dead weight being thus reduced

to a minimum." He thought most engineers would agree that Mr. Sadler. it was desirable to be able to get at steel girders to paint and examine them periodically. Anyone who had taken out cast-iron girders which had borne jack arches was well aware of the large quantity of rust which formed on them; and it was impossible to tell what amount of corrosion was going on if the girders were embedded in brickwork.

Mr. CUTHBERT A. BRERETON observed that the Paper was parti- Mr. Brereton. cularly interesting to those who had to do with the construction of railways in the Metropolis and its neighbourhood, where London clay had, as a rule, to be dealt with. It had been suggested that in constructing the tunnels on the Metropolitan Division of the Great Central Railway, some advantage might have been obtained by driving a heading in advance of the main tunnel. His experience of working in London clay was that, when once the ground had been opened out, the sooner the work was completed the better, and the less the material was disturbed the greater was the chance of doing this with success. In driving a heading the clay was generally exposed to the action of the atmosphere, and it was very liable to be disturbed by that cause in the immediate neighbourhood. Consequently, when the heading was enlarged to put in the tunnel the clay would be found to be in a disintegrated state, and therefore would be much more difficult to deal with. The bearing power of London clay varied very considerably, according to the depth of the foundations below the surface. In some experiments which he had made at Kew Bridge it had been found that at the surface the test-loads subsided much more rapidly than when placed at a greater depth below. That was only to be expected; but he wished to call attention to the fact, as in considering the bearing power of London clay the depths at which loads were applied must also be taken into account. As an example, he might mention that at the Charing Cross Bridge the test load on the cylinder-foundations had been something like 8 tons to the square foot without further movement, but in the case of the Tower Bridge, with a working-load of under 4 tons, some slight subsidence had been observed. With regard to the arrangement of the Marylebone Station, other things being equal, it would naturally be desirable to avoid the use of columns if possible, inasmuch as by so doing an opportunity was afforded of rearranging the lines, should it be necessary in the future. In the case of St. Pancras Station the structure was formed over large cellars and vaults, and the girders forming the support for the rails and platforms also acted as ties for the ribs. At Charing Cross, where the

Mr. Brereton. land was very valuable, it had been considered advisable that there should be no impediment in the way of altering the lines of way in the station. That point had also been taken into account in the construction of the new Blackfriars Bridge, where, instead of adopting the former method of placing the girders between the rails, the bridge had been constructed with a flat top, so that cross-over roads might be put in as necessity arose to facilitate the traffic. The terminal stations in London had more or less been formed on three principles. At Euston the general station and booking-offices were in the centre, with departure platforms on either side; at Paddington the booking-offices were on the side only, while at Charing Cross, Victoria, and other places, they were placed at the end. The last-mentioned plan had been adopted at Marylebone, and no doubt an arrangement by which the lines could be extended was generally the most suitable. The question, however, had to be dealt with on its merits in each individual case, and no definite rule could be laid down as to which system was the most desirable, until all the circumstances had been taken into consideration.

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Sir DOUGLAS FOX said that, as far as he was personally concerned, he had been very much encouraged and cheered by the discussion which had taken place. There had been a ring about it which had reminded him of the old times when he had been but a young member of the Institution. It was a good thing that the members should speak plainly to one another, and offer honest criticisms of any work which came before the Institution. In a Paper like that under consideration, there were many points of great importance to the profession, and the more fully they were discussed the better. He quite agreed with Mr. McDonald that it was a pleasant thing for an engineer to start with a clean slate, but the advantages depended to some extent on the shape of the slate. In the present case, anyone referring to the plan would see that the shape of the property was anything but ideal. The engineers had been tied by a number of useful clauses which had been introduced by a careful legislature, and also by the existence of a canal, which, as would be seen, ran through the middle of the site. In addition, they had been hampered by being required to provide a new street which separated the passenger station from the goods station, and another new street at right angles to the former, connecting with the Marylebone Road. The area was certainly large, but it was by no means an easy place on which to lay out a thoroughly efficient station. At the same time, looking at it as a plan which had not been laid out by themselves, but which had been originally devised by the late Mr. Charles Liddell,

and had been handed to them, to a certain extent, cut and dried, to be carried out in detail, he felt the result was a thoroughly efficient London terminus—efficient in all the main requirements which such a terminus ought to satisfy. One very important point in connection with it was that the entrances to both passenger and goods stations were on the level of the ground. He had had to travel backwards and forwards for a good many years *via* Waterloo Station, and, if he had not been in favour of having a station on the level before beginning that peregrination, his experiences would certainly have converted him. No one could visit a raised station of that kind without realizing, not only the serious injury to horse-flesh occasioned by it, but also the great inconvenience to passengers. He therefore considered it a wise step on the part of Mr. (now Sir William) Pollitt and Mr. Charles Liddell to fix upon the present site of the Marylebone Station as one which enabled them to bring a new railway into London, after an interval of some 30 years, at the level of the road. Another point which had been emphasized in the discussion was that, in laying out a large terminus, the engineers must have foresight; and he ventured to say that in the present instance great care had been taken in the matter of looking ahead. It was true that at present there were only two lines of way from Finchley Road to the neck near “Lord’s,” but the whole of the property had been acquired by the Company, and all the arrangements had been made in building the tunnel to enable a second tunnel to be added at any time with the least possible difficulty and delay. Practically therefore provision was made for four lines of way from the opening of the tunnel at Finchley Road to the commencement of the sidings near Wellington Road, a little to the north of “Lord’s.” With regard to “Lord’s,” which was sacred ground, they had felt that, whilst they had the chance, they had better provide amply for contingencies, and consequently seven lines of way had been constructed under that property. Whilst speaking of the lines of way, he would answer a practical question put by Mr. Inglis as to whether the sidings into the goods shed and into the coal-yard had not been found to be very short. They had been tied by the position of the canal in regard to the length of those sidings, but a bridge with a great many lines on it had been placed across the canal, and in addition there was a shunting-neck over 500 yards in length running under “Lord’s.” At the present time there was room for five sidings, and, when the main line was increased to four lines of way there would still be room for three shunting-sidings for the whole of that length.

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With reference to the coal-yard, powers had been taken over property to enable the present area to be doubled; and, with regard to the present passenger station, the Company were in possession of property right up to the new road, so that at any time when the traffic required it (which he hoped and believed would be soon, when the new line was made in connection with the Great Western Railway Company) that station could be enlarged to an area of 1,000 feet in length and 400 feet in width, which would make it one of the largest in the metropolis. He mentioned that in order to show that the question of the future had by no means been lost sight of in dealing with the design of the station. In reference to the position of the booking-offices, he was strongly of opinion that, in almost every case, the most convenient course to adopt where there were several platforms, as was the case in all large terminal stations, was to put the office-buildings across the end of the platforms. Of course with only one departure platform, it would be a different matter; but where, as in the present case, there would be several departure platforms, he thought it would be unwise to build the booking-offices along the side of the station. It had been asked why a connection with the Metropolitan Railway had not been made. As to that, there were many wheels within wheels, but the practical objection to it had been that it would have run under the hotel. The hotel was a beautiful structure—he had had nothing to do with it, and therefore could praise it—and its proprietors had made it a condition that no railway tunnel should pass under it. Mr. McDonald had raised a practical point as to the retaining-walls, of which there was a considerable length upon the line. They were of considerable height, some of them being about 36 feet high, and were very close to the tunnel of the St. John's Wood branch of the Metropolitan Railway, so near that the vibration due to the trains in that tunnel could be readily felt. In consequence of that, after the walls had been built, although they did not show any signs of weakness, it had been thought well to put in a toe, to prevent any possibility of the clay at the foot ploughing up. Any engineer who had had much experience of London clay with large retaining-walls would agree that the great danger was that the walls would slip forward at the toe with a ploughing action. An additional toe of concrete had therefore been put into a trench at the foot of the wall. Movement of the wall during this operation had been prevented by carrying out the work in very short lengths, and there had not been the slightest movement of any part of the work. With reference

to the strength of walls in London clay, the opinions of engineers varied somewhat, but, in the present instance their practice had been to make the greatest thickness 0·4 of the height. He did not think that was any too much to ensure absolute safety. He agreed with former speakers that the load which the clay would support depended largely upon the position of the clay—whether it was on the upper surface, or at a considerable depth below the surface. In the neighbourhood of Marylebone, on the upper surface there was a yellowish clay, which was certainly a weaker material than the blue clay lying beneath it. It had not been thought right in any of the works described to expose the clay to a greater pressure than 3 tons per square foot. In reference to that matter, the remarks made by Sir John Wolfe Barry and Mr. Brereton as to Charing Cross Bridge should be borne in mind. He remembered that, when his father and himself had been engineers for widening the Victoria Bridge over the Thames, they had thought it well, as they intended to join up with the old structure, to load the brickwork in the cylinders to a very considerable extent. They had imposed a load of about 5 tons per square foot, with the result that there had been a distinct squeezing of the clay. It had never moved afterwards, and there had been no crack in the connection made between the two bridges, but at the time the clay had been distinctly squeezed by that load. The chief point which seemed to have been touched upon in the discussion was the design of the goods warehouse. It was not possible to compare that warehouse with the sheds referred to by Mr. Johnson and Mr. Ross, against which he had not a word to say, as they were very useful sheds for their purposes. He did not wish to say much upon that point, because Mr. Ross had put the whole matter plainly before the members, and had shown that the object of the warehouse at Marylebone was entirely different from that of the sheds in question. The problem before them in the case of the warehouse had been as follows: they had had a very limited site—only $2\frac{1}{2}$ acres—and upon that they had been asked to provide a floor-space of 11 acres, which had been done. Since the opening of the discussion upon the Paper the practical men in charge of the warehouse had been consulted, and they had stated that it worked admirably, and caused no unnecessary delay, either with the wagons or with the carting. On one point he agreed with Mr. Galbraith. If the warehouse were to be constructed again, even at the risk of making it a little more costly than it had been—and it had been quite costly enough—an extra 5 feet would be added to the middle cart-road. There was room at present—it was only a

Sir Douglas Fox, question of a little more care on the part of the drivers—but an additional width of 5 feet would certainly be of advantage. In other respects the whole of the arrangements of the shed worked admirably. The shed had been designed in the year 1895, and immediately before that Mr. Geo. H. Turner, the General Manager of the Midland Railway, than whom no man could be more respected as an expert upon traffic questions, had read a Paper¹ before the International Railway Congress of which Sir Douglas Fox happened to be a member. Having stated that during the preceding five years accommodation for goods traffic had been provided by the Midland Railway Company, on the most approved principles and adapted to the newest appliances, and in which arrangements calculated to lessen the cost of working had been adopted, Mr. Turner had said: “I shall be pardoned if I refer to a sample of the new Midland structures, in detail, as being, in my opinion, among the most approved establishments of the kind in the Kingdom, for first-class stations.” After referring to the Somers Town shed, Mr. Turner had proceeded to describe a goods warehouse at Birmingham built by the Midland Railway Company, called the Lawley Street warehouse. Mr. Turner had laid down some axioms which might be stated shortly. The first was that there should always be feeders to the sidings alongside the platforms where hydraulic power was available. That was the very thing which had been adopted at Marylebone, and it was for that purpose that those turn-tables, of which so much had been heard in the discussion, had been introduced. He wished to explain, however, that turn-tables were not placed on the main lines, and the shunting-engine which ran close to the shed did not pass over them. They were only used for the purpose of sorting wagons when there was special need for dealing with goods of a certain class. Mr. Turner had further stated that there should be platform-cranes to lift direct from the cart to the truck, or *vice versa*. Such an arrangement existed in the shed at Marylebone; it did not and could not exist in the sheds referred to by Mr. Johnson (*Figs. 26 and 27*), where the traffic had to be wheeled—often to a considerable distance. Another important point was the desirability of having carts on the side of the platforms throughout their entire length, so that a number of vans could be loaded and unloaded simultaneously opposite the trucks. The Marylebone warehouse embodied the whole of those requirements;

¹ “Report on the question of Station Working.” *Bulletin de la Commission internationale du Congrès des Chemins de Fer*, vol. ix. p. 765.

it was, in fact, as close an adaptation as possible of the Lawley Street warehouse of the Midland Railway Company. Sir Douglas Fox.

Although the subject hardly came within the scope of the Paper, he would like to refer to the question of through headings in tunnels, which had been raised by Mr. Galbraith. In the case under discussion they had been compelled to drive a heading through, against their wishes, in order to get access to the work, and enable them to get rid of the material. He had had a good deal of experience of tunnelling during the last 40 years, and his firm opinion was that, in a chalk tunnel, such as Mr. Galbraith had referred to—he had had the pleasure of walking through that tunnel, and it had made his mouth water, for there was hardly a bit of lining in the heading, and it was a beautiful chalk tunnel—or in the case of the tunnels near Liverpool, through sandstone, the driving of a through heading was the best course, because it opened up communication, gave good air, and enabled a number of break-ups to be put in. On the other hand, if anyone attempted to run a through heading in bad ground he would burn his fingers. At the north end of Catesby Tunnel they had been obliged to drive a heading for a certain distance, and the greatest possible difficulty had been experienced in keeping that heading open. At the beginning it had been a splendidly timbered heading; it had been not quite, but very nearly, a wreck at the end. The 14-inch timbers had been crushed into themselves; in fact, the men had often refused to work because of the sound of the crushing. He was quite sure that, if some of the practical men in that room would state their views, they would say that through headings were all very well in good ground, but that the great thing in bad ground was to get the permanent work in as soon as possible. The question of an iron tunnel, to which Mr. Galbraith had referred, had been carefully considered, but it had been found that such a tunnel would be far more costly than the structure adopted. Whilst he had had the privilege of dealing with a good many iron tunnels, he did not look upon them as desirable things if good solid brickwork could be obtained instead. In the particular case before them they had a thoroughly sound brick tunnel, which was better than any iron tunnel in the world.

As to the roof at Marylebone, he admitted that it was not monumental; it was very simple, perhaps some people might say it was rather plain, but he maintained that it answered its purpose, that it looked well, and that it had been far more economical than larger spans. With reference to the idea that a large span was

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desirable because in the future the traffic manager might want to alter the disposition of the platforms, he had never known that to happen, and he thought there would be no adequate return for the heavy expense of a large span constructed with that idea. In the case of Marylebone it had been impossible, because at the north end of the passenger station there was the very important road already referred to, and the spans of the bridge carrying that road regulated the position of the rails in the station. Therefore the columns of the roof had been so arranged that the very best use could be made of the space, allowing for the arrangement of the station to the north of the passenger platforms. An inspection of the station would show two features in connection with it which he ventured to think were useful ones. The first was that, on entering the station, a cross roof, extending 100 feet from the booking-office, would be seen, which gave a very fine open promenade, and secondly, the vista of the station was straight in front. Mr. Galbraith had referred to the roof at Victoria; he had probably meant the London Chatham and Dover Railway Company's roof, because that was of good appearance, and not of very extravagant span. It had been designed, he thought, by Sir John Fowler, and the spans were in the right direction, namely, longitudinally. He never could admire the roof of the London Brighton and South Coast Railway Company; he admired no roof in which the vista was cut off by cross girders. He might mention that in a very important station about to be erected at Buenos Ayres, in which other engineers of great experience had been consulted besides his own firm, it had been decided to adopt moderate spans, very little longer than those at Marylebone. That had been determined upon after most carefully considering the possibility of pleasing the eyes of their friends at Buenos Ayres by putting in a span of large dimensions, and somewhat monumental aspect. He did not think the duty of an engineer was to seek for anything of that kind; the great thing for him to do was to adapt everything to the object which it had to fulfil, at the least possible cost.

Mr. Hawksley. Mr. CHARLES HAWKSLEY, Vice-President, remembering a Paper¹ on the St. Pancras Railway Station communicated by Mr. Barlow shortly after it had been opened, could confirm what Mr. Brereton had said, viz., that one of the objects of the large span of that roof had been to enable the platforms to be rearranged as the varying requirements of the traffic in future years might demand. Mr. Barlow at the time had laid considerable stress on that point. No doubt

¹ Minutes of Proceedings Inst. C.E., vol. xxx. p. 78.

some of those present would know whether the platforms had been rearranged. [Mr. J. A. McDONALD remarked that the original scheme had been carried out, which included two extra platforms in the middle of the station.] During the discussion both sides of the question in regard to large and small spans had been heard, and no doubt both types were desirable under certain circumstances. Mr. Parkinson had referred to a difficulty met with in the use of some bricks coming from Fletton, which had been found to part from the Portland-cement mortar in which they had been laid. Recently his firm had had a similar experience with bricks from a yard about 5 miles from Fletton. The work was a brick service-reservoir with brick arched roof, and here and there cracks were to be found in the brickwork, which had been put together as well as could possibly be done. The work had been done without the intervention of a contractor, and every means had been taken to make it solid and of the best possible quality; nevertheless, cracks had appeared here and there, mostly in the horizontal joints, the bricks rising in places slightly off the bed-joints. It had not occurred to such an extent, however, as to render it necessary to pull down the work or to do more than watch it, and the defect had not been found to spread. His firm had been anxious to ascertain the cause of that action, and they had found that when the mortar joint was taken out it was covered with a kind of greasy substance. He might mention that the bricks themselves had been of a somewhat greasy nature; in fact, the clay from which they had been made had contained so much oily matter that very little coal indeed had been used in the burning of the bricks. The matter had been placed in the hands of Messrs. Stanger and Blount, who had been asked to investigate it, and samples of the cement, the bricks, and the mortar, with the greasy deposit upon it, had been sent to them. As the matter was of great interest to engineers who might have to use similar materials, he would read the following extracts from their report:—

“We have been informed (and the samples submitted to us bear out this information) that bricks apparently well and carefully set in cement mortar have parted spontaneously from the mortar, in some cases with so expansive an action as to destroy the structure of which they formed part.” That, as he had already explained, merely meant that some bricks had been lifted from their bed-joints. “Both cement mortar and bricks appeared hard and sound. At their surface of junction a soft white deposit was found, which might be a product of the failure of the mortar or the cause of its parting from the bricks. Our inquiry has led us to definite conclusions on this point.” A sample of the white

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Mr. Hawksley. deposit had been analysed, and then followed the figures of the analysis. "The sample consists substantially of calcium sulpho-aluminate (corresponding with the formula $Al_2O_3 \cdot 3 CaO \cdot 3 CaSO_4 \cdot 28 \cdot 5 H_2O$) mixed with débris of decomposed cement. This body, which contains a large quantity of water of crystallization, results from the action of calcium sulphate on the calcium aluminate naturally present in cement. The process of its formation is attended by enormous expansion, sufficiently forcible to drive off and detach mortar from surfaces to which it is adhering strongly. It is to the formation of this body that we attribute the failure described. Samples of the bricks were analysed. Both the red and the yellow were found to contain a considerable quantity of calcium sulphate, doubtless due to the presence of gypsum in the clay. These results prove conclusively that both cement and mortar are of good quality, and that the parting of the mortar from the bricks is due to the presence in the bricks of calcium sulphate, which being slowly dissolved and carried by percolation to the surface of junction of the bricks and the mortar, has acted on the latter to form calcium sulpho-aluminate. The great expansion occurring in the formation and crystallization of this substance has forcibly separated the bricks from the cement mortar, and has caused the failure." He trusted that that information might possibly be of some use to other members who had occasion to use bricks of a similar kind.

Mr. Wragge. Mr. EDMUND WRAGGE, in reply, said it had been a source of great gratification to him that the Paper had proved of so much interest, as evinced by the length of the discussion. He wished to answer briefly a few of the questions which had [possibly been left untouched by Sir Douglas Fox, who, to a very large extent, had taken the ground from under his feet. With regard to the Fletton bricks, nearly twenty millions of them had been used on the work, and, so far as he could remember, no fault had been found with them at all. He had never noticed any points where they separated from one another in the way that had been mentioned. A question with regard to the angles of crossings had been asked by Mr. Myers-Beswick, who had noticed that the angles of crossings had been mentioned as 1 in 8. He thought that, in his cursory reading of the Paper, Mr. Beswick had been misled. The "1 in 8" referred only to the straight lines at the Neasden Yard. With regard to the heading through the tunnel, as the end of the work had been approached it had been found that the heading was crushing a good deal, and for long distances the timbers had practically to be duplicated all the way. During the length of time they had been in the pressure on them seemed to have been gradually

increasing, especially as it was near to where a portion had been opened out of the tunnel. Consequently he quite agreed with Sir Douglas Fox in saying that it was undesirable, if it could be avoided, to have a heading through London clay. He would like to compare the goods warehouse at Marylebone with one with which he had been familiar on the Grand Trunk Railway in Canada. The goods warehouse in question was in Toronto, where, as local manager of the railway, he had had charge of all the departments for something like 10 years. It was not by any means a new or a model warehouse. It was about 2,000 feet in length, and had the roadway on one side of it and the rails on the other. It was divided into four lengths. The original part of the goods warehouse was 60 feet in width with a very narrow platform on either side, there being only 6 feet between the side of the shed and the edge of the platform where the trucks were loaded on the one side, or the wagons on the other. The length was about 500 feet, and it held a train of about fifteen cars, which averaged about 32 feet in length. The next length of the warehouse was reduced in width by 11 feet, which made it something less than 50 feet wide. Those two lengths were entirely used for the inwards goods. The next length was also about 500 feet, and was reduced again in width by 11 feet. The last length was 11 feet narrower still. The last two lengths were used for the outwards goods, because they were passed practically straight through from the landing-platform to the trucks. When he had taken charge of that work in Toronto, he had found it necessary to widen the platform, not on the side of the trucks, but on the roadway side, and the width had been accordingly increased to 16 feet, this making a difference of about $1\frac{1}{2}d.$ per ton in the cost of handling. The material could be unloaded from the wagons on to the platform and trucked through more readily at leisure, after the wagons had been unloaded as quickly as possible and had been got away. The same course had been adopted with the loading; goods which had to be loaded could be gradually taken out of the shed and collected on the platform. It would be very interesting to ascertain the cost of handling traffic of that character in London; he fancied it was a great deal higher than it was in Toronto. In that place there was not a very large amount of traffic handled, probably nothing like so much as was dealt with in some of the large goods warehouses in London; still there was a fair quantity—between 1,200 tons and 2,000 tons a day, according to the season of the year. He did not think that at the highest $9d.$ per ton was exceeded for handling, that was, for clerks and porters. He had made a few enquiries as to the cost in

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Mr. Wragge. London, and he could find no place where it was done for less than 2s. per ton. As he had stated, the warehouse in Toronto was not at all a model one; there was not a single crane in it, everything being trucked. Nothing had been said in the Paper with regard to signals, the reason being that there was nothing very new about them. Personally, he would have been glad to see something new. In 1895, when he had re-arranged the passenger station in Toronto, and had practically doubled its size, he had lighted all the semaphores and ground-disks—in fact, everything—by electricity, and not the slightest trouble had been experienced. He understood that since he had left there had never been any inconvenience. The signal-cabin on the west side of the station had about sixty levers, that on the east side had about fifty levers. The signalman on duty, whenever he found it was getting dark enough to require a light, had merely to switch on the light in his own cabin to all signals controlled by him. At St. Louis Station the signals were worked on what was called the electro-pneumatic principle. It was worked by electricity, but compressed air moved all the points and signals. He hoped some day a little improvement in that direction would be seen in some of the London stations.

Mr. Hobson. Mr. G. A. HOBSON, in reply, said Sir John Wolfe Barry had mentioned that he did not understand why the shaft of the goods-warehouse column was splayed out in one direction and not in another. The point had been answered very well by Mr. Robertson; it was also clearly explained in the Paper. The load was taken in the transverse direction by the base-plate itself, which was composed of a series of steel joists. A little examination of the diagram would make the matter quite clear. Mr. Myers-Beswick had raised a question about Loudoun Road Bridge. There were two bridges at Loudoun Road, but he presumed that the roadway bridge was the one referred to. Mr. Beswick, assuming that the bridge had been constructed with two main girders and cross girders, did not understand how half the bridge could be built at a time, and this without interruption of the roadway traffic. The bridge, however, was constructed with a series of longitudinal girders laid parallel with the roadway; therefore it had been quite easy to build one half at a time and to keep the traffic of the road open. The same bridge had been referred to by Mr. Sadler, who had challenged the wisdom of making it in the manner described in the Paper, Mr. Sadler's objection being that the brick arches weighed considerably more than would the steel flooring, as used in the four central spans

of Rossmore Road Bridge. He would like to have this point answered by the authorities of the London and North Western Railway. As it crossed their line, the design for the bridge had to be submitted for their approval. The first design made had shown a bridge with longitudinal girders and steel flooring, the object being to reduce to a minimum the weight and cost of the steelwork. But the authorities of the London and North Western Railway had refused to sanction that design, and the present bridge had been carried out in exact accordance with their instructions. Mr. Beswick also seemed rather uneasy about the Lodge Road Bridge. The main girders in that case were longitudinal, with steel flooring across; the headway was exceedingly limited. Mr. Beswick seemed to think that it was a mistake to use box-girders, but there had been a very good reason for doing so. The span was considerable—97 feet—and it had not been permissible to connect the main girders together by means of overhead bracing. Therefore, the width of the flange of the girder was considerable, being 3 feet, or possibly a little more, which was too much for a single web. There were two webs, therefore, but ample provision was made for access to the interior for examination, by means of man-holes. Mr. Beswick had also said that in some warehouses he had provided for a load of as much as 5 cwt. per square foot on the upper floors. In Marylebone the load was 3 cwt. per square foot on the upper floors and 4 cwt. per square foot on the ground-floor. He had made a rough calculation, and found that if the upper floors were loaded with as much as 5 cwt. per square foot, the load on the clay of the foundations would be increased from 3 tons, as it was at present, to 4·2 tons, and he thought the clay would safely bear that. No fault or subsidence of any description had been observed in any part of the warehouse, which was perfectly sound. So far as the girders were concerned, they were strained in tension to 7 tons per square inch. If the load on the upper floors were increased to as much as 5 cwt. per square foot, as it probably would be some day, the stress would be about $9\frac{1}{2}$ tons per square inch—well within the limit of elasticity of the steel. Sir John Wolfe Barry seemed to think that, owing to the scarcity of traffic on the railway, the columns had never been loaded to the full extent. It was true that the whole of the columns had not been loaded simultaneously, but, individually, many of them had been fully loaded both since the warehouse was opened and during construction. The test of one column would apply to them all, and he had stated they had stood every test perfectly well. The criticisms of Mr. Johnson

Mr. Hobson.

Mr. Hobson, upon the general plan of the goods warehouse had been admirably answered by Mr. Ross, with whose remarks he fully agreed. All the other questions had been answered by Sir Douglas Fox, by his colleague, and by previous speakers.

Mr. Mansergh. Mr. JAMES MANSERGH, President, observed that frequent reference had been made during the discussion to the question of the load that might be safely put upon London clay, and he wished therefore to relate a little experience that had befallen him when acting as engineer and agent to the contractor for a railway in South Wales some 36 years ago. A lattice girder bridge of about 170 feet span had been in course of construction over the River Towy, the girders resting upon cast-iron cylinders filled with concrete. These cylinders, 6 feet in diameter, had been sunk whilst empty by excavating inside and weighting each one with 22 tons of rails. The material passed through from near the ground surface had been dark grey clay of about the strength and hardness of the best London blue clay. The inspecting engineer had approved the bottom and had given instructions that the concrete might be put in, there being then five 6-foot lengths of cylinder below the ground, or rather below an inch or so above the top of a whole timber guide-frame fixed level upon the ground. These cylinders had been filled and no settlement had ensued, but within a few days a big flood had buried their tops under 10 feet or 12 feet of water for over a week. The day after the flood had subsided the foreman in charge (Jim Mathers—one of the best and most reliable men he had ever had in his employ) had come up to the office, when the following dialogue had taken place:—

Mathers (with a very serious face): Them cylinders has gone down.

Mansergh: Where have they gone to? (*Speaking down the tube*) Tell John to put the old horse in the dog-cart.

Mathers: Well, as you're coming along, you'll see for yourself, but I should say about an inch and a quarter.

Mansergh: How can you tell?

Mathers: Well, I know exactly how much they all stood above the frames before the water rose.

There had been no mistake; all the four cylinders had settled down just as Mathers had stated. The weight upon the base without the water had then been 2 tons 4 cwt. per square foot, and the water had brought it up to about 2 tons 10 cwt. On thinking it over, Mr. Mansergh had come to the conclusion that, whilst the ground had been dry, first the load of iron cylinders with the

metals, and second, the iron plus the concrete, had been supported Mr. Mansergh. in great part by the grip of the clay all round the cylinders, and not merely by the bottom. Then, when the flood had come, the water had passed down the sides under the pressure, and had thus lubricated the iron and diminished the grip. He had immediately gone to work to get on the three remaining lengths of the cylinders, had filled them with concrete, and had gradually piled on each pair 220 tons of permanent rails. The effect had been to push down those on the right bank something over 1 foot, and those on the left bank nearly 2 feet. The load had then been about 7 tons per square foot. Under that load the clay could not be further compressed. Making up pieces had then been cast and put on, the concrete and heavy girder-bed stones fixed, and the building of the bridge had proceeded. At the official inspection, Colonel Yolland had gone down on his knees to see if the cylinders budged when his two locomotives were run over the bridge, but on this story being told him, he had desisted. This recalled another little incident that had occurred on this inspection. Mr. Mansergh had left the centre bay of the timber staging, upon which the bridge had been built, to facilitate testing the deflection under load, by means of a piece of wood sliding tightly in a dovetailed groove. This timber had been right under a cross girder, with about 9 inches or 10 inches clearance, and after testing the main girders Colonel Yolland had wished to try if there was any additional deflection under the middle of the cross girder, and had asked Mr. Mansergh (then young and slim) to squeeze in, if possible, with the slide. It had been a case of lying full length, and a very tight fit, and when the locomotives had been run over, each pair of wheels had made it tighter by about $\frac{5}{8}$ inch, but no harm had been done and the Colonel had gone away happy.

Correspondence.

Mr. A. W. MANTON wished to ask the Authors what had been Mr. Manton. the size, and the method and dimensions of the general timbering, of the very long temporary heading referred to on p. 88; whether the invert had been kept from rising by the timbering, and whether the pressure exhibited had been thought to be due to the expansion of the clay immediately outside the timber (through contact with the air), or whether there had been actual general settlement or movement, as seemed to have been the case, in connection with the tunnel. Also, whether such movement, if