Discussion.

The PRESIDENT, in moving a vote of thanks to the Author, remarked that the Paper dealt with one of the most up-to-date terminal stations in the country, and The Institution was especially indebted to the Author for the trouble and care he had taken in the preparation of the Paper and its illustrations. The President.

The AUTHOR observed that it was very gratifying to him that the Paper had met with the approbation of the President of The Institution, especially when the President was the General Manager and Consulting Engineer of one of the most important railways in the country. In the primary consideration of the character of the Paper it had been thought desirable to write from the point of view of the traffic and engineering policy rather than to describe the structural works. As could be seen from the illustrations, the structural works at the Glasgow Central Station were of considerable magnitude, and in execution they had presented features of considerable interest. It had been thought, however, that a discussion of the rationale of the plan of the station might be valuable, having regard to the economics of traffic-working, as everyone recognized that the lay-out and equipment of a terminal station were very important matters. The character and the cost of the equipment of a station could be readily governed by the railway-company, but a railway-company was frequently hampered in the lay-out by the inordinate demands of local authorities and the relative want of sympathy of parliamentary committees, as well as by the extravagant cost of land. The cost of land had had a ruling effect on many of the terminal stations of great cities, and, as in the case of the Glasgow Central Station, had injuriously affected their character. The high valuation of railways was directly associated with the swelling of capital expenditure by the statutory obligations to local authorities and the high cost of land; and, notwithstanding the resulting local betterment, in addition to other annual charges which had to be met, the completion of an undertaking such as the Central Station was immediately shadowed by the spectre of rates and taxes, the *bête noire* of a railway-company. In those and other respects the drain on the resources of railway revenue might with much advantage be constantly borne in mind by parliamentary committees and by the Railway Commissioners The Author.

The Author. and other authorities, although he was one of those who would paraphrase the expression of a well-known politician in regard to the House of Lords, and from an engineering point of view would say, "Thank goodness, we have a Board of Trade." Having regard to the present position of railways and the circumstances of the time, there appeared now to be a necessity for statutory intervention; and from the engineering standpoint a first step might very well be at any rate a partial amendment of those relics of the past, the Railways Clauses and the Lands Clauses Acts. The Paper might possibly be described as discursive, but it had purposely been so written because experience showed that much that was of interest was frequently brought out in discussion of incidental matters. Besides being extended, the Central Station had been more or less entirely remodelled, and the Paper was presented in the hope of eliciting the latest ideas on a subject which was of much importance to railway men.

The Author then exhibited and described briefly a series of lantern-slides showing the old and new stations, with views of the constructional work, etc.

Sir John Wolfe Barry. Sir JOHN WOLFE BARRY, K.C.B., Past-President, was sure the members would agree that they had listened to a very interesting account of a remarkably fine work. It was described in such a way as to lay down for the consideration of engineers many points which perhaps had not always been thought out with the care that the Author had given to them. Although Sir John Wolfe Barry had acted as Consulting Engineer to the Caledonian Railway Company, and had been frequently in consultation with the Author, the whole credit of the work was unquestionably the Author's, and there had never been a single point of difference between them throughout the whole of the work. The Paper was a remarkable account of the requirements of a great terminal station, studied in an exhaustive and scientific manner. No point had been neglected, not even the smallest; and it was easily to be seen that all the items of the design were interdependent, producing together a highly successful outcome. No one could have seen the station in full working-order without recognizing that it thoroughly fulfilled its purposes, that its working must be economical, and that little could be suggested by way of improvement or addition. The work was also very interesting because the capabilities of the site had been used to the utmost. He knew the site extremely well, having advised the Caledonian Company for 20 years or more. All the work had thus come directly within his personal cognizance, and he well knew what a difficult site had had to be dealt with.

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First of all, it was no light thing to interfere with the structure of the Central Station as it was when the Author began his work; and it required much thought and care to keep the enormous traffic of that station going during the enlargement, without any contretemps or accident. That achievement in itself reflected great credit on all concerned. But there were other great difficulties connected with the site. It abutted immediately on the River Clyde, at such a distance as to render it impossible to construct a satisfactory station without building the station-yard over the river. That had been done with great success, but at the cost of making a bridge over the Clyde varying in width from 114 feet to 205 feet. The result achieved had been a remarkably good station-yard, with extremely good curves. The cardinal point to be kept in view in designing railway-stations, which he had enlarged upon in The Institution on former occasions, was not only that every platform should be available for both arrival and departure, but also that the maximum number of simultaneous movements should be possible: that was to say, if there were two lines of rails leading into a station and two lines of rails outwards, all four lines should be available to the utmost for trains entering and leaving the station simultaneously. That result had been attained in the present case; and it was one of the most important principles to be borne in mind in laying out a large terminal station that there should be no cramping due to concentration of traffic at points which would impede the free simultaneous movement of as many trains as possible. The difficulties of the site were greatly accentuated by important public streets—Broomielaw Street and Argyle Street—streets which the Corporation of Glasgow considered almost sacred, and which they thought ought not to be profaned by railway-trains passing over them. The result had been acute contests in Parliament, and the payment of about £175,000 to local authorities, for what might be termed wayleaves over public streets and a public river—an outlay which involved a very serious permanent burden on the railway-company in the shape of interest. He could not help thinking that this was a bad policy for any municipal corporation to pursue. The object of the public authorities of a great city should be to encourage in every possible way efforts to provide for the flux and reflux of its population inwards and outwards. It was well recognized now that it was impossible to house the population properly in central situations, and that therefore every encouragement should be given for the dispersal of the working population and others to the outlying districts and the less crowded suburbs of great cities. Another serious difficulty in constructing the works under consideration had been encountered in the soil. A large portion of the work,

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particularly where the underground railway ran beneath the station, had had to be constructed in running sand of a dangerous character, and extraordinary precautions had had to be taken, in both the upper station and the underground railway, to avoid risk of the sand flowing from beneath the old adjoining buildings or the more newly finished structures of the Company during the execution of the work. Most engineers who had had to do with running sand could appreciate the extreme importance of preventing any movement whatever of the sand, and in connection with the low-level station that had been effected by a series of most ingenious contrivances for which the late Mr. Charles Forman, M. Inst. C.E., was largely responsible. The success had been complete. The underground railway had been carried down the middle of Argyle Street at a very considerable depth, involving the underpinning of old houses on both sides and absolutely touching the works of the railway. He believed there had been few instances of any structural damage, although the foundations were many feet below the level of the Clyde, and at a short distance from it, and rested on running sand of practically unlimited depth, which probably more or less formed part of the old bed of the Clyde, or, at any rate, was connected with that river. He hoped that some day the Author would write a Paper for The Institution descriptive of engineering construction in running sand, for he was resident engineer at the time for Mr. Forman, and was thoroughly acquainted with all the contrivances adopted for dealing with the difficulty. One feature of the design of the Central Station was the use that had been made of the substructure. It would be seen from the illustrations that the substructure of the station on the north side of Argyle Street was used for a Parcels Office and other similar purposes of the railway-company. Facing Argyle Street, the substructure was chiefly used for shops which were let at very considerable rents. South of Argyle Street, behind the shops, a great deal of the substructure was occupied by vaults which were let for bonded stores and other commercial purposes, also at considerable rents. He did not know the actual figures, but from the experience he had had in London, he thought the rents obtainable for the vaults and shops at Glasgow would pay a more than handsome rate of interest upon the cost of the substructure; and of course those vaults which were used by the Company for their own purposes afforded accommodation which would otherwise have had to be provided by buying land at or near the station; so that both for the Company and for commercial purposes, the substructure of the station was productive. The substructure of Cannon Street Station (London) paid in the

shape of rents more than 6 per cent. upon its cost, neglecting, of course, the cost of the land; thus showing that, if a substructure in a great city was designed with commercial uses in view, no more ultimate expense need be incurred by building on it than by building directly upon the land. That should be borne in mind, and engineers should study carefully the design of the substructure in large towns so as to realize as much rent as possible, and ensure that the substructure should pay its way. While at Glasgow the main-line traffic and traffic between the Clyde and the coast were very large and important, there was also a considerable amount of short-distance suburban traffic in the Central Station. It was very disheartening that after all the money spent by the Caledonian Company for the accommodation of such suburban traffic, that traffic, even outside the city, was now being assiduously competed for with the assistance of public rates, and some of the important reasons for the heavy expenditure on suburban accommodation were being rendered nugatory by rate-aided competition. It was a still more disagreeable thing that the services which competed with the railway-company were largely paid for by the railway-company itself. It would not be so bad if the tramway-traffic was conducted upon the same principles as commercial undertakings; but when the fares were fixed on such a scale as no commercial company could work at, and when the rates were behind the enterprise to make up any possible deficiency, it certainly seemed as if everything was being done to discourage private enterprise in trying to deal with the great problem of the dispersal of the population into the suburbs, to better surroundings, better and cheaper buildings, and more open air. It appeared to him that public bodies, instead of penalizing companies in that way, should do all they possibly could to help them to deal with the problem of locomotion; but unfortunately in this country that had never been the attitude. Railway companies had in numerous instances been fair game, and in the case of Glasgow enormous sums had been paid by the Caledonian Company to the Corporation not only in respect of the Central Station, but also, and to a still larger extent, in respect of the Underground Railway. Every right which the Corporation possessed had been sold at extreme prices and the burden of expensive subsidiary works had been laid on the Company. In these respects there appeared to be marked difference between the way in which such problems were dealt with on the Continent, and that in which they were dealt with in Great Britain. In Paris, that remarkable work the Metropolitan Railway was carried under the public streets, parks, and public places, and wherever possible the accesses to the stations were

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provided by making small abstractions from either the public way or open spaces—abstractions which did no harm to anybody, and which greatly relieved the capital of the railway-company. In London it was quite different. Any attempt to put up even a staircase in one of the open spaces of London was, with very rare exceptions, tabooed. There was a striking example at Hyde Park Corner, where there was an underground railway passing beneath the street, and the railway-company had been obliged to buy three or four expensive houses facing the Park, merely for the sake of giving an outlet to the street. Immediately opposite, in the park, the public authority made no scruple whatever in using, for public lavatories, lodges, and accommodation of that sort, ten times the area that would have been needed for an outlet from the railway. He was glad to say that the Royal Commission on the Traffic of London had distinctly recognized those matters and had drawn pointed attention to the great difference between the way in which such conditions were dealt with in London and in Paris, Budapest, and other cities. One point with regard to the suburban traffic which he thought had not yet received sufficient attention was the great undesirability, inconvenience, and cost of reversing suburban trains at terminal stations, and the great lack of through running of such trains, which would avoid reversal. If the suburban lines coming into London or any other great city could be linked up with other lines coming in from opposite directions, and through running could be effected, one great source of expense at terminal stations would be eliminated; and it would not have been necessary in that case to spend millions of money for suburban accommodation at, for instance, such stations as Liverpool Street, Charing Cross, and Victoria. The suburban trains might come in from the east and go out towards the west, or come from the north and proceed to the south, and vice versa. People argued that such ideas would not do, because all the traffic flowed one way in the morning and the other way in the evening, and the trains would always be running empty or less full in one direction; but he did not think there was anything in that argument, because, from whatever directions the trains came, they equally had, after reversal at a terminus, to go out empty or full, as the case might be. If there could be some common running of trains over through connecting lines passing through great cities it would be an enormous advantage to the railway-companies in diminishing the capital cost of terminal accommodation and the terminal costs, and it would be an equal advantage to the public, because it was obvious that everybody did not want to be put down at one

particular terminus. In a great city like London or Glasgow the people coming in from the suburbs wanted to get out at different places in the city convenient to themselves, and the concentration of traffic at terminal stations was a thing which was undesirable in itself and led to many public inconveniences. Of course in many cases such a system would involve amicable arrangements between different railway-companies and joint working; but where all were interested the difficulties of such arrangements ought not to be insuperable; and he submitted that suburban services on railways should begin and end their journeys in the suburbs and not in the heart of great cities. He did not wish at that late hour of the evening to enlarge upon the subject, but threw out the suggestion for serious consideration. He did not know that such an arrangement as he had in mind was possible for the high-level services at Glasgow, but there were many places where it was possible, and he thought it should be encouraged. He heartily congratulated the Caledonian Railway Company upon being now in possession of one of the finest stations that had ever been built in this country—he should almost think in any country—one which was very convenient and was worked in the most successful manner. The Author must have had a very arduous task, for the trouble and anxiety of carrying out the widening of the great bridge and station, while keeping the traffic going during so lengthy a period, must have been unusually heavy and burdensome. Sir John Wolfe Barry.

Mr. ALEXANDER ROSS remarked that the experience of the Caledonian Railway Company with regard to its terminal station in Glasgow was not an isolated one. There were few stations in large towns which had not experienced the same difficulty of growing too small for the ever-increasing traffic. Some of those stations had been dealt with already, many were now in hand, and others were waiting to receive attention. In no case, he thought, had a railway-station been widened or enlarged without the expenditure of a considerable amount of money, and in many cases the cost had been onerous and the works very difficult. In the last category he placed the Glasgow Central Station. It was well known that facilities for travel created travel, and railway travelling had been increasing by leaps and bounds, year by year, and decade by decade. Many causes contributed towards that result. First of all, the population itself had increased, though he did not think that the increase of passengers was due very largely to that cause. To a much larger extent it was due to more journeys being made annually by each individual, particularly as the result of the preference of all classes of people, from the highest to the lowest, for living outside rather than inside towns, Mr. Ross.

Mr. Ross.

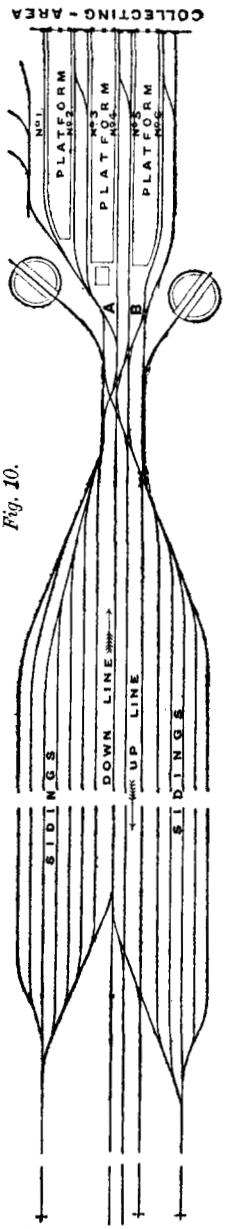


Fig. 10.

The trouble at the London stations, particularly in connection with the suburban traffic, was principally due to that cause. There were two lessons which stood out prominently. One was that railway-companies should, in all prudence, endeavour to have a margin of property and land in their own possession around their stations, so as to make use of it when required; and if such property could be purchased so that the rental would give a fair return on the money expended, nothing was lost by the transaction. In dealing with large stations, even at the present day, engineers might be led to assume, as engineers had assumed before them, that they were dealing with them for all time. It was not quite fair for engineers now to take that attitude, and therefore all stations leaving their hands should be designed and left in such a way that whatever additions were needed in the future should be additions and should not entail destruction of any part of the existing works. To his mind the laying down of the general plan was not only the first operation the engineer had to undertake in connection with a work of that kind, but was also the most important. In that operation he laid down particular lines and outlines for which he had to provide the details afterwards, and fixed the length and width of his platforms, and the number of sidings. Another thing of great importance, though neglected in many cases, was to see not only that all classes of traffic were given suitable positions but that all streams of traffic, such as passengers and luggage along the platforms, should be clear of each other. The passenger who entered a station should—in taking his ticket, seeing to his luggage, buying papers, or whatever else he had to do—be moving forward until he

got into his train at the platform. It might be laid down as an axiom that the capacity of a terminal station was not so much what it held as the facility and rapidity with which it could be filled and emptied, and in that connection very much depended upon the outside accommodation, such as the provision of auxiliary sidings. *Fig. 10* (p. 76) was a diagram of a station at a popular seaside resort which he had carried out in his own practice. The traffic of a seaside resort showed a large influx in the morning and forenoon, a lull in the middle of the day, and a sudden outward rush at night. Assuming that the morning traffic was commencing, the first train came along the down line and was disposed of at the outer platform No. 1. That train was no sooner clear of the sidings than the main line was free and the signalman might take on the next train. In the meantime the passengers in train No. 1 had been disposed of and it was pushed back into the sidings. The next train might now go into any of the platform-sidings, but for illustration it might be assumed to be put into No. 6. As soon as it was cleared, the third train might be taken on, while the second train discharged its passengers and was put back into the sidings. That process could be continued as long as the siding-accommodation was sufficient to hold the trains, and it might proceed so rapidly that the block-sections on the main line were in no way interrupted: indeed, the main line rather than the sidings became the gauge of the amount of traffic that could be carried. During the lull in the middle of the day, the engines were detached from the trains, turned on the turntable, sent off to the other end into the shunting neck, and then attached to the trains with heads in the homeward direction, so that when the evening came the first train was at the platform before its time and succeeding trains were brought quickly to the platforms, loaded, and sent on their journey in a manner similar to that in which they had been received and sent to the sidings. In that way a large amount of traffic could be dealt with by few platforms. The place he had in mind where that had been carried out was working with the precision of clockwork. That method of course applied to sidings at the immediate end of the platform, but in a large town it was not always possible to obtain the ground so conveniently situated; and, desirable though it was to have land for sidings in that position, circumstances might compel the engineer to go 3, 4, or 5 miles away. Still, the same system might be adopted, with the exception that the two lines, one on each side of the main line, would become the through carriage-siding lines to connect the sidings with the passenger-station. At the other end, so as to avoid crossing the main line, there would be an over- or an under-bridge. He would prefer to have the two carriage-line sidings on the same

Mr. Ross

Mr. Ross. side of the main lines with all the sidings also on one side of the main lines, so that the only crossing would be that of half the trains at the platform ends. The engines would run on to the sidings 5 miles off, and go to the turntable, the coaling-stage, and the shed. But while that was a good way to overcome the difficulty when land could not be obtained, it by no means gave the same facilities as did sidings close to the station. Again, it was more costly in working, inasmuch as, with the sidings close up, the engines which brought in and took out the trains did the whole of the work, whereas in the other arrangement shunting-engines had to be provided. There was no doubt that a proper system of sidings, arranged more or less in the way he had described, would, in many cases where the platforms had become congested by superabundant traffic, enable the enlargement of the station to be left in abeyance for years. Another method of dealing with traffic was to have a series of dead-end sidings with engine-spurs at the entrance end, the platforms being between the dead-end sidings. In that case tank-engines had to be provided in the spur sidings. A train came in, its engine was detached, and the engine on the spur came out and was attached to the train, which meanwhile had discharged its passengers and taken a new lot; it was then taken away by the engine from the spur, and the engine behind run out into the spur. That method could be elaborated to a high degree, and one of the best examples of it was to be seen at the St. Lazare station in Paris. During the busy Exhibition year (1900) he watched it very carefully and found it to work with the precision of a machine. A great deal depended upon the auxiliary facilities if a station was to be worked properly and easily, without undue expense in providing special accommodation. In the St. Lazare station the booking-hall and all the arrangements for luggage and cabs were on the low level, while the rails and platforms were on the high level. The passengers ascended to the high level by lift or by a short staircase, and the luggage was taken up by a rolling staircase. At the Quai d'Orsay the reverse was the case, the passengers coming in at the street-level and the platforms and rails being at a low level. At Glasgow there were two levels, and he would like to ask the Author whether he had considered the question of dealing with the matter in the manner just referred to. As to the Glasgow Central Station itself, he thought the Author had made the most of the situation. The parcels-traffic was one of the most important traffics at passenger-stations nowadays. Before the advent of the telegraph and the telephone, most traders stored goods in warehouses or in shops; but nowadays if anything

was wanted that was not in stock they telegraphed to the manufacturers for it, and consequently the stations were becoming thoroughly crowded with parcels-traffic. He quite concurred with the Author that that traffic should be separated from the other platform work and should be either on the low level or the high level, and he had no doubt the Author had done his best. He himself, however, would have preferred to see the parcels-premises at the end of the platforms rather than in the middle. He also agreed with the Author's remarks as to maintenance; in the past maintenance had often been neglected in designing stations and railway-works generally. That was not as it should be: maintenance was the first charge on the revenue, and made or marred the dividends, and therefore it should receive special attention. He was sorry to see the Author had so much bare steelwork, subject to corrosion, and thought he might have devised something which could have been covered. Signalling was a large subject, and no doubt there were members present who would deal with that matter, but he thought the Author's observations were fair and were such as he could corroborate. The Paper was full of points that might be argued, but he would not pursue the matter further. Mr. Ross.

Mr. J. W. Jacomb-Hood remarked that the subject of the Paper seemed at first almost too familiar for discussion, but, as the Author had found out, it covered many exceedingly intricate and interesting problems. Having had the advantage of seeing the Glasgow work under the guidance of the Author himself, he could appreciate the scheme fully. When in Scotland it struck him very forcibly—and he took the liberty of submitting the point to the Author—that it was a great pity the directors of the Caledonian Railway Company had not taken the opportunity of laying out their station really well on the north-east side. It seemed to him a pity—and he believed the Author agreed with him—that the property between Jamaica Street and the north-east side of the station had not been taken, so that all the platforms numbered 1 to 6 could have been extended to a better length and made straighter. When such works were being undertaken by capitalists it was a pity they could not look ahead a little; and engineers should do whatever was possible to enforce that view upon them. It was clear that if the property had been acquired, and if the platforms had been made straighter and longer, there might have been, a few years hence, a large return to the Company for the £100,000 or £150,000 necessary to buy the property. That brought up the question of the characteristics of platforms, and he would take the opportunity of emphasizing what the Author had drawn attention to. Platforms could not Mr. Jacomb-Hood.

Mr. Jacomb-Hood.

be too straight. The advantage of straight platforms was not always as obvious as it might be, but it was very great for every class of traffic, particularly suburban traffic, in respect of the rapid loading and unloading of trains. In fact, straight platforms were one of the chief requisites for handling traffic quickly. They possessed an advantage also for long-distance traffic, though he was not quite clear as to the exact reason. The surface of platforms was another interesting matter, which several engineers of other railways had investigated. It was interesting to note that another Company had arrived at practically the same conclusion as the Author's, namely, that there was scarcely a better surface than high-class asphalt for such a station as the Glasgow Central Station: it was laid quickly, was soon fit for use, and could be repaired easily and inexpensively. With reference to the coping, he understood that in the Glasgow Central Station it was granolithic. Several railway-companies had tried granolithic coping—the London and North Western had been using it for years—but whether on the whole it afforded the best surface for coping was another question. It might do for the inner portion of platforms. One railway-company had been using largely, and with much advantage, a coping of slate, which, in his judgment, had proved to be a valuable material. Another point of interest about the laying-out of the Glasgow Central Station was the "concourse." A concourse, or large collecting-area, at the ends of the buffer-stops, with the buildings arranged along the end of the lines, was of the first importance in dealing with traffic, whether large or small. Noticing how the principle had gradually developed from small beginnings, it was impossible to overestimate the importance of putting the buildings at the end of the station, allowing the traffic to pass through them, and giving it a large, well-lighted, unobstructed area in which to move about freely to the trains. It was surprising how little that principle was recognized. He knew of a station not very far from The Institution where there was once a set of buildings arranged at the side: now those buildings were right in the heart of the station, and in order to get at any other platforms than those adjoining the booking-office a number of the lines had to be crossed. Yet he had heard a great authority say that he did not know how the enormous traffic of that station could be carried on by any other means. The members had listened recently to an interesting and valuable Address in The Institution, when they had been called upon to regard the works of past engineers with admiration, and one of the monuments pointed to was a station in London, where the sideways principle, in his opinion, interfered to some extent with the

economical and convenient working of the station. The remark had been made—he did not think it could have been meant—that the reason why that station worked so well was that its arrangement was based on sound principles. He questioned whether that was so in the light of modern railway-stations. With regard to roof-construction, the Author had been obliged to support the roof on the west side of the Glasgow station by a series of double columns. Of course, in moving the wall which supported the old roof, a double-column arrangement was much better than a single-column, and he only referred to the point because the Author justified double columns on platforms in a manner that required a little consideration. The Author suggested that the double-column arrangement was better than the single-column because it separated the flow of the passenger-traffic into two streams, leaving the central area of the platform available for luggage. Luggage also flowed in two directions with the passengers, and therefore, if the argument were worth anything, it would demand three rows of columns for four streams of traffic. The Author would probably agree, however, that on the whole the best arrangement was to dispense with columns on a platform, and, next to that, to have only one row. He was greatly interested in the subject of the main bearing-girders, although he did not quite agree with the Author's view that the semi-elliptical form was necessarily beautiful. It was a matter of opinion; but in his judgment a plate girder having the lower members parallel with the top members would have been just as beautiful and certainly a little more convenient. The ironwork of the roof generally had a handsome appearance, and he congratulated the Author upon it. With regard to the glazing, there was nothing quite so unsatisfactory for maintenance as puttied glazing, and almost any form of mechanical holding of the glass was more satisfactory. As to the signalling, he would like to emphasize what the Author had said—that if there was one thing which justified the employment of a power plant it was the comprehensiveness secured in the signalling-arrangements: any expense in reason was worth that. Clearly the working of the station was so satisfactory that nothing could be better; and the fact that the signalling could be worked from one box, instead of from the three which a manual system would require, was a powerful argument in favour of the power plant. He had not had the opportunity of seeing the figures for the cost of the power installation or of its maintenance, so that he was speaking under correction, but he was a little surprised to hear from the Author that the cost of maintenance was greater than the cost of maintenance of a manual plant

Mr. Jacomb-Hood.

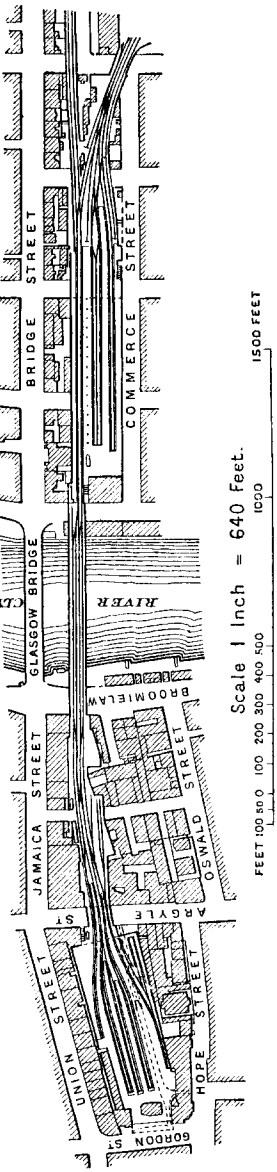
Mr. Jacomb-Hood.

would have been. He did not think that was the experience in all other cases. He hoped that the question of power signalling would be discussed much more fully.

Mr. Hall Blyth.

Mr. B. HALL BLYTH remarked that, as one of those who had been responsible, more or less, for the laying-out and construction of the original Gordon Street Station, he would like to say a few words upon the Paper. The Author had passed—probably unintentionally—what looked like severe strictures on the design of the old station, and therefore he wished to have the opportunity of explaining the matter to the meeting. *Fig. 11* was a plan of Gordon Street Station, which was completed in 1879. The Act was originally obtained in 1873, and then it was intended to carry the approaches to the station close to Glasgow Bridge by two lines of rails, extending Glasgow Bridge underneath the railway. The Act was passed in face of the opposition of all the public bodies in Glasgow, every railway-company, the Corporation, the Clyde Trustees, and the Bridge Trustees. As part of the price for the passing of that Act, for a strip for two lines of rails over the River Clyde, the Company had to pay to the Clyde Trustees £22,500. While the working-plans were being made, it was found that it was going to be a risky thing to build a large, heavy viaduct in close proximity to the Glasgow Bridge then existing, with its shaky foundations, and it was also found that property was much more expensive than had been anticipated originally. Therefore, in 1875 the Company

Fig. 11.



Mr. Hall Blyth.

applied for a deviation from the original plan, and the line was then constructed as sanctioned by Parliament. He wanted to show the difficulties that had to be contended with. In the first place, the new bridge over the Clyde was restricted, at the instance of the Clyde Trustees, to a width of 55 feet over the girders, and the Company had to pay, in addition to the £22,500 they had already paid, a further sum of £48,000 to the Clyde Trustees for crossing the river. With regard to the Corporation, the Company were to pay the Bridge Trustees—which was the same thing as paying the Corporation of Glasgow—£25,000 for relief from the parliamentary obligation to make the bridge adjoining the old Glasgow Bridge. With regard to the railway-companies, the line shown on the plan, which was a main line, passed through the old Bridge Street Station belonging jointly to the Caledonian Railway Company and the Glasgow and South Western Railway Company. In the Bill every provision was made for preserving the station, so that the traffic should not be interfered with, and so that the accommodation of the station should not be reduced. But the Glasgow and South Western Company wanted a great deal more; they said they must have an entirely new station, and so the station known as the New Bridge Street Station was built by the Caledonian Company for the Glasgow and South Western Company at a cost of £150,000; but from the day that station was opened until it was sold to the Caledonian Company not one Glasgow and South Western train ever came into it or left it. Further, finding that the station after it had been completed was not used by the Glasgow and South Western Company the Caledonian Company in 1881 went to Parliament for power to buy the station. There was a very severe contest, and the Bill was carried through the House of Commons, but in the House of Lords Sir Benjamin Baker and other eminent engineers were called to support the South Western Company, and the Bill was thrown out. At a later date, however, the Company sold the station to the Caledonian Company, and thus enabled the Author to carry out the great improvements that had been made. The neck of the station was the crossing at Argyle Street, the main thoroughfare in Glasgow, a very busy street, a very untidy one, and one that might be covered with a bridge to any extent; but that was not allowed. After a great deal of difficulty the Company obtained from the Corporation 75 feet as the ultimate limit of the extent to which that street was to be covered. He thought he had sufficiently explained the difficulties in connection with the old station, and possibly the Author would withdraw the objections that he took to the station as originally laid out. In 1873, when the Bill was

Mr. Hall Blyth. first promoted, the population of Glasgow was only 600,000; the number of trains using the two stations, Bridge Street and South Side, was only 155; and the total number of passengers per annum was 4,460,000. Therefore, in providing a station such as was shown in *Fig. 11*, the engineers provided a station not only amply sufficient to cope with the traffic of the day but amply sufficient to cope with a very much increased traffic in future years. There was no doubt that the traffic of Glasgow had increased far beyond anybody's expectations, and the station had become too small and needed reconstruction. The sidings shown in *Fig. 11* were originally intended to be carried straight through to the Clyde Bridge, but difficulties in connection with the purchase of land prevented this. There were two or three points in the Paper to which he would like to call attention. The site was, as the Author said, a very awkward one, but at the time it was selected every other available site in Glasgow was carefully examined. The Caledonian Company owned at that time, and he believed still owned, a considerable amount of property bought in 1865, at a place called Bothwell Street. But that site involved so many complicated crossings of streets and such a very sharp curve that it was discarded, and it was thought the present site was an admirable one for the station. That was the reason why the site was selected, and, speaking from a knowledge at the time, he could say with confidence that it was the only site in Glasgow available to accommodate that particular traffic. Mr. Ross had dealt ably with the question of working sidings for accommodating trains coming into and going out of a station, but there was one point in the Paper of great interest to engineers who had to do with building railway-stations, namely, the question whether dock lines should have two or three lines coming into them. Many contended that two were best, and others three. When he was building the Waverley Station some years ago there were four dock lines at the end of the station, and he had a keen controversy with the General Manager as to whether they were to have two lines or three. The Manager contended strongly for three, while Mr. Blyth was equally confident there ought to be two. They "split the difference," and the station was built then, and now existed, with two dock lines containing two lines of rails and other two dock lines having three lines of rails. The great objection to the third line in a large terminal station, where property was very expensive, was that it really served no useful purpose whatever. The purpose it was intended to serve and did serve at the Waverley Station was that an engine after drawing its train in might go on to the end of the platform, back out through the middle line, and take the train away. That meant

losing a considerable length of the most valuable part of the platform, because the engine had to stop short of the cross-over, in order to get back by the middle line. It was much better in his opinion to have a pilot- or shunting-engine standing in a small siding outside the dock to draw the trains out and put them into their place; or, if that was not found practicable, to have another working engine to take the train away on the next journey, the engine which had brought it in following the train out and taking the place of the first engine. From experience of the working of a railway-station he was quite satisfied that two lines in the dock were infinitely preferable to three. With regard to the "concourse," he was afraid that, both in name and in nature, it was the result of the Author's American visit. He disliked the name, and he thought a concourse such as the Author had devised was a very bad thing indeed. The original idea in designing Gordon Street Station was to bring the platforms as far forward and as near to Gordon Street, both in site and in level, as could possibly be done. The Author's idea was to make a large assembling-ground for the public, and it was well known in Glasgow that the place the Author called a concourse was the sheltering place of the people in bad weather; they went there in hundreds, having no intention whatever either of travelling by train themselves, or of meeting friends coming by train. Whenever it was a wet night in Glasgow the concourse would be found crammed with people. His own idea of a station was that the sooner the people were got to the platform and into the train they were going by, the better for the station and the better for the public using the station. The Author made much of the train-information board. It was a fine board, but it seemed to be in the wrong place. Going into the station the passenger saw nothing in front of him, and he had to go a considerable way and look around before he could find the board. Again, the lavatory was down below, there being hardly any lavatory accommodation on the departure platforms at the level of the platforms. The lavatory proved to be a palace when it was reached; but, if a passenger was trying to catch a train with only a minute or two to spare, he had to pass the palace by. He congratulated the Author not only on his admirable Paper, but on the excellent way in which it was illustrated. He felt that one great object the Author had had in writing the Paper was to elicit the opinion of his brother engineers as to whether anything could be done in the way of standardizing the construction of railway-stations. He himself had constructed eight large terminal stations, and in his opinion it was absolutely impossible to lay down any guiding rule, either as to the size, shape,

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Mr. Hall Blyth. or area, or as to the length, breadth, and number of platforms, or as to the ratio between the approach-lines coming into the stations and the lines between the platforms. In no two of the stations he had constructed had the circumstances of locality, level, shape, or traffic to be accommodated, been at all comparable, and his experience was that the design of each station was a distinct problem in itself. The engineer had to take a site; he could not make one. If an engineer were ordered to build a station on a prairie in South America to accommodate a population of 500,000 people or a million people, he could lay down hard and fast rules as to how it should be done, and could carry them out; but the misfortune was that all the stations now built were in more or less crowded places, and the site had to be taken as it was and dealt with so as to give the most accommodation for the particular traffic it had to deal with, in the best way. As illustrations he might mention two stations that he had made, the Citadel Station at Carlisle and the General Station at Perth. At first sight people would say that the stations were precisely similar, and that what applied to one ought to apply to the other. But, to begin with, the station at Perth was built at the level of the ground, while the greater part of the Carlisle Station was built about 20 feet above that level, with a large amount of under-building. At Perth only three companies worked into the station and only one of them had through trains. At Carlisle seven companies worked into the station and there was an enormous through traffic from London by the Midland and the North British to Edinburgh, by the Midland and the Glasgow and South Western to Glasgow, and by the London and North Western and the Caledonian to Edinburgh and Glasgow; and all those through trains arrived and departed from Carlisle at practically the same time. All the north traffic rushed into Carlisle about mid-day, and therefore exceptional arrangements had to be made, in laying out the sidings and in forming the cross-overs and junctions; to deal with that traffic. Two fairly comparable stations were the Princes Street Station of the Caledonian Company at Edinburgh and the Central Station in Glasgow. Yet the one in Glasgow was built over the streets, with a great deal of under-building, while the Edinburgh station was built at the level of the ground and crossed under the street. Whereas in Glasgow great difficulty arose in finding siding-accommodation in the immediate neighbourhood of the station, in Edinburgh it was only necessary to go about 200 or 300 yards from the mouth of the station to be practically in the country and find plenty of such accommodation. The Waverley Station at Edinburgh was unique, because there was not only a very heavy

local traffic to be dealt with at the two ends of the station, but an immense through traffic of a peculiar description. No single train went through Waverley Station. Through carriages from Glasgow, from Perth, and from Aberdeen came into that Station and were taken to London, part by the East Coast route and part by the Midland. That traffic was entirely different from what had to be dealt with at Carlisle. In Edinburgh the trains had to be sorted, the individual carriages going through by the one line and the other being taken off and attached to the proper trains; and that necessitated an entirely different construction from any other station he had built. A few figures with regard to the Waverley Station might be interesting to The Institution. The station was 23 acres in extent, 11½ acres being under roof; there were nineteen platforms, with an aggregate length of 13,980 feet. In the previous week the trains in and out of that station numbered 1,319, but the train-movements were so numerous that they could not be counted. The estimated number of passengers exceeded 30 millions a year, and that estimate was well within the mark. The last matter he wished to refer to was one which formed the only blot upon a valuable Paper. The Author had given a very able description of all the works, with admirable drawings, but he had said absolutely nothing about the cost. To an engineer who was responsible to a board of directors for the cost of works, the details of the cost of the station and of the roof would be of considerable interest; and in order that the Author might have some figures to compare with, he might say that the original Gordon Street Station cost £190,000 inclusive—rail-laying, signalling, roof, under-building, and everything. Mr. Hall Blyth.

The PRESIDENT asked whether that referred to works only. The President.

Mr. BLYTH replied in the affirmative. All the substructure, which the Author had used exclusively for railway purposes, was let out at a rental of 5*s.* to 9*s.* per square yard, and formerly brought in a revenue equal to about 9 per cent. on its cost —actual rental obtained, without allowing anything for the part of the arches used by the Company itself. That had now disappeared, because nearly the whole of the substructure was used by the Company. The roof was 211 feet 6 inches in span and 603 feet long; its area was 14,193 square yards, and its total cost was £35,358, equal to £2 9*s.* 2*d.* per square yard. He hoped in his reply the Author would furnish some similar figures in connection with the reconstruction. Mr. Hall Blyth

Mr. CHARLES L. MORGAN observed that the Paper dealt with a subject which had been rather forced upon his attention during the Mr. Morgan.

Mr. Morgan. time he had been in the engineering profession. It was his fortune in the early seventies to be associated with the construction of Liverpool Street Station and all the widenings into that station for the Great Eastern Railway Company, he being at that time a pupil under the late Mr. Edward Wilson. Subsequently he went through the whole of the widening of the approach-lines and the enlargement of the station as assistant engineer under Mr. John Wilson, M. Inst. C.E., in the early nineties. That station, which had been spoken so well of, only lasted 20 years before requiring enlargement. Recently he had been engaged in the reconstruction of a station not far from The Institution. The Author said that, in designing the Glasgow extension, he allocated various parts of the station to different classes of traffic. In Mr. Morgan's own experience of dealing with terminal stations, that was well enough for the first part of the scheme—in considering how the station was going to be used; but he was convinced that the parts of a station must not be too strictly allocated to particular classes of traffic: regard must be had to the altered conditions of working that prevailed from time to time. In the Glasgow station there was excessive traffic on fair-days and holidays. The station should be so arranged that the platforms were interchangeable, that was, that suburban platforms might take main-line trains during the stress of special excursion traffic. Platforms Nos. 5, 6, 7 and 8 in the Glasgow station were only capable of accommodating short trains; it was not possible to put main-line trains into them. His experience showed that that was a blot on Liverpool Street Station, which otherwise was one of the best working stations known. There the main-line trains were in the centre, and on each side were the suburban platforms. It frequently happened with heavy excursion traffic that the long trains had to be dealt with in the short or suburban platforms, thus necessitating dividing the trains by putting a certain number of carriages into a second platform. In a terminal station the whole of the platforms should be capable of taking the longest ordinary train on the line. The Author also considered that long platforms in a city terminal were undesirable and had far-reaching consequences, which he attributed to the cost. Perhaps he would throw a little further light upon the subject. Mr. Morgan's own idea was that to have one or more platforms longer than were required for the ordinary traffic in a station was a very great advantage, because in many cases they could be utilized for horse-box traffic, and things of that kind. It was a manifest advantage to be able to break a train in the platform and drop in a horse-box at a point suitable for a particular station; but if the

platforms were only dead to length that could not be done. Auxiliary sidings, if obtainable, were well worth having. They should be as near to the platforms as possible, but in all terminal stations in large cities that was almost an impossibility, having regard to the cost of land and works and other reasons. He was not in accord with the Author as to the length of approach-lines such as were shown on the diagram; they would be excellent if they were long enough to be used as standing loops, but such was not the case. Between King Street and Nelson Street, if there were length enough for an incoming train to platforms Nos. 10 and 11 to stand between the points in order to clear a section behind, that length would be very valuable, because the train could wait there until such time as a platform became vacant and then could go on in a very short section into the station; but the existing loops were not long enough. For ordinary working it was a manifest advantage to be able to get on to the right road as soon as possible after leaving the platform. When a train was going out from No. 9 platform, a train coming in from the upper roads in Fig. 2, Plate 1, would be blocked until such time as the train out of No. 9 had cleared through the junction. If it could take its proper road sooner, a section would be cleared much earlier. Having to traverse a long length before getting on to the proper running-road tended to delay. After laying out terminals it was really a serious question whether there should be two or three lines between platforms, and he thought that for some classes of traffic a third line was essential; but every terminal must be dealt with according to circumstances, the ratio of main-line traffic to suburban traffic and the geographical position being two things which had to be considered. On most main lines horses and carriages had to be dealt with and loaded up somewhere; and if between the main-line platforms there was a third road, they could be brought down and dropped into that section of the train in which they would be carried most conveniently. If there were only two lines they would have to be put on in front, and that might lead to delay in working the traffic in the country. Looking at the platform accommodation, he thought the first thing to be noticed in the station under consideration was that it was insufficient: the approach-lines could carry more trains than could be dealt with by the platforms. At Liverpool Street there were six approach-roads and eighteen platforms, and those platforms were fully occupied and fed by the six approach-roads. At Glasgow there were six approach-roads and thirteen platforms. Of course a great deal depended on the relative proportions of the suburban or local working and the main-line working. With a larger proportion of main-line working,

Mr. Morgan.

Mr. Morgan. more platforms were needed, because they took longer to clear, owing to the luggage, etc. If there was a larger proportion of local lines and a shuttle service, probably the Author's ratio was quite sufficient; but Mr. Morgan did not see, except on one or two of the platforms, where anything approaching a shuttle service could be worked. As to the roofing, the shape of the girders was a matter of taste, but he thought that in all cases where it was at all possible it was much better to have the roof designed so that the ridges ran longitudinally with the station rather than crosswise. In that way a much better effect was obtained, the perspective was better, and the arrangement gave height, which was of great advantage. The question of the cab-rank was a very important one, and perhaps the Author would say what difficulties, if any, were met with in the working. It would be seen from Fig. 2, Plate 1, that all full cabs coming out of the station would be crossed by the empty cabs going in; and, worse still, the cab-road was on a falling gradient towards Gordon Street, and emerged into the street at right angles in a single line of traffic. Any block of traffic in Hope Street would be reflected back into the station. Of course, he was aware that the matter was difficult to deal with, and probably this was the best that could be done. With regard to the concourse, or, as he preferred to call it, circulating-space, he did not agree with Mr. Blyth that the indicator-board was in the wrong position, because it stood very well indeed for passengers coming in from Gordon Street and Union Street, who had to go beyond the board to get to the platforms. As to the parcels-accommodation, the only thing he was surprised at was the vast space that was provided—6,000 square yards or $1\frac{1}{2}$ acre. Such a space required a lot of parcels to fill it, and it would appear to be necessarily rather costly to move the parcels from point to point in the Parcels Office itself. Turning to the signalling, did the Author find the working of the system as quick as that of the old manual system, in which a large number of movements were necessary for working any particular train? One of the earliest examples of that method of signalling was installed on the Great Eastern Railway and had proved to be an excellent and safe system; but it had the objection that the signalman had to wait for a return-indication after he had pulled a lever. There was in fact quite a sensible pause during which the man was waiting. Where a number of movements were necessary in a mechanical frame, the signalman worked like a piece of mechanism, and his final operation showed that everything was right. In the power system there were several operations and an interval between each, the signalman having to wait for a click before making another movement. That

drawback might have been overcome in Glasgow. The idea of one signal-box might, he thought, be carried a great deal too far, especially in an atmosphere such as was found at times in Glasgow and in London. It was very desirable indeed that the signalman should be able to see the operations that were taking place. It was all very well to say that he was in connection with the platforms by telephone; anyone who had been in a busy signal-box knew the confusion that arose from the telephone. According to the Author, a very essential feature was turntable accommodation near the platforms; but Mr. Morgan could not consider that that requirement was satisfied by the turntable shown in Fig. 2, Plate 1, which was not where it should be. A turntable should be quite close to the ends of the platforms. Every time an engine had to come out to reach the turntable it obstructed most of the other traffic and reduced the earning-capacity of the approach-lines. The proper ratio of the platforms to the approach-lines was put down in the Paper as 1 to 2. So much depended on the class of traffic that no fixed ratio could be laid down; but he thought that, as the suburban traffic was being reduced and the long-distance traffic increased, the platforms would be found to be fewer than was desirable. An objection made by the Author to stations generally was that insufficient attention was paid to the æsthetic point of view, and he quoted French stations as being very beautiful; but they had the Government behind them, and no doubt as soon as the railway-companies in this country reached that stage, the stations would be more beautiful—and more wasteful. Mr. Hall Blyth had dealt so fully with the question of the impossibility of a standard design for a central station that Mr. Morgan would not say more than that he quite agreed with him. In his judgment the Author had made as much as any man could make of the site, having regard to all the difficulties. That was only what all who knew the Author, his energy and his earnestness in his work, expected from him. Mr. Morgan.

Mr. W. W. GRIERSON considered that the Author had thrown out a challenge to the Great Western Railway Company to explain how it was that while in this country, in America, and in France—and he might add, in Germany, and in Switzerland—so many stations had been reconstructed during the last 10 or 15 years, Paddington appeared to stand the test of time. The explanation clearly did not lie in a decrease of traffic. The President had stated quite recently that the number of passengers using Paddington in the course of a year was 26 millions. He did not know what the number might have been in 1854, but the time-tables indicated that 22 trains then entered and 22 left the station daily, while at the present time there Mr. Grierson

Mr. Grierson. were 266 in and out, making over 500 in all. The explanation clearly must be looked for in some other direction. The first Great Western terminus occupied a site west of Bishop's Road bridge, was built in 1838, and was swept away in 1854 when the new station was built. The roof then, as now, occupied an area 800 feet in length by 288 feet in width, exclusive of a covered portion at the rear of the station which was now used for van-traffic. There were four platforms, and the central bay was used as a carriage-shed, turntables being provided at the end of the station to enable the carriages to be transferred to the platform-lines. It was quite evident that Brunel designed the station with a view to future development of the traffic, but there had been other causes contributing to what might be fairly described as the wonderful efficiency of Paddington over such a long period of time. Not least was an increase of accommodation due to a cause evidently not contemplated by Brunel, namely, the conversion of the broad gauge to the narrow, a conversion that enabled the platforms to be widened and also an additional platform to be provided. Another important factor was the diversion of some of the suburban traffic from the main-line station into Bishop's Road; while the construction of the Hammersmith and City subway had enabled the lines of that company to be carried underneath the Great Western main-lines instead of as formerly across them on the level. Another important reason was the expenditure of a considerable sum of money on improving the approaches to the station itself during the last 20 years. It was clear, therefore, that the result in question was due to several causes, namely, the great foresight of Brunel, the conversion of the gauge, the construction of the Hammersmith and City subway, and the judicious expenditure of money on improving the railway access to the station. It would be difficult and valueless to attempt to criticize as a whole the scheme described in the Paper. It was clear that an engineer must shape his designs according to circumstances, which in every large city were bound to vary. The great value of the Paper seemed to lie in its suggestiveness. The Author had not failed to emphasize the objects to be striven for which were common to every design, and especially had he called attention to the necessity for provision of auxiliary sidings within easy reach and for freedom of access to the station. Mr. Morgan had contrasted the eighteen platforms and six approach-lines of Liverpool Street Station with the thirteen platforms converging into six lines in a distance of 300 to 400 yards at Glasgow. At Paddington the approved plans for further extension provided for eleven platform-lines converging into four at a distance

of about $\frac{1}{4}$ mile; but there were two, and for part of the way three, additional lines to be used wholly for locomotives and carriages, and for marshalling trains right up to the door of the station itself without interfering in any way with the passenger-lines. With regard to the increase in size and power of locomotives, the modern locomotive was able to haul fourteen and even sixteen eight-wheeled carriages where the gradients were fairly good, and necessitated a length of platform not thought of a few years ago. As to the question of a covered-in roof as against an awning or "umbrella" roof, it seemed to him the umbrella pattern had many advantages; it was utilitarian, and it ought to meet all the requirements of the public, who were apt to be somewhat uncommercially exacting where railway-companies were concerned. With regard to power signalling, he agreed with the Author that, except in special cases—and possibly terminal stations were such cases—the advantages to be gained from the adoption of power signalling were not sufficient to justify its adoption. In conclusion, he wished as a railway-engineer to express his appreciation of the value of the Paper to engineers who might be faced with a similar problem to that so ably described by the Author. Mr. Grierson.

Mr. W. B. WORTHINGTON observed that, while the work described was one of great magnitude, and had been very skilfully carried out, the principles of its design were those which guided railway-engineers generally in the laying-out of terminal stations; and although, as far as he knew, those principles had not before been collected together in a Paper, which would in future be a kind of text-book on the subject, there was little in the Paper that could be criticized. He wished first to congratulate his old friend and former assistant—whom, since he first knew him, he had respected for his thoroughness and ability—on the successful manner in which he had reconstructed a magnificent station, adding to the works of former engineers, Messrs. Blyth and Cunningham, who made the first station, and Mr. George Graham, who carried out the first enlargement. It was interesting to note the parallel which the Author himself drew between the Glasgow station and the New York Central station. Both seemed to have had to be reconstructed once every 10 years, an experience which it was to be hoped would not apply to every large terminal station. He considered that there were four features on which the Author was especially to be congratulated. The first was the fine open platform at the entrance. He could not blame the Author for calling this a "concourse"; it might be a foreign word, but Englishmen had been always in the habit of adopting a word from another language to describe something for which they had no concise term in their own. A concourse Mr. Worthington.

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like that in the Glasgow Central Station was only too scarce in large terminal stations, and no doubt many of them, if they had to be rebuilt, would, notwithstanding Mr. Blyth's criticism as to the uses to which the concourse in Glasgow was put, be provided with such a space. As to its beneficial effect on the working of the station and the comfort of the passengers, there could hardly be two opinions, and he thought Mr. Blyth was probably scarcely serious in his criticism. The second outstanding feature was the excellent arrangement of the approach-lines, the best use having been apparently made of the available area in leading up to the station. It was noteworthy that the Author had thought it worth while to go to the heavy expense of bridging the river with so wide a bridge in order to get adequate approach-lines. The temptation to "bottle-neck" the station over the river, in view of the heavy expense of approach-lines, must have been strong, and he congratulated the Author and those who had found the money on having had the pluck to make the bridge so wide. The importance of sidings for standing carriages as near as possible to a terminal station, in addition to approach-lines, could hardly be overrated. No doubt in busy excursion times the auxiliary sidings would prove anything but too many for dealing with the trains. In that connection he might instance similar accommodation provided at one of the great Lancashire seaside resorts, where the Company, of which he was formerly Engineer, had two large terminal stations dealing with vast crowds of excursionists at holiday-times. In those stations there were sidings solely for the reception of the trains after delivering their loads and the storing of them ready to take up their loads again: for that purpose there were $4\frac{3}{4}$ miles of sidings in one station and $5\frac{3}{4}$ miles in the other. Hence the auxiliary lines in Glasgow were far from being a maximum for what was required in such places. He would be glad if the Author would explain how he arrived at the almost precise mathematical formula that at a point about 600 yards out from the average of the ends of the platforms the ratio of the main through lines to the platform-lines should be "about as one is to two, or rather somewhat less than one-half." He had never heard it put in that form before, but he had no doubt the Author had given very careful thought to the matter and could explain the reasoning more fully. Speaking about getting rid of trains at sidings and storing them until they had to take away the great outrush naturally brought up the question to what extent it was possible to improve upon terminal stations, which as far as heavy suburban traffic was concerned must be looked upon as a necessary evil. There appeared to be three classes of traffic, roughly speaking, to be dealt with: the

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long-distance traffic, the daily suburban traffic with its rushes in the morning and in the evening and subsidiary rushes at mid-day, and excursion traffic. With regard to the long-distance traffic, where passengers were arriving with large quantities of luggage, there was obvious convenience at a terminal station for access to the trains by platforms for luggage and passengers. In excursion-traffic and suburban traffic the same conditions arose; there was an inrush and outrush at one time, and a corresponding outrush and inrush at the other time, at the beginning and end of the day. But the two classes of passengers were of quite a different character. The suburban traffic consisted of passengers who knew exactly where their train was—assuming the train always departed from the same platform—and they went straight to it. In the morning they got out of the train and went straight away. The excursionist going away at the end of a long day of enjoyment, say at Blackpool, was not quite in the same position; he was hurrying along—probably with his wife and several children—to find his train, and it was of great importance that the train should, if possible, be standing ready for him, so that he could be readily sorted out from the general concourse and taken straight to his train. At Blackpool there might be fifteen to twenty trains all standing ready for the people, and obviously it would not do for those trains to be following one another on through lines. Therefore, for excursion traffic the terminal station possessed convenience. But for surburban traffic the proper method of dealing with large numbers of passengers was by a through line, and in respect to that traffic a terminal station was frequently a necessary evil. Sometimes, however, he thought it was not a necessary evil. The ideal arrangement for a terminal station for suburban traffic, using the word "terminal" in rather a different sense, was to have it on a loop, somewhat like the outline of the stem and bulb of a thermometer, so that the train could come in, go round, and out again. It should not have to come into a bay with the engine in front of it, and then have to be pushed out tail first. Even in dealing with traffic electrically worked, although there was not an engine in front, still the train had to be pushed out in the face of the incoming traffic. Suburban traffic ideally arranged would go flowing on in the one direction when it came in in the morning, and in the same direction when it went out at night, and there would be no back shunting. Whether the Caledonian Railway Company, with two terminuses in Glasgow, which it would have been an enormous convenience both to themselves and to the travelling public to have connected as a through route, had considered the possibility of going through Glasgow and joining them together he did not know; but he thought the suggestion

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had hardly escaped the keen vision of the Author, and possibly he would say something about it when he replied. The third and fourth features in the Glasgow station which he wished to emphasize as being good were the low-level parcels arrangements—which were magnificent, and to which the site undoubtedly lent itself—and the equally magnificent, though somewhat criticized, underground lavatories. The Author remarked that there might be some advantage attending the withdrawal of suburban and local traffic from a large terminal station, from the point of view of the possibility of the lines and platforms being more advantageously used in connection with longer-distance and more remunerative trains, and it would appear from the facts in the Paper that the Caledonian Railway Company had had some opportunity of considering those advantages, their traffic having been withdrawn by the competing tramways after they decided to enlarge the station. The subject had become additionally interesting by the publication recently of the first "Report of the London Traffic Branch of the Board of Trade." That Report only came into his hands during the past week, and therefore he had not had the opportunity of studying it as thoroughly as it would have to be studied. There were some points of great interest in it. In the General Conclusions the Report said (p. 74):—

"While, on the one hand, the financial results of the working of the new tube railways have been disappointing, and the effect of electrifying the old underground railways has not come up to expectation,"

—he expressed no opinion on either of those propositions, and it should be borne in mind that the Report applied to London only—

"on the other [hand], the electric tramways have proved that they are capable of carrying a large volume of suburban traffic, and of competing successfully with railways to a limited extent."

That was endorsed by the Paper as far as the Glasgow Central Station was concerned. The Report went on to say:—

"If the roads in which they are placed were widened, tramcars might run at speeds little inferior to the speed of suburban railway trains. The cost of widening radiating roads in the outskirts and making new roads on which tramways might be laid would be much less than the cost of constructing railways of any kind."

That was a suggestion that radiating roads should be widened to permit of tramways running at high speeds for the purpose of competing successfully with the railways. The Report went on—

"For these reasons tramway extension on a large scale, coupled with the unification of the tramway systems and the removal of obstacles to through running, seems at present to offer the best practicable means of dealing with the dense suburban traffic up to a distance of 8 or 10 miles from the centre of London."

He did not say that those propositions were unreasonable, but they did not tend to the enlargement of terminal railway-stations for dealing with suburban traffic. From reading the Paper he had come to the conclusion that the experience of the Caledonian Railway Company would give pause to other companies who might be considering the extension of their terminal stations, for it was not every engineer who was in the fortunate position of the President in having a station which was made something like half a century ago and which had never yet required enlargement. Mr. Worthington.

The PRESIDENT observed that that was not quite the case. The President.

Mr. WORTHINGTON pointed out that he had said "enlargement" and not "improvement." Mr. Grierson had explained the important improvements that had been made outside the station, which had rendered it able to cope with traffic vastly greater than that for which it was originally built. Mr. Worthington.

THE PRESIDENT observed that the moral he had tried to draw from the facts of Paddington Station was simply that a station designed on sound lines lent itself to such additions from time to time as made the whole station more efficient. The President.

Mr. WORTHINGTON agreed, but he thought engineers were not all so fortunate as to be in possession of stations designed on those sound lines. His point was that the Report of the Board of Trade Committee, which applied only to London traffic, would become a text for dealing with traffic in other great centres of population, such as Glasgow, Manchester, Leeds, and Liverpool. He did not propose to say anything about the signalling, as he understood that would be discussed by experts; but the system adopted was far from being new in England, there being other large installations in use. With regard to the "principle in design," every engineer who had had to do with the laying-out of large stations would agree with the Author's view that the design of a railway-station in a great city would in a measure always be governed by the circumstances of environment. It was a very rare thing now in this country for an engineer to have to lay down a large terminal station in a green field; it usually fell to his lot to have to fit his station or enlargement into a site which was hampered in every direction. It appeared to Mr. Worthington that that was just where the engineer came in, and it was in that respect that the Author of the Paper had carried out his task with such conspicuous ability and success. Mr. Worthington.

Mr. G. A. HOBSON considered that the Author had taken a comprehensive grasp of the intricate problem with which he had to deal, and had thereby won the highest credit. He wished to say a word of appreciation of Sir John Wolfe Barry's attitude in giving Mr. Hobson.

Mr. Hobson. magnanimously the full credit for the work to the Author. The honour thus given to the Author was to a considerable extent reflected upon Sir John. Even the youngest engineer understood how helpful and welcome was the counsel and support of a man of Sir John's calibre in times of stress and perplexity. He had never seen a subject better displayed in respect of both Paper and illustrations, and as the last speaker had observed, the Author had gone so minutely into the question that he had to a certain extent disarmed, or at any rate anticipated, criticism. However far the Glasgow Central Station extension might fall short of being an ideal structure, it certainly was not the Author's fault, and it would be difficult for even an expert, without going deeply into the circumstances of the case, to say how it could be designed better or the work be more successfully accomplished. It was clear a very difficult site had had to be contended with, and the Author had had little freedom of choice and not much liberty of action. Ample auxiliary sidings outside the station, facilities for the simultaneous movement of as large a number of trains as possible, and a modern power signalling system, were indispensable features, about the necessity for which there could be no two opinions. So, also, were turntables. Other things were more matters of taste and opinion. Even the question of columns on a platform was not a vital one, and the roof could have been designed in more ways than one with practically the same result. He did not like the view of an almost interminable succession of bottom flanges of transverse girders which had a somewhat depressing effect, from their solidity and heaviness; although the Author had avoided the very depressing effect of one of the Glasgow stations by substituting for the horizontal lines a graceful curve, which was certainly a great improvement. He had doubtless been compelled by the peculiarity of the site to adopt a transverse system of girders for carrying the principals. Mr. Hobson preferred the longitudinal system, where the ridges of the roof and the supporting girders ran parallel with the longitudinal axis of the station; but the site in question was so irregular that the longitudinal system was scarcely applicable. That system, as was proved by recent stations built on those lines, really presented a lighter and a better effect generally. It might be said that, the greater the span and the height of the roof, the greater the cost; and beyond a certain limit he thought it might be also added, the greater the mistake. It was doubtful whether ventilation in a high roof was better than in a low one, because the less distance the smoke of the locomotives had to travel to the outlets, the sooner it escaped. In a very lofty roof it probably never got out at all, but hung about underneath, giving the inside of the station a

gloomy and cavernous appearance. Was there any sufficient reason why there should be a covering over the railway-lines at all? Personally, he thought a covering was not indispensable. It was to a certain extent a matter of climate, but in all cases there would be more light, more air, and better air without it. A well-designed awning over the platform, and a glass-covered roof over the concourse, enclosed at the sides, would provide all that was absolutely necessary and all that comfort and convenience could demand. Whether the climate of Glasgow would permit of such an arrangement only the natives could decide. In the south of England the arrangement would no doubt do quite well in most cases. The objections to it were, that such a station would be draughty and would not have that magnificent appearance that some people desired; but it should not be forgotten that a terminal station was generally completely walled round and to that extent was protected from draught. The Author might well grudge the floor-space occupied by the cab-rank, because it occupied the room of two or three lines and sacrificed the edges of two platforms, and it also gave rise to the unpleasant odour of the stable. The corkscrew entrance and the exit were at the same end of the cab-rank, and that meant that all the cabs had to turn round—by no means an ideal arrangement. Could not the Author have removed the cab-rank from the inside of the station, and have provided for one by doubling the width of Argyle Street and by slightly altering the stairs on the platforms, and perhaps the subway? By that means he would have secured a circulation of wheeled traffic through the streets of Glasgow, and would also have had increased accommodation in the station. With regard to the unpleasant smell, he remembered that in one of the stations of Glasgow the odour on a very hot and stuffy day was positively nauseating; and if the cab-rank could be moved to the outside of the station it would be very much better. Philadelphia station, to which the Author referred, was a very fine example of a double-floor station, and for beauty and comfort it had no equal in this country. With regard to the concourse, he did not agree with the remarks made by Mr. Blyth, and was inclined to think, with Mr. Worthington, that Mr. Blyth could not have been serious, because it was essential to the working of the station to have a large circulating-area, or gathering-ground, and all modern extensions went to prove that. Waterloo could not be worked without a large concourse, and the fine one lately brought into use at Victoria Station was of great value. Marylebone Station,[1]

Mr. Hobson.

[1] G. A. Hobson and E. Wragge, "The Metropolitan Terminus of the Great Central Railway," Minutes of Proceedings Inst. C.E., vol. cxliii, p. 84.

Mr Hobson. with which he had had something to do, had a fine circulating-area 100 feet in width and about 300 feet in length. The Author had said nothing about the cost, and Mr. Hobson did not blame him. The work had been carried out under extreme difficulty, and was not comparable with work carried out under normal conditions.

Mr. Fox. Mr. Francis Fox remarked that the mention of Paddington took him back to the days when he played on that area as a child, at the time when the roof was being put up for Mr. Brunel by his late father, Sir Charles Fox, who a few years before had designed and put up the roof of Euston Station for Mr. Stephenson. Afterwards he constructed the great roof of Birmingham station which had a span of 212 feet. His father-in-law, Mr. Francis Wright, built the roof of St. Pancras Station for Mr. Barlow, and finally his own firm, with the assistance of their colleague, Mr. Hobson, constructed the station at Marylebone. With regard to the length of stations, the tendency since the introduction of corridor-trains was for the length of platforms to become inordinate; in some stations the length was so great as almost to necessitate an electric tram or a *platforme roulante*. As to the very onerous conditions imposed upon railway-companies by municipalities, it was asked why English railways cost so much. The answer was very largely this, that if the demands of corporations and public bodies could be eliminated, and also the demands of large landowners, the cost of lines would not compare unfavourably with the cost in other countries. Several cases had come to his own knowledge in which a landowner had alleged that the property through which the railway was passing was a building-estate, and had asked to have bridges built wherever a street was laid out on some imaginary plan. In order to get the Bill through his conditions had been conceded, but so soon as the Royal assent had been obtained the landowner would come and say, "How much will you give me to let you off building the bridges?" That was nothing more nor less than—if he might be permitted to use the word—blackmail, and was a very unpleasant condition of things to have to deal with. The Birkenhead Corporation put in a clause that they were to receive £50,000 as compensation for the loss of their traffic owing to the Mersey Railway—a loss which it was suggested would occur to the ferry-boats; but the first thing they did was to put on very powerful ferry-boats and run in competition with a work that had proved of enormous public utility but which commercially, owing to the Corporation's action, had unfortunately been a failure. Referring to the conditions that were imposed upon promoters by the legislature, it was at one time considered that a deposit of 5 per cent. on the estimated cost was a

sufficient guarantee of the *bona fides* of the promoters, but now the Chairmen of Committees would say in effect, "You must put into the box a witness who will guarantee that the whole of the capital shall be forthcoming when wanted." That was all very well with large companies like the North Western and the Great Western, but it immediately stifled enterprise, and no financier would go into the box actually to guarantee the payment of the whole thing. Another thing which militated very much against enterprise was the blocking of Bills by Members of Parliament. It was a very serious position of affairs. In one case, one of the largest railway-companies in England lost their Bill, and the work which would have been given to the working classes in Lancashire, in Yorkshire, and in Wales and elsewhere, had to be postponed for something like 2 years, simply through some little misunderstanding about a building in the City of London. More co-operation and assistance should be given by the public bodies and landowners, and by people who were interested in the success of the lines, and then work would be more abundant. Mr. Fox.

Mr. HENRY WARD observed that it was probably unusual for anybody in The Institution to defend municipalities, and it might be somewhat of a change if the members heard a few words from the municipal side of the question. Although he was an engineer, he spoke that evening rather from his experience as a member of the London County Council and of the Metropolitan Water Board. As an engineer it had been his duty in times past to design and lay out certain railways and works of this sort, and then he could see the railway side. Now, as a member of a municipality, he thought he was able to see the other side, which he hoped to place before the members that evening. The Author very mildly attacked the Glasgow Corporation for having demanded £175,000 for certain things which the Paper was not very clear upon, but which were called concessions. Such a thing was not known in London, and he did not think that could be quite the meaning of the £175,000 which the Glasgow Corporation had obtained from the Company. He had no doubt that the Glasgow Corporation and Glasgow itself had suffered very largely by the making of the railway. Engineers had only to look at the plan and think for one moment—putting aside the fact of being railway-engineers and looking at it from the point of view of municipal engineers—to see what the effect was. Argyle Street, for instance, was the Oxford Street of Glasgow; he knew it more than 30 years ago when dock-making in that neighbourhood, but if he went to Glasgow now he did not think he would recognize it. In the middle of the main Mr. Ward.

Mr. Ward. street of Glasgow there was now a tunnel about 300 or 400 feet long; no light or air in the whole of that length. He was bound to say that if any company were to come forward to the London County Council and suggest that a London street—and that a main street in the City—should be covered for 350 feet of its length, there would be very small hope indeed of their Bill passing. Then, as to the material injury a municipality suffered from such works. It was all very well for engineers to speak of the advantages gained by the public. He was not one to underrate those advantages, but the plan showed a railway 21 feet above the street with another railway crossing at right angles 23 feet below the street, and the question was, what was to happen if a municipal engineer afterwards wanted to carry a sewer or gas- or water-pipes through. Where would his levels be? London had suffered very gravely indeed as the result of many of the great engineering works that had been carried out. He was not going to say that the total good was not greater than the evil, but the harm suffered as a municipality was very great. Take, for instance, the main-drainage works upon the doubling of which London during the last few years had been spending some millions sterling. It was desired to have storm-water sewers from the high ground in the north direct to the Thames, and on the route it was necessary to cross the Metropolitan Railway on the north and the District Railway on the south. The roof of the District Railway ran at about the level of high-water mark alongside the Thames for a considerable distance, with the result that the storm-water sewers which ought to enter the Thames at various parts along the Embankment were absolutely cut off from all communication by gravity with the Thames. It had been necessary to make drainage-works far more expensive than they would otherwise be, largely by continuing to carry the storm-water down to Old Ford and there raising it by pumps so that it might flow by gravity to Barking. Engineers had naturally thought perhaps that siphons would be possible under the railway, but the amount of sand and detritus brought down by sewers was so large, especially in flood-times, that the siphons would be stopped very quickly. Sir John Wolfe Barry had attacked the municipalities generally and London in particular, and had said that the Corporation of Glasgow considered Argyle Street almost sacred. All Mr. Ward could say was that any corporation which allowed 350 feet of a main street to be made into a tunnel without asking for some compensation at any rate from the railway-company—who after all were trading for private profit and were not a philanthropic institution—would be grossly neglecting its duty. When a railway-company did such injury to a city as they had done in

Glasgow, they should be called upon to pay some compensation. Turning to tramways, which had also been attacked, he was afraid Sir John Wolfe Barry had taken his facts rather from some unreliable newspaper than from any accurate source. He hoped there was no representative of the Glasgow municipality present, as otherwise he was afraid he would be taking upon himself, in what he was going to say, a defence which he ought not to take. Sir John had stated that the tramways were run with the assistance of the rates—largely paid by the railway-company itself—that they were not conducted on the same principles as a commercial undertaking, and that the fares were fixed on a scale that no commercial company could think of working at, thus penalizing the railway-companies. So far from any of those facts being true, the truth lay almost in the opposite direction. He had looked up the balance-sheet of the Glasgow municipal tramways, which had been charged with the whole capital cost of their construction; on that sum they had paid interest, sinking-fund, and every possible charge; and yet after paying all expenses, ordinary running-expenses, they had made last year no less than £400,000 profit. They applied that profit to all sorts of uses: £53,000 went to interest, £68,000 went to sinking-fund, £100,000 went to depreciation-fund, and £88,000 to permanent-way renewals, and £35,000 was placed to the "Common Good" fund. Apparently they did not know what to do with the balance. The tramways of Glasgow were abnormally successful, so much so that he could not understand Sir John Wolfe Barry's suggestion that they were being run at the expense of the rates. Turning to the special way in which London had suffered by the operations of the railway-companies, he had dealt with the main-drainage system, the cost of which had been largely increased owing to the railway work, and would like to point out now a few other facts. He did not say that it was not good for all concerned, but unfortunately the person who suffered by the operations of the railway-company was often not the person who gained. He did not wish merely to refer to the 300- or 400-foot tunnel in Argyle Street, but every parallel street there appeared to be turned into a long tunnel. The next street had a tunnel of about 300 feet, and the next one of 250 feet, and right across the plan there was a series of streets made into tunnels. In London there was a somewhat similar case in a work in which Sir John Wolfe Barry himself was interested, in Bermondsey. The municipality had to make a street going southward from the Tower Bridge and had to pass under the London, Brighton and South Coast and South Eastern lines, twelve lines broad. The tunnel was not as long as those in Glasgow,

Mr. Ward.

Mr. Ward. but was about 120 to 140 feet in length. Anyone who would go to Bermondsey and see how Bermondsey was made still more squalid by that dark and dismal hole would think the inhabitants of the district only right in demanding some compensation, even though some other inhabitants of the United Kingdom gained advantage by that railway. He had been on the London County Council now for 16 or 17 years, and during that time about half a dozen different deputations had come forward urging the Council to build a railway-bridge across the District Railway at Cromwell Road. For a length of about $\frac{3}{4}$ mile there was no crossing of the railway, and the district was divided into two by a deep cutting. The bridge would cost £150,000 to £200,000, and again and again the deputations had been told that they could not have what they wanted because the expense was too great. That expense was solely the result of the operations of the railway-company, and he did not think railway-engineers could have fully taken that into consideration when they came into a large town and divided one part from the other by a huge cutting. Sir John Wolfe Barry had also complained that railway-companies were met with objections when they wished to take portions of parks and open spaces. Mr. Ward for one was very glad indeed that there were some municipal bodies now who were determined to look better after the common good than some of these bodies had done in the past. At Wandsworth Common the railway-company had split a magnificent open space into two by driving a cutting right through. Of course, as a railway-engineer, if he desired to make a railway he would draw the lines as far as possible through a succession of green-coloured spaces on the map, knowing that he would have to pay little for land, comparatively speaking, and nothing for buildings or trade compensation. London had suffered in the past. A great deal of open space had been lost because corporations did not look after the public good so well as they should have done, and in that respect he thought he had shown that there was something to be said for municipal action at the present time. In conclusion, he might mention that the London County Council desired to extend the tramways down the Mile End Road, but found that the District Railway brought the roof of its tunnel within about 2 feet of the crown of the road. As about 2 feet 6 inches was required for the conduit, this rendered the tramway almost an impossibility, or if the tramway were built it would be necessary to alter the roof of the railway or to try some other system for the tramway. It seemed to him that was another case where railway-companies would have to consider, when they were condemning municipal authorities, whether those authorities were not

right in looking a little ahead and seeing whether they would not in the future require to undertake some of those public works and whether the works of the railway-company's engineer would not add largely to the cost of the municipal works. Mr. Ward.

Sir ALEXANDER BINNIE, Past-President, would not have risen to take part in the discussion except for what he could not help thinking was a lapse on the part of his friend Mr. Ward. Mr. Ward had put his case in a very trenchant manner with regard to the iniquities of railway-companies, but had forgotten to state what the London County Council had done itself. When the first tube railways were brought forward, a very important Committee met under the presidency of the late Lord Farrer—a public servant revered for his long services to the State and to the County Council—and the result of the deliberations was that it was to the interest of the County Council to promote and facilitate, in every possible way consistent with the preservation of the public rights through the public streets, the construction of lines of traffic into and out of London. That resolution was carried without a single dissentient, and it then became a question how the London County Council could best assist those who were proposing to construct underground railways in London. Very little deliberation was necessary to arrive at the state of the law with regard to the County Council itself. Under the Metropolis Management Act of 1855, which governed the work of the Council, the Council could construct sewers anywhere that it thought proper without going to Parliament and without paying for the land or for the easement when they passed through private property, merely paying the owner of the land for any damage that might be done. For many sessions of Parliament he, as the exponent of their views, pleaded that case before Committees—that the underground railways of London should have the same right which the Council possessed, of passing under private property without paying for the land but merely recouping the owner for any damage done. As the witness of the County Council he was on every occasion cross-examined in a somewhat severe manner: but no attention had ever been paid by Private Bill Committees, although recommended by the Joint Committees of Lords and Commons that had sat on this important subject, to carry out that useful suggestion of the County Council which would have saved the underground railway-companies in London many hundred thousand pounds now added to their capital. Sir Alexander Binnie.

Mr. R. ELLIOTT-COOPER, alluding to the remarks of Mr. Ward, thought he might claim that he did not take an extreme view on either side. When associated with railways he always tried to Mr. Elliott-Cooper.

Mr. Elliott-Cooper. look at the subject, to a reasonable extent, from a municipal point of view, knowing that the general public must be considered. But a railway was just as much a public undertaking—even if it was initiated and carried out with a view to private profit—as any work of a municipality. In many foreign countries railways were Government undertakings, and their works were carried out in a manner that would make the hair of a municipal councillor in England stand on end. Yet what was the result? They had magnificent stations, built at reasonable cost, because they were able to make the public understand that they could not have a great railway-station built for their convenience, with all its attendant advantages, without the stopping-up of a street here and there being entailed by the work. In Glasgow undoubtedly a very large area had been covered in building the station, and certain streets had unfortunately been made much worse from a traffic point of view: but contrasting the number of people who were inconvenienced by reason of the covering over of those streets, with the number of people who received the enormous advantages of additional facilities for getting out of Glasgow into the surrounding country—he was perfectly certain that if he put the ratio as one to ten he would be well within the mark—it was very unfair that corporations should forget that side of the question of moving people from the centre of the town, and dealing with the general traffic of the district. The municipalities were of opinion that that could very well be done by building tramways, and they used perhaps three-fourths of a street for the purpose of enabling the public to get cheaply and conveniently from one point of London to another. Speaking not as an engineer but simply as an inhabitant of London, he would infinitely rather go under one of these bridged Glasgow streets two or three times than drive along the Westminster Bridge Road at the east end of Westminster Bridge. He was told that a man must not expect, because he was fortunate enough to possess a carriage, that his personal inconvenience was to be in any way considered when there were multitudes of people able to get to their homes quickly and cheaply by the tramways. Exactly the same thing occurred in Glasgow. Why should not the people who desired to use the roads which were now practically made into tunnels be inconvenienced to that extent, in the same way as a man was inconvenienced who wished to drive along some of the streets now made practically impassable by the County Council tramways? He did not complain, because everybody had to make the best of the world in which he found himself, and there had to be a little give and take; but the manner in

Mr. Elliott-Cooper.

which the municipal authorities and Government departments made railway-companies pay exorbitant sums for very little return was extraordinary. He did not think the practice really attained its object, because it simply hindered development which would be of the greatest advantage to large towns. About 10 or 12 years ago he constructed a rather large terminal station in Chesterfield, where about 6 or 7 acres of the worst slums imaginable, covered by a large number of so-called houses, were cleared, and the Local Government Board, working with the Corporation of Chesterfield, made the company build what might almost be called a little suburb, for the housing of the working classes displaced by the work. So many cubic feet of space had to be provided in each room, and there were little gardens with tiled walks in the front. The new houses cost about £350 each, and about £16,000 was spent by the railway-company in building that little village about a mile away from the site of the slums; and when that had been done it was found utterly impossible to get a single person who had lived in the cleared area to live in these little palaces. Although provision had to be made for the displaced people, there was nothing to prevent the company from selling the whole of the new buildings afterwards, and the place had since been sold and was now occupied by working classes of quite a different kind from those displaced. But the company obtained only £7,000 for what had cost them £16,000 and in addition they paid an exorbitant price for the land upon which that portion of the station was built. He did not complain of what Mr. Ward had so forcibly put forward, that compensation ought in some cases to be paid; but in a matter of that kind the compensation was paid to the public, represented by the municipality, by a body—namely, the railway-company—which represented another class of the public. The fact that the railway-company was a private undertaking was no reason why its usefulness to the public should be forgotten. With regard to the well-known case of Cromwell Road, when that railway was built there was practically not a house on the west side of the railway. There was nothing to connect, and there was no reason to suppose that there would be anything to connect. The company had served its purpose for all those years, and by the travelling facilities given had been largely instrumental in bringing about the development referred to, and it was not unreasonable that the public should now pay for a connection across the railway if it was required. It could not be said that the railway-company had created a gulf between east and west, because when the railway was built there was nothing on the west. Probably the reason why local authorities were now

Mr. Elliott-Cooper. asking for 40-foot roads to be built over or under railways was because possibly at some remote date the land on either side might be turned into building-land. He did not think it was fair or reasonable to expect private money to be sunk in that way in what he was bound to call a public undertaking. With regard to the use of open spaces, he did not know whether Trafalgar Square was included in that category, but it certainly seemed that the arrangement that had been made there for giving access to the Baker Street and Waterloo Railway was infinitely better, even from a general point of view, than the buildings which served as stations of the tube railways. These stations had gone a long way towards rendering non-profitable undertakings which ought to be profitable, and which were certainly of great public convenience. No possible harm could have been done by following the system in Paris and allowing a little strip of the park or other open space to be used as access to an underground station. In Paris, along the Rue de Rivoli there were to be seen little railed-in spaces giving access to underground stations, and they were much more sightly than a building in the middle of a row of houses, a building which was incongruous, expensive, and served no other purpose than would have been served by small railed accesses to underground stations. Referring to the Paper, and speaking as a passenger, he entirely agreed that a station with access to the platforms from the end was much more convenient than a station with side entrances. In London, the new Victoria Station was a very good example of direct access from the street to the platforms instead of having to go round.

Mr. Walmisley. Mr. A. T. WALMISLEY pointed out that although a railway might not be public property it was described in the Act of Parliament as being constructed for local and public advantages. With reference to the remark that the Underground Railway of London had interfered with the carrying of storm-water drains directly into the river, it should be remembered that the main sewers of the metropolis running east and west had also stopped underground railways until the advent of tube railways, so that the argument that had been advanced cut both ways. The form adopted for the roof of the Glasgow station was commendable in so far as it afforded facilities for getting to the roof-covering for the purpose of repairs; every part was accessible to the painter's brush, an important matter where corrosion was liable to take place. At Smithfield, under the Central meat-market, the girders over the railway, not being entirely covered with concrete, had become greatly corroded where exposed, and it had been very difficult to arrive at their strength because it was impossible to say what unit stress corroded metal

would safely sustain. The City authorities had had to provide relieving girders on either side, as it was impossible to replace some of the girders on the platform on account of the superstructure of the markets supported above. The effect of corrosion had been serious upon the exposed material, which was subject to the influence of sulphur and moisture, the moisture serving to convey the corroding influence along the girders. Electric traction where introduced would of course considerably minimize the effects of such corrosion. As a contrast might be mentioned the roof over the Albert Hall. He examined that roof a little while ago, after it had been standing for 40 years, and he found no corrosion at all, simply because it had been constantly cleaned and painted, and was not exposed to sulphurous fumes. The structure, although not of the girder type, contained trusses held together by a connecting ring in the centre and a curved curb round the top of the wall, and there were a number of tie-bars in the radiating principals to this roof. In painting a roof with tie-bars the men often put the planks over the centre of the tie-bar, producing a cross-strain which the bar had not been calculated to bear and a deflection which was very detrimental. Planks for painting a roof of that sort should be slung up from the attachments. In the Albert Hall there were proper platforms to every principal, and the whole covering was quite easy of access; and thus it had been possible to maintain the roof and keep it in proper repair. With regard to columns, a roof without columns enabled the lines and platforms to be shifted, if required, without affecting the roof-covering, and that was the reason St. Pancras Station was built with a single span. The effect of intermediate columns was well shown in the case of the London, Chatham and Dover station at Victoria, where the central columns were in the centre of the narrowest platform. The roof of the old Bridge Street Station in Glasgow was built upon transverse parallel lattice girders 12 feet deep and 31 feet 6 inches apart, but in order to reduce the effects of corrosion there were uncovered spaces in the transverse girders over two lines of rails of 21 feet, so that the locomotive smoke could escape through the roof, the platforms being protected by flat vertical screens on either side running longitudinally. That was a method that might be copied in other stations where it was not considered advisable to confine the covering to roofs over the platforms.

Mr. Walmisley.

Mr. CHARLES HAWKSLEY, Past-President, considered the extension to be a striking example of a work carefully thought out from beginning to end. In many stations the general design was prepared, and many of the accessories were left to be put in

Mr. Hawksley.

Mr. Hawksley. afterwards as well as possible, with the result that the work was often not satisfactory. A good example of the attention paid to details in the Glasgow station was the train-indicator, which, although perhaps not a great thing in a station, was often of the first importance to passengers, and which in the station under consideration was arranged so as to be visible from a considerable distance, even when there was a crowded concourse. With all that care and attention to the utilitarian requirements, the Author had not lost sight of the æsthetic in so far as it was possible to combine it with due regard to the requirements of the structure. The work was one of great utility and convenience, both to the passengers who used the station and to the officials. That had been combined with a pleasing appearance, which was something he was afraid engineers very often disregarded. As an early example of care and attention in that respect Paddington Station might be instanced, designed by Mr. Brunel, and now under the care of the President. He commended the Paper to all students, whether intending to follow railway practice or not, and would draw their attention to that part of the Paper dealing with the principle of design, and more especially to the remarks of the Author on pp. 67 and 68. When he had had the pleasure of addressing students he had always endeavoured to impress upon them the necessity of studying appearance as well as good engineering construction.

Mr. Brereton. Mr. CUTHBERT A. BRERETON considered that some of the remarks which had fallen from Mr. Ward appeared to be of a somewhat personal character, although he had no doubt that was unintentional. It was only right to say—and he was sure every member would agree—that Sir John Wolfe Barry was not in the habit of making statements which, at all events, he did not believe to be correct. However, whether the Glasgow tramways paid or not did not affect the point in question; the real issue was that those works, like all other municipal undertakings, had been paid for originally with money provided on the security of the rates. If there was any failure in the undertaking the loss fell on the ratepayers, of whom the railway-companies, as a rule, were among the largest. If, on the other hand, the venture succeeded, it was generally at the expense of the railway-companies, by the abstraction of traffic which would otherwise have been carried by them. Therefore it was a case of "Heads I win, and tails you lose," which was obviously unfair. Mr. Ward had said that the Metropolitan and the District Railways caused obstructions to other works in London. It should, however, be remembered that the District Railway Company had to pay £200,000 for leave to go along the

Embankment, and now the line had to compete with tramways laid above it. Mr. Ward had also complained that in constructing the Whitechapel and Bow Railway, Mr. Brereton had omitted to leave room for the conduit system of traction; but it must not be forgotten that the plans and sections of every yard of that line had been submitted to and approved by the London County Council, and if at that time they had had any intention of putting down such a conduit system he would have done what was possible to meet them in the matter. If Mr. Ward had seen the innumerable sewers, pipes, and drains, and had understood the difficulties that had to be contended with, he would have seen that the railway company had rather more cause for complaint against those who had laid the sewers, etc., than the County Council had against the construction of the railway. The fact of the railway being near the surface had given them the opportunity of trying the stud system, which, however, did not appear to have been a success. Those who had had an opportunity of seeing the Glasgow extension under construction could well realize all the difficulties with which the Author had had to contend in the actual carrying out of the details of the work. The sections showed the complications that had to be dealt with along Argyle Street, but that was only one instance. In view of the nature of the foundations and the general difficulties met with, the manner in which the work had been carried out, without interrupting the traffic of the railway or the streets, reflected the greatest credit on those engaged in it. Mr. Brereton.

Mr. ALEXANDER SIEMENS observed that one section of the Paper had been hardly touched in the discussion—that referring to the signalling. It would be seen that the section of the Paper which dealt with the signalling was written in a different style from the other sections. The other sections, as Mr. Worthington had said, might serve as a text-book on terminal stations, but in the signalling section the Author was neither as definite and clear, nor as sure of his ground, as he was in the other sections. Speaking of the power system of working the signals, the Author said that the decision had to some extent been influenced by consideration of the inconvenience which would have resulted from there being more than one block section, and he spoke about the annual value of the efficiency of the station being increased, and mentioned that with the power-system the scheming and arranging of the permanent way was facilitated. He went on to speak about the "inestimable advantage," mentioned that he was able to dispense with point-rods, cranks, and signal-wires, and stated that the difficulties connected with the manual system would have been insuperable at the Central Station. The power system had Mr. Siemens.

Mr. Siemens. enabled him, he said, to lay at least one additional single line of rails across the river. The conclusion drawn by the Author was the following:—"With a power system the annual costs of maintenance are greater and the cost of working little, if any, less than in the manual system. There are, however, compensating advantages with a power system, amongst which are greater efficiency in the working and increase of the capacity of the station. In a terminal station—but in a terminal station only—with power working, the balance is on the credit side." It seemed rather curious that after the Author had spoken about the inestimable advantage and had shown that he had been able to lay an additional line of rails on the bridge, and so on, he should conclude so lamely. Why did he confine the advantages of a power signalling-system to a terminal station? All that he had said in the Paper would just as well apply to a through station. Supposing for one moment that the Central Station was connected with the Buchanan Street Station of the Caledonian Railway, the saving would have been exactly the same, the position of the signal-box on the bridge, which the Author said could not possibly have been occupied by a manual box, would have been exactly the same, and the Author would still have required three manual signalling-stations instead of one power-station. Therefore the Author was not at all justified in confining the advantages of a power system to a terminal station. The conditions under which power signalling was advantageous were exactly what the Author stated. If it was possible to save space, or if for some reason it was necessary for the station to occupy only a narrow space, power signalling was the right thing to use. Even a small power signal-box might be of advantage if it replaced two or three manual boxes. Therefore in that way the Author did not really do justice to the power signalling. What had he to say against it? He said that the cost of maintenance was high. That was curious, because the Author was singular in that experience. The signalling-engineer of the Midland Railway, who was present, had had the Derby station under his control for 4 years, and no doubt be would be able to say what the cost of the maintenance of a power station was in comparison with that of a manual station. It was the same at Didcot, where Mr. Siemens did not think the cost of maintenance was any higher than in a manual station. On the contrary, as far as he knew, at Didcot the ordinary man in charge of the electrical-power box was found to have so little to do that, to put it in an Irish way, the Company had given him an assistant and put two other boxes under his control. The maintenance question was entirely in favour of the power system.

Mr. Siemens.

The Author stated that power stations were comparatively new. They might be new to him, but the all-electric system, in which Mr. Siemens's firm was particularly interested, was first installed in 1894 in Prerau, and since then it had been applied in 110 stations and there were over 12,000 levers at work; so that it was not quite a new system. The same remark would apply to the Westinghouse system, which had been in use for a very long time. To one paragraph in the Paper he strongly objected, namely, that in which the Author said that the power systems were all comparatively new, and that no reliable information could be obtained as to either their first cost or the cost of their maintenance. In the Bulletin of the International Railway Congress for 1904 there was a Paper[1] by Mr. Weissenbruch, who was the Signal Superintendent of the Belgian State Railways. That gentleman was not interested in any particular system, and in his Paper he investigated the question from the beginning and went into all the details of the various power systems on their merits. If the Author had looked at the Paper, which no doubt the railway-companies had filed, he would have had a great deal of information on the subject. The Author went on to say, "It was therefore determined to experiment, and, after exhaustive trial of five systems, having special regard to the cost of maintenance, it was concluded that the Westinghouse electro-pneumatic system was in all respects best suited to meet the circumstances." Anyone reading those words and not knowing the conditions of the trials would certainly regard the statement as an excellent testimonial for the Westinghouse system, and every British railway-engineer would be justified in saying, "Well, why should we trouble about the other four systems? Here exhaustive trials have been made, and the Westinghouse has proved the best." Considering that the system of his firm was one of the five, Mr. Siemens felt hurt; he thought the Author was not quite justified in using that language. Everybody would conclude that the five systems had been tried in the open or under working-conditions, and that the cost of maintenance had been really ascertained by actual experience. But the experiments were not conducted in that way. A pair of points, two signals, and the frame and other appliances forming part of each system were put in some of the vaults under the station, where an inspector was told off to make so many thousand movements per day with each system. Those experiments, of course, were useful, and they probably convinced the

[1] "Electric Interlocking of Switches and Signals at Antwerp Central Station." Bulletin, etc., p. 651.

Mr. Siemens. Author that some of the systems were, mechanically, not fit to be tried in the open; but the Author himself stated, and showed on the plan, that for the pneumatic system an additional power-station was necessary, and it would be seen that it was the same size as that required for the generating-plant of the hotel and the station. What Mr. Siemens maintained was that the maintenance of that plant was an integral part of the maintenance of the Westinghouse signalling-system and ought to have been taken into account. To give a rough comparison between the two systems, the Westinghouse system had exactly the same electric conductors and the same electrical contacts as the all-electric system, but at the points and signals the currents did not work motors but electro-magnets, which actuated valves which in their turn admitted air to the main cylinders. It was therefore possible to put an all-electric frame in the place of the Westinghouse frame and work the system, or to replace the pneumatic piston which worked the switches at the points and the signals by electromotors and use the Westinghouse frame for working them. In addition to the electrical appliances needed in an all-electric system, the pneumatic system required a main for the compressed air and the motor-compressors and other paraphernalia. It was a question, of course, of general interest how an engineer like Mr. Westinghouse could make such a complication, because to any impartial man it was surely apparent that it was useless to have two sources of power for working one set of apparatus, when it was possible to do all that was needed from one source of power. The only explanation appeared to be that Mr. Westinghouse was an inventor, and inventors had a habit, when they had a good idea, of applying that good idea everywhere, on the principle "There's nothing like leather." Mr. Westinghouse found that compressed air was excellent for railway-brakes, and asked himself why it should not be excellent for railway-signals. Of course, one reason might be that at the time he designed the system there were no cheap small electric motors in the market. He did not think an engineer of Mr. Westinghouse's ability would go in again for an electro-pneumatic system if he had to do the inventing at the present day. He would suggest to the Author that his words "exhaustive trial of five systems, having special regard to the cost of maintenance," were really not quite correct, and that when the Paper was printed in the Proceedings a footnote ought to be added explaining exactly how the experiments were carried out: then it would be seen that the conditions under which the experiments were made were absolutely artificial and not at all such as to give a correct idea of the cost of maintenance.

Mr. W. WILLOX observed that there was one consideration in connection with the extension of a large station that had not yet been mentioned in the discussion, a consideration which had been taken into account in the enlargement of stations abroad, and which was illustrated by two cases in England, namely, the possibility of spending money on the electrification of the trains instead of on costly land and works for the extension of the station itself. One of the cases in this country was the Exchange Station at Liverpool, which he understood would have cost a great deal of money to enlarge and the enlargement of which had been avoided by electrifying the line between Liverpool and Southport. The other case near at hand was London Bridge. That station would be extremely difficult to widen, and the Brighton Company were trying to use it to better effect by electrifying their suburban line. No doubt long platforms were necessary for main-line traffic, but for suburban traffic he could cite instances which showed that short platforms could deal with a very large traffic. Baker Street East, the terminus of the St. John's Wood line, was a small station with only three lines and four platforms. The Author said there were 550 booked trains in Glasgow Central Station per day; at Baker Street East there were 520. The total number of passengers using the Glasgow station in the year was under 22 millions; at Baker Street East there were just under 18 millions. Another case was Aldgate, with two through roads, two bay roads and four platforms. There were 322 through trains per day, 404 booked trains in and out of the bay roads, and 104 trains passed through the junction just at the end of the platforms to the left. That showed clearly that an enormous number of electric trains could be dealt with where there was no shunting. With regard to the cost, no figures were given in the Paper, the only sum mentioned being the £175,000 extracted from the Company by local authorities. Judging from its size he would say that the Glasgow Central Station had cost about £1,500,000. Victoria Station was said to have cost £2,000,000. Supposing, however, that the Glasgow station cost a million and a quarter; if he might give, not an estimate, but actual figures in round numbers, for something less than $1\frac{1}{4}$ million it was possible—and it had been done when electrification was more in an experimental stage than it was now—to provide a power-station giving a daily average of 140,000 kilowatts to electrify 20 miles of double line with upwards of 40 miles of cable carrying 11,000 volts, and to provide eight sub-stations to reduce the 11,000 volts to 650 volts, forty-eight six-coach corridor-trains, twenty electric locomotives, and sheds for housing twenty-four trains. The six-coach corridor trains

Mr. Willox.

Mr. Willox. were not very convenient for London traffic because of the difficulty of getting people in and out, but the cost of electrifying a train of seven good bogie-coaches, which could be cleared in about 15 seconds, only came to about £4,500. With regard to power signalling, it seemed a strange thing that there should be any doubt of its efficiency for a place like Glasgow Central Station, especially if track-circuiting and illuminated diagrams were employed. It saved a great deal of space and had a much longer reach than manual signalling. The signal-box could be put almost anywhere. In one case on the City lines a signal-box controlled the shunting with a scissors crossing and two roads and a junction to the main line, and the box was in such a position that the man could not see the shunting, which took place in a tunnel right away from him; but by means of an illuminated diagram he could see every movement of the trains. In time of fog the power signal-box with an illuminated diagram showing all roads in the station was a very great help indeed. There were no bells to distract the signalman's attention and his physical labour was much reduced. He quite agreed with Mr. Siemens in thinking that two separate powers were a waste. He had had some experience of estimates for the two and also with the working of them. On the Metropolitan Railway there was one junction worked entirely with the all-electric system, where there were 880 trains passing through in 20 hours of the day with almost perfect punctuality. There were other systems of all-electric signalling, one of which the President was no doubt acquainted with, and they all seemed to give complete satisfaction.

Mr. Royal-Dawson. Mr. F. G. ROYAL-DAWSON thought there was still room for discussion of the question of a third siding between platforms. It had been said that the design of a large station could never be standardized, as each case was governed by local conditions; but in India engineers had often to design a station-yard on practically a blank sheet of paper, with no guide but the cost of the land and the traffic prospects; and they were driven to search for general principles in order to determine the precise conditions under which this or that type should be adopted. As a rule, when a line was under construction there was no great difficulty in getting all the land necessary, and in view of the fact that land increased in value by leaps and bounds after the line had been opened it was generally advisable to acquire at the outset a considerably larger area than was necessary for immediate requirements, with a view to future extensions. The Author said that it had originally been intended to provide third sidings for the liberation of arriving engines, but that that idea was abandoned on economic grounds connected with

Mr. Royal-Dawson.

the site. The implied argument was that the absence of such sidings involved undue detention of engines. It was interesting to see how that argument worked out. It was said that 550 trains were dealt with every day, or an average of forty-two to each platform. According to London examples the full capacity of a terminal platform might be reckoned at upwards of 80 trains per day, so that on that basis the station was now worked at something like half its maximum capacity and could deal with 1,000 trains per day, 500 in and 500 out. Adopting that figure, and assuming for each arriving engine a detention of 10 minutes due to the absence of outlets, that was a total detention of 5,000 minutes, or $3\frac{1}{2}$ engine-days wasted daily, involving the use of four more engines than would be otherwise required. Omitting the cost of the site, a third siding about 1,000 feet long could be inserted between each pair of platforms for £250, or £1,750 for seven such sidings; so that practically for the cost of one engine four engines could be dispensed with. Assuming a strip 11 feet wide for each siding the total area would be about 8,500 square yards. If that area could be acquired for the price of three engines the rate would work out at something like 12*s.* per square yard. He was not an expert in land-valuation, but he thought that land on the site of a station of that importance would be very rarely obtainable at anything like that figure, and hence the present arrangement might often prove to be the lesser of two evils from the economic point of view. Taking half the traffic, and allowing 40 trains per platform, which more nearly corresponded with actual facts, by the same process of reasoning the sidings would save two engines, and to be economical the land should cost not more than 4*s.* per square yard. Taking one-fourth of the traffic, 20 trains per platform, the absence of sidings would involve the use of one extra engine only, and inserting sidings to save the engine would cost as much as the engine. That argument, however, required modification, for when traffic did not exceed a certain limit, say, 20 trains per platform, the adjacent platform-sidings, connected by a cross-over, might be regarded as available as an outlet. There would be no detention, or practically none; but, as the traffic increased, the detention would increase until a certain maximum was reached at about 40 trains per platform, when the use of a pilot-engine became imperative. After that the detention of engines would decrease as the frequency of the train-service increased; for with a well-arranged time-table a train came in and went out again in a few minutes, and a liberated engine found another train ready to be taken out at once. In designing a yard, the adoption of a pair of platform-sidings as the unit would

Mr. Royal-Dawson.

establish a type suitable not only for traffic below 20 trains per platform but also for traffic exceeding 40 trains per platform. The shoe might pinch where the traffic ranged between 20 and 40 trains per platform. In such cases, if the land were fairly cheap, it might sometimes appear economical to have middle sidings instead of extra engines; but that would disturb a type found suitable for the lowest as well as the highest development of traffic, and therefore it would frequently be preferable either to employ extra engine-power or to add another platform and relieve the pressure in that way. There was yet another argument against the use of a third siding. If it were provided as an outlet for engines, the traffic-department would not always respect its function as such, and sooner or later it would become merely a receptacle for spare stock. If that happened there would be no advantage in having the siding between passenger-platforms. For one thing, the ratio of one such siding to the two platforms would not be sufficient for all the reserve stock; other auxiliary sidings would have to be provided elsewhere, and they might as well be all put together. It was no handier from a working point of view to put a spare train on a central siding between platforms than to put it in another part of the yard, because it would have to be shunted out beyond the nearest points before it could be brought up alongside the platform. Carriage-cleaning and lighting could not be performed properly on a central siding, and special platforms would have to be provided for those purposes elsewhere. In short, it would appear that the use of a third siding as an engine-outlet was very rarely necessary or economical, and that it should never be provided merely as a receptacle for spare stock. With the exception of one line in the new Victoria Station, none of the London termini had a third siding in the sense of an engine-outlet. He had questioned two or three line-superintendents as to their views on the point, and in one case only did the superintendent deplore the absence of a third siding; and curiously enough in that case the traffic averaged between 30 and 40 trains per platform, whereas in the other cases it averaged upwards of 60 trains. That confirmed the foregoing theory as to where the shoe might be expected to pinch. With regard to signalling, he agreed with the Author that for the driver's sake the signals should be as few and as unambiguous as possible consistently with safe working, especially in a large yard. The Annett type of signal-indicator appeared to meet the case, but the number would hardly appear to concern the driver, who obeyed the arm and not the number-board: the latter would be more of the nature of a visible indication of the setting of the points, and would concern the station-staff more than the driver. He suggested

that when the Paper was published a diagram might be added showing the position of the signals and the direction of the traffic on each of the running-lines, because without that it was impossible to follow the movements of the trains. Presumably there were definite points from which, for the purpose of block-working, the up-and-down system was introduced. Mr. Royal-Dawson.

Mr. W. C. Acfield remarked that the installation of all-electric signalling on the Midland Railway at Derby, to which Mr. Siemens had alluded, might be considered purely experimental. It was put in 3 or 4 years ago, and so far had worked very satisfactorily, but it had been altered considerably, and he understood that Messrs. Siemens's present method of installing the apparatus was the outcome of many altertions. The cost of maintenance was found to be higher than that of the mechanical system; but it had been very difficult to obtain actual figures, on account of the changes that had been made from time to time. He did not wholly maintain the apparatus, as the maintenance was divided between the Electrical Engineer, Mr. Sayers, and himself. With regard to the Glasgow Central Station, he had the privilege of going over the installation in October, 1908, and he thought the signalling was very well arranged. The signals on the signal-gantrys were certainly very clear, and were reduced to a minimum in number by the Annett type of "route" indicator. It did not strike him that there was anything new in the installation of electro-pneumatic signalling, as it appeared to be practically the same as was in use at other stations in the country. Unfortunately the Author did not give any figures with regard to the initial cost of signalling. Mr. Acfield would like to know what diminution in the number of signalmen had been effected by adopting power signalling, as compared with the number of signalmen that would be required in a manual system, bearing in mind the look-out signalmen in the overhead signal-box in the middle of the station and the men required for working the dwarf frames placed on the platforms. Those dwarf frames were placed on the platforms because certain of the points in some roads, particularly Nos. 12 and 13, were obscured from the view of the signalmen by the structure supporting the roof at the south end of the station, and when trucks were standing in the fish-, fruit- and milk-platform there was an even greater obstruction to the signalman's view. Telephonic communication was installed between the dwarf frames and the signal-box, but the fact of the frames being provided necessitated additional interlocking and complications. Mr. Acfield.

Mr. S. P. Wood, as the Managing Director of the Company responsible for the installation of signalling at the Glasgow Central Mr. Wood.

Mr. Wood. Station, wished to make a few remarks in reply to Mr. Siemens and more particularly to endeavour to show that the Author had been fully justified in selecting the electro-pneumatic system. Mr. Siemens had mentioned that plenty of information could be obtained about the various systems, but the Author in his remarks referred only to the United Kingdom, the American and German systems not being altogether the same as those used on British railways. Mr. Wood's own experience was that they were not suitable without considerable changes. The electro-pneumatic system was the only one with a large number of levers at work in this country, and the only system about which information could be obtained—though not of the maintenance, because there was no reliable information to be obtained throughout the country with regard to maintenance of any of the installations. The Author put the five systems down, and as Mr. Wood's Company was equally as interested in an all-electric as in an electro-pneumatic, he did not propose to quarrel with Mr. Siemens with regard to his general remarks; either kind would have suited his firm as sellers. Mr. Wood saw the trials made by the Author, and he thought they were very exhaustive, even though they were not made in the open. Upon the data acquired the Author decided in favour of the electro-pneumatic system. Mr. Wood thought it might safely be said that every other system tried there was to-day radically different from what it was when the Author tried it, which appeared to him to afford entire justification for everything the Author had done; and he would challenge Mr. Siemens to contradict his statements. [Mr. SIEMENS said he would do that at once.] Was the installation Mr. Siemens was putting down at Birmingham, about which he had read a Paper, the same as the installation he had put down at Didcot?

Mr. Siemens. Mr. SIEMENS replied that it was not. His firm might try to persuade clients that the electric control was the best, but if they preferred check-locking, the firm had to meet their wishes.

Mr. Wood. Mr. WOOD thought he had made his point.

Mr. Read. Mr. R. J. G. READ observed that a point had been raised in the discussion as to the damage done to Argyle Street by covering it over, and it seemed to him that the present condition of affairs might have been improved if light-areas had been made between the lines, in the floor of the station. He would like to know whether there was any insuperable difficulty in making them. With regard to the roofing of the station, it had been said that the appearance was improved by making the lower flanges of the girders a graceful curve. He did not think that an improvement, because it made the girder look like an arch. If an arch was stuck against the side of a column as shown

in Fig. 6, Plate 2, there was a feeling of a tendency of the arch to bulge the column, which was contrary to the principle of a column. With a column the most satisfactory thing was to have a horizontal girder, and he thought the whole roof would have looked equally well, and perhaps better, if the girders had been perfectly straight and carried right across, even over the two central columns. He had noticed that a satisfactory effect was seldom produced in ironwork if arches were made to spring out of an arch. A good instance of that was to be seen in York Station where the predominant feature of the station was the fine arched ribs which sprang from the columns on the platforms, and from intermediate longitudinal girders between the columns. The connection between the transverse arches over the line and the smaller longitudinal arched girders was anything but satisfactory. On the other hand, in Paddington Station the longitudinal girders were made with parallel flanges, and the arched ribs sprang from them; they were all uniform in character and looked well. Mr. Read.

Mr. L. FORTESCUE WELLS thought that often some system of train-indicator mounted outside stations would be useful, especially where there was a station-approach or yard, which was the property of the railway-company. Passengers hurrying for a train would see which platform they had to go to before they entered the concourse, and a great deal of rushing to and fro in the concourse would often be avoided. There were many terminal stations in large towns where at times of great pressure—for instance, at about noon on Saturdays—it was difficult to make one's way through the hurly-burly of the concourse; and if an indicator were arranged so that as a passenger came to the station he would know exactly where to find his train, a great deal of discomfort would be saved. With regard to the roofing, the Author had already been asked for some particulars as to the cost, and he himself would like to have the cost per square yard of covered area. If the Author would give that, and also the weight of the roof per square yard and of the girders, the figures would be very useful. Mr. Wells.

Mr. E. DE M. MALAN, referring to Mr. Siemens's remark that a very good comparison of systems of signalling had been published some years ago, regretted that when Mr. Weissenbruch wrote the article in question he compared the latest Siemens with some obsolete Westinghouse installations. If it came to discussing that comparison in any other place he would be very pleased to discuss it with Mr. Siemens, and to point out that there were many "terminological inexactitudes" in it. It had also been made a reproach to the Westinghouse system that it had two Mr. Malan.

Mr. Malan. powers. The electric system, as Mr. Siemens knew, had the same power at two very different potentials, 100 volts and 25 volts, which very often had to be obtained from different batteries. He did not wish to take up time by discussing the question of "check-locking" versus "constant indication." The Westinghouse Company had been installing "constant indication" for many years and would do it when required, but there were many things in favour of check-locking, and he did not think it was altogether obsolete yet. Mr. Siemens had remarked that he had naturally to do what his patrons asked him to do, and it could be easily understood that Mr. Westinghouse had to do the same, and so he continued to offer the electro-pneumatic system; and it was taken up by the railway-companies.

Mr. Tait. Mr. W. A. TAIT had had opportunities of seeing a great deal of the work at Glasgow, during construction and he congratulated the Author on the excellent arrangements he had made for temporarily supporting the roof when altering the old walls, and on the way in which he had accommodated the traffic during the operations. Mr. Blyth had mentioned how the Caledonian Railway Company had to pay its footing to get into Argyle Street, but had not explained why he did not go farther west after crossing that street; while Mr. Ward had proceeded to justify the extortion, erroneously describing Argyle Street as the Oxford Street of Glasgow, when it was nothing of the sort. Mr. Ward seemed to think that because the Caledonian Railway Company made an underground railway in Argyle Street they ought to have paid some considerable sum in wayleave. As one of the resident engineers, his recollection was that the railway intersected a great many sewers, and new sewers had to be made on both sides of the railway. The railway-company at their own cost abolished many wretched, antiquated sewers, some of which were silted up, and they also trapped many house-connections that had not previously been trapped. The Company also constructed at their own cost several miles of sewers 5 feet to 7 feet 6 inches in diameter to lead sewage from a large district of Glasgow to the site of purification-works about to be constructed by the Town Council. This was practically the first step in the very important work of purifying the River Clyde. In addition to that, the Company diverted water-pipes and large mains laid at the time the water was introduced 50 years before, and, again at their own cost, replaced them with new pipes in other streets; and generally the Glasgow Corporation seemed to have done very well on the transaction. The underground lavatory had been criticized by Mr. Blyth, but as far as Mr. Tait could see the only

admissible objection applied also to the lavatory at the foot of Parliament Street, Westminster, which was 4 or 5 feet deeper than necessary, the extra steps being a drawback. For some reason of which the Author gave no explanation, the main arrival-platform was very considerably shorter than the departure-platform. The length of the engine had to be taken into account in the former and not in the latter, and it would be interesting to know whether there was any special reason for the difference in length. He desired also to hear something about the train-weight per passenger. It appeared from the general development of railways, and the greater attention shown to the comfort of passengers that very large carriages were used now, and it would be rather useful to have the weight of carriage per passenger, for either suburban or main-line traffic. It would be interesting to know why the Caledonian Company in crossing the Clyde in a line parallel to the Glasgow and South Western Railway's crossing had not turned their station east and west like that other Company, because this would have been the first step to get the connection with Dumbartonshire which had only been got at very heavy expense by the construction of the underground railway. Mr. Tait.

The AUTHOR, in reply, acknowledging the cordial reception of the Paper, observed that any success it had achieved was due to the discussion it had evoked, and he was under special obligation to those who had taken part in it. He desired especially to acknowledge the kind appreciation of Sir John Wolfe Barry, with whom he had been associated in professional work for many years; and he was sure that all engineers would appreciate the immense value, not to speak of the feeling of personal comfort, it had been to have enjoyed the advantage of consulting at any time with one who, to quote Dr. Smiles, could be described as a "Field-Marshal" in the profession. It was also very gratifying to him that two of his former chiefs, in the persons of Mr. W. B. Worthington and Mr. B. Hall Blyth, had taken part in the discussion. Mr. Worthington had been too flattering in his personal references, but the Author appreciated the kindness that prompted them. The frank criticism of Mr. Blyth had lent a little colour to the discussion, and had served to prompt rejoinder. It was fair enough—in a measure it was complimentary —except perhaps the suggestion that the Paper appeared to criticize censoriously the design of the original station, which he regretted and strongly disclaimed. Mr. Blyth's defence of the original station was unnecessary, as it had not been attacked. The Author had been careful to indicate in the Paper that, having regard to the circumstances of the time, the original Central Station appeared to be amply large and well-equipped when first constructed, The Author.

The Author. It was a great engineering work, boldly conceived and splendidly achieved, and its creation reflected the utmost credit on all concerned with it. Several speakers had completely answered Mr. Blyth's criticism in respect of the adoption of the American designation "the concourse," and in relation to this the Author believed that much could be learned from the modernized terminal stations of America.

The observations of Mr. Alexander Ross, especially in respect of auxiliary siding accommodation were particularly interesting. Mr. Morgan had misunderstood the reference which Sir John Wolfe Barry had made to the place of Glasgow Central Station amongst the other great terminal stations of this country. Sir John had merely described it as one of the finest, thereby suggesting that it ranked with Victoria, Liverpool Street, and other important stations. While many of the principal points suggested in the Paper had been discussed, he was disappointed that so little had been said about the statutory obligations of railway-companies under the Railways Clauses and the Lands Clauses Acts—as distinguished from the municipal burdens, which had been spoken of—to the extent to which the design of terminal stations was affected. The statutory obligations under these Acts were onerous, and since the reading of the Paper the effect of a decision of the House of Lords had been to make railway-companies in Scotland liable for the maintenance of the portion of a city public street under which the approach-lines to a terminal station had been constructed, in so far as the surface of the street was originally interfered with in the construction of the railway. In Scotland it had been thought hitherto that the obligation did not extend to street approaches to bridges within a city boundary. It might be reasonable enough that where a railway-company interfered with an ordinary country road, it should, for a time at least, maintain that road; but it was surely an injustice that such an obligation should be extended, as had been decided by the House of Lords, to urban streets, the character of which was quite different from that of ordinary country roads. The climax of this hardship was that owners of property *ex adverso*, as well as the municipal authority, would be relieved of their obligations by the railway-company. Then, in connection with the approach-lines to the Buchanan Street terminal station of the Caledonian Railway in Glasgow, since the Paper was read it had been decided in the Scottish Law Courts that fire-clay adjoining and underneath the railway was a mineral in the meaning of the Railways Clauses Act. If these approach-lines were to be properly maintained, the railway-company would have to reserve and pay for the fire-clay adjoining and

underneath, in the same way that coal and stone had to be reserved and paid for, and this would necessitate the expenditure of much money. These were new examples of the obligations under the Railways Clauses Act. There were similar hardships under the Lands Clauses Act. The suggestion that railway-companies should acquire property in the immediate vicinity of terminal stations with the object of ultimately using it for railway purposes when required was rendered difficult under the restrictions of the Lands Clauses Act in respect of "surplus lands." Railway-companies were thereby practically prevented from participating in the benefits which accrued from that betterment of property which usually followed construction of a city terminal station. One would naturally have thought it fair to allow even a railway-company, in view of possible future requirements, to purchase without restriction more land than was immediately necessary, in order that, when such land was actually needed for station purposes, the railway-company should not be penalized by the betterment which they themselves had created. The extraordinary allegation made by Mr. Henry Ward to the effect that Glasgow had suffered largely by the making of the railway was not justified; on the contrary, the railway had been the making of Glasgow, and in this particular case the demolition of slum property and public-houses, not to speak of the benefit arising out of the primary object, had been attended with much public advantage. Then, in regard to the crossing of Argyle Street, instead of being a tunnel, the portion of the street covered over was really a pleasing arcade. The light-wells suggested by Mr. Read would have been inconvenient and objectionable. They would have taken up much valuable space in the station, and would have been of little use for lighting, as the light would have been "borrowed" light. As a general principle, light-wells in an overhead bridge were objectionable. The Corporation of Glasgow had objected to light-wells being formed in the Argyle Street bridge. Mr. Ward's complaint as to the underground railway below Argyle Street, and the alleged impossibility of constructing sewers, was not well founded, as by arrangement with the Corporation special provision for sewers had been made on each side of the covered way, and, similarly, there were arrangements for the passage of pipes. It might be of interest to state that the *quid pro quo* from the railway-company to the Corporation for the permission to make the railway under certain of the public streets of Glasgow had been the construction of many outlying interoepting sewers and relative works forming the first part of the city drainage and purification scheme; and in addition, as Mr. Tait had indicated, the reconstruction of other sewers,

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The Author. and the renewal of gas- and water-pipes, which altogether cost the railway-company nearly a quarter of a million sterling. Part of this expenditure had been rendered necessary by the construction of the underground railway, but a large amount of it was in the nature of a payment for wayleave under the streets. The interest on this money was a heavy financial burden on the railway-company, and there was hardship in more ways than one, for no sooner had the underground railway developed a large and lucrative traffic than the City Corporation installed the system of street electric tramways directly over it, and in competition they abstracted a very large part of that traffic from the undergrouud railway. Several speakers had alluded to the inexpediency of spending private money for the public purposes of municipal corporations. Nowhere had such burdens been more grievous than in Glasgow. The matter was one of outstanding importance to railway-companies, and amendment by legislation of the public Acts to which reference had been made had become a crying necessity. The enterprise of railway-companies was greatly fettered by such restrictions and obligations, and nowhere had the effect of the possible penalizing been more noticeable than in the plan of Glasgow Central Station. Few commercial undertakings could long bear such burdens, and yet surprise was expressed that, in these times of unrest and uncertainty, railway-companies were unable to maintain their dividends. Instead of endeavouring to encourage the enterprise of railway-companies tending to benefit the community, imperial as well as the local authorities frequently appeared to desire to discourage it. In contrast with this, it was pleasing to find that in France and in America, there was precedent for the city corporation and the railway-company combining, with the object of providing in the joint interest the best and most convenient railway-station, it being recognized that adequate railway accommodation was an indispensable factor of general prosperity. The Glasgow Corporation were, by means of their extended tramways, competing with railway-companies at a direct dead loss to themselves, and it was well known that beyond the city boundary the Corporation tramways were being run at a loss. The lines beyond the city boundary were indeed a heavy financial burden, and it was idle to allege, as Mr. Henry Ward had done, that Sir John Wolfe Barry was in error in contending that the tramways were not conducted on commercial lines. The effect of this tramway competition had been to take nearly 3,000,000 passengers per annum out of Glasgow Central Station, so that the railway receipts from suburban traffic had been seriously affected. Fortunately this traffic was to

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some extent being recovered. Notwithstanding the competition of municipal tramways, railway-companies must, perhaps unfortunately, continue to run many suburban trains. In the working of terminal stations, dealing with suburban traffic was always a difficulty, and, notwithstanding what Mr. Morgan had suggested, the Author concurred with others in holding that separation and allocation of traffic was an important first principle in working as well as in design; so that in the scheming of a terminal station there should be such arrangement as would ensure the absolute separation of suburban and main-line and other traffic where such separation was possible. Suburban traffic should indeed have, if possible, a separate station entirely to itself, or at least a place for itself if worked in the main terminal station. The advantage of this was well illustrated by Mr. Grierson's description of what had been done at Paddington in the diversion of suburban traffic to Bishop's Road. The importance of dealing properly with suburban traffic had never been lost sight of in the scheming of the extension of the Central Station and, through running to another station being practically impossible, inspection of the "racquet" loops of the terminal stations at the Porte de Vincennes and the Porte Maillot on the Paris Metropolitan Railway, and of a similar but much larger "racquet" loop in connection with that fine example of a modern American railway-station, the Boston Southern Terminal, suggested the construction of a "racquet" loop in Glasgow Central Station to allow of the ingoing trains going round and out again, along a line which had been alluded to by Mr. Worthington as "the outline of the stem and bulb of a thermometer." A station on a high level relative to adjoining streets, such as Glasgow Central Station, might be said to be ideal for the construction of a low-level "racquet" loop for working suburban traffic. Investigation showed, however, that the position of the river and the cross streets would have rendered the gradients impracticable, even if the cost of the works had not been prohibitive; and while, undoubtedly, with such an arrangement there would be a saving of cost in working, such saving might be neutralized by the annual charge in the form of interest on the first cost of construction. With a view to avoid the reversal of traffic in terminal stations, Sir John Wolfe Barry had suggested the possibility of through running by extending at least some of the lines in a terminal station beyond the station, with the object of linking them up with lines coming into the city from an opposite direction. A glance at the map of Glasgow suggested that effect might have been given to that idea by connecting the lines in the Central Station with

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those in Buchanan Street Station. The possibility of this had been carefully considered in connection with the recent extension of the Central Station, but the circumstances of the site of the Central Station together with the necessity there would have been to purchase very costly property, had rendered the idea financially prohibitive. Had the Central Station been constructed on the Bothwell Street site, and this could readily have been done, there might have been a great comprehensive through station connecting with Buchanan Street, in which, as Mr. Worthington had suggested, the north as well as the south traffic could have been accommodated, and from which a line could have been led to Dumbartonshire and the west. It had been said that, having regard to the varying circumstances, it was impossible to lay down guiding principles in terminal-station design. The circumstances of each station and its site had, of course, to be considered, but there were many imperative general principles to be observed, and these had been stated in the Paper. Experience of the working and of the character and equipment of the old Central Station had taught what was really necessary in the new one. There was also, however, exhaustive inquiry and careful consideration of other terminal stations in this country, as well as in France and America, not only in regard to what had proved satisfactory and desirable in these, but also as to what had been found insufficient and unsuitable. Further, the methods of station traffic-working, and the facilities provided therefor, were investigated and the habits of crowds of people were carefully noted. With such information and the knowledge of local circumstances, the requirements of the new station were determined and recorded, and a definite problem was thus presented for solution. The scheme of the station, as well as the design of parts of the structural work, particularly the roofing, were carefully studied in model, and certain principal parts of the "plan" and of the details of the structural works were also studied in perspective sketch. The desirability of scheming railway engineering work with the view of its being part of an ultimate whole had been referred to. This had been largely done in Glasgow Central Station Extension, and it might be mentioned that while there was an outside wall on the west side of the station, the roof-girders were really supported on a series of steel columns embedded in the wall. This wall was merely a thin screen, and in the event of enlargement of the station, it could be removed without interfering with the roof in any way. Similarly the Clyde Bridge at its north-west extremity had been so built as to provide for approach to a possible future extension of the station on the west

side. The plan of the seaside station which Mr. Ross had submitted was an excellent example of the necessary outside equipment of a terminal station, and, judging from his description of the working, it might be accepted as a model. It served to mark his concurrence that the measure of the capacity of a terminal station was the facility with which it could be filled and emptied, and it emphasized the absolute necessity of providing a sufficiency of auxiliary siding accommodation from the point of view of the true economics. As Mr. Morgan had stated, however, it was frequently impossible, by reason of the cost of land and other circumstances, to have all the necessary accommodation of this character provided in the immediate vicinity; and this was a reason why Mr. Worthington's suggestion of the possible insufficiency of the auxiliary accommodation in connection with the Central Station was not perhaps unwarranted. It was particularly noticeable that the seaside terminal station alluded to had two turntables in the immediate precincts, one on each side of the approach-lines. Such equipment was doubtless magnificent, but at most terminal stations it would be, having regard to the cost of land, in the nature of a luxury. The critical observations of Mr. Morgan to the turntable accommodation at Glasgow Central Station were quite justified; but the best possible had been done by having the turntable near Cook Street. Much consideration was given to the desirability of having the turntable accommodation in the vicinity of the ends of the platforms of the Central Station. Turntables at terminal stations must nowadays, however, be at least 70 feet in diameter, and directly and indirectly they took up a great deal of space if facilities for coaling and watering—their natural complement—were also provided. The statement of the ratio of the number of the approach-lines to the number of the platform-lines as 1 to 2 at a point 600 yards out was somewhat arbitrary. It had been made on the basis of the experience of the arrangement and of the working at the Central Station and other stations, and was meant to be merely suggestive. The principle could scarcely be stated in mathematical formulas because circumstances varied, but the matter of such ratio was important enough to be called to mind in terminal-station design. There appeared to be a somewhat similar relationship between the number of the approach-lines and the number of the platform-lines at Paddington Station and this might be taken as a criterion. It was an undoubted advantage to have a sufficiency, indeed, perhaps a surplus, of approach-lines. Mr. Morgan had surmised correctly that the idea in the arrangement of the parts of the approach-lines in the vicinity of King Street and Nelson Street was to have standing

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The Author. room for approaching trains in the precincts of the station-yard—another desideratum at a terminal station. These parts of the approach-lines were, no doubt, somewhat short, but they were long enough to accommodate the majority of the trains likely to use them for such a purpose. The relative positions of the bridge over the River Clyde and the junction with the railway to Gourock and Wemyss Bay prevented these parts of the lines from being longer. In reference to Mr. Morgan's criticism of the length of the lines of the station-yard and his example of an outgoing train from platform No. 9, experience of the working and maintaining of the old station showed the necessity of having easy curves as well as good diamond crossings. As the approach-lines to the several platforms were interchangeable, even with a shortening of the connecting lines, there would still have been blocking; so that any saving of time by the suggested shortening could only, under the most favourable circumstances, have been measured by seconds. With interchangeability, there must of course be at times fouling of several of the other lines. At the Central Station the lesser of two evils had been chosen. In the matter of expediency of having three lines between platforms—an auxiliary line between the two running-lines, the question was, as Mr. Royal-Dawson had indicated, a matter of general economics, to be decided after consideration of the cost of land and possibly also the cost of roofing, as against the cost of working with the shunting-engine, referred to by Mr. Blyth. The cost of land which Mr. Royal-Dawson had suggested was so trivial, compared with what had had to be paid in Glasgow, that it would be idle to follow him in his argument. The contention that with the third line an incoming train had to stop short of the cross-over, and that therefore certain platform accommodation was wasted, was not borne out by investigation, because the engine could in the first instance be stopped close to the buffer-stops, and after passengers had alighted the train could be shunted back sufficiently to allow the engine to go through the cross-over, and pass out by the third line. The cost had always to be counted, but as a general principle it might be safely assumed that a third line between platforms was a very desirable thing from the traffic-working point of view. At the Central Station a third line was not required for the horse-box traffic which had been referred to, because nearly all the horse-box traffic was dealt with at the special platforms at the end of the cab-rank (Fig. 2, Plate 1). With respect to the desirability of very long platforms, the Author considered that the separation and allocation of traffics, which had been made such an important feature in the scheming of the Central Station, appeared to render it unnecessary to have

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all the platforms of the maximum length. The result of such an arrangement would have been that many of the platforms would have been used to their full length on only very few days in the year. The question of general economics came in again, and while Mr. Jacomb-Hood had suggested that the expenditure of an additional £100,000 or £150,000 in property in connection with a terminal station was a comparatively unimportant matter if platforms could be made long and straight, the interest on such a sum, even if the Company could have conveniently afforded to spend the money at the time, would have been a much greater burden than the extra cost and inconvenience (if there were such extra cost and inconvenience) attaching to the working of a few excursion-trains on special days in the year. Platforms Nos. 1 and 11, each about 800 feet long, might be taken respectively as standards to judge by. Platforms of such length were required for the main-line trains, which were made up of the long, large and luxurious dining- and sleeping- and other heavy coaches referred to by Mr. Tait; but it would be wasteful to have platforms 800 feet long for suburban omnibus trains of three or four coaches. With proper allocation, enormous suburban traffic could be expeditiously dealt with at short platforms. The reference to the difference between the weight of the passenger and the dead load which had to be dragged for him was apposite, for the disparity was directly and indirectly detrimentally reflected in costly works in terminal stations, not the least of which was the long platform. Straight platforms were preferable, particularly when the lines were level; although, with the approach-lines on a falling gradient, as they were at the Central Station, curved lines were not objectionable, having regard to the desirability of train-resistance. The main disadvantage of a platform on a curve appeared to be that the versed sine on the length of the footboard of a long bogie-vehicle was such that there might be a dangerous space between the footboard and the platform-edge, and that was to be avoided. Another objection was that in the starting of a train the rear guard could not see and signal directly to the engine-driver; and there might be some difficulty in coupling up the vehicles if the curvature of the platform lines were considerable. The matter of the surface of platforms was very important. Rock asphalt was in many respects better paving than granolithic, but its cost was higher. On the other hand, granolithic coping was superior to a coping of slate.

The general question of the roofing of terminal stations had not been discussed as much as its importance appeared to demand. Those speakers who had made reference to the subject had dealt more

The Author. or less in generalities, and had indicated diffidence in stating a definite opinion as to the distinctive characters which had been referred to. The Author approved Mr. Hobson's phrase "the greater the span, the greater the cost, and the greater the mistake." With regard to the suggestion that awnings over the platforms and a glass, covered roof over the "concourse" provided all that was necessary in station-roofing, it was conceivable that such roofing might under certain circumstances be objectionable in some respects; and, taking everything into consideration, the Author thought that the reasonably high all-over short-span roof, supported by intermediate columns, like the roof of Liverpool Street Station, appeared to be the best. Such a type of roof, however, necessitated intermediate supporting columns on some of the platforms. It had been argued that there should be no columns at all on the platforms, but that if columns were needed then there should be a single column in the centre and not two. The Author, however, adhered to the opinion expressed in the Paper, though on narrow platforms a single column might be a necessity. The opinions expressed in respect to the roof running longitudinally rather than transversely were sound from the point of view of general principle, but in the extension of Glasgow Central Station the circumstances attaching to the roof of the old part had necessitated the main girders of the new part being also transverse. The bottom flanges were made of elliptical form in order to relieve what Mr. Hobson had described as the "depressing effect, from their solidity and heaviness, of an almost interminable succession of bottom flanges of transverse girders." With the double-column arrangement of support, there was no feeling of the tendency of the "arch" to bulge, as had been suggested, even if the main transverse principal had been an arch, which of course it was not. There was no reason whatever from a theoretical point or practical or æsthetic point of view why a series of steel arched ribs of roofing should not be supported on intermediate columns, provided that the thrust, or rather the feeling of thrust, was taken up, or apparently taken up, by abutments at the extreme sides. The question of the merits of putty glazing and "patent" glazing fixed mechanically was very interesting from the point of view of maintenance. With regard to the glazing of the roof, many engineers held an opinion contrary to that of Mr. Jacomb-Hood, and in the Author's judgment the more general experience was that patent glazing was very costly to maintain. The older systems of "patent" glazing appeared to be better than those of more modern date. Much of the ordinary "patent" glazing of the present day was too cheap to be used with economic advantage, and this should be

carefully considered in selecting a system. Having regard to the method of dealing with passengers' luggage on British railways, it would be impossible to adopt the suggestion of Mr. Ross and apply the arrangements for the working of luggage and cabs in the St. Lazare and Quai d'Orsay stations in Paris to the stations of Great Britain, even where the levels were favourable. In all the great terminal stations of this country it was necessary to have a cab-rank inside the train-shed in order that cabs might draw up immediately alongside the trains. In France and America where cabs were not brought into the station proper, passengers' luggage was dealt with differently. With a similar idea to that of Mr. Ross, Mr. Hobson had suggested that the cab-rank at Glasgow Central Station might have been constructed underneath the station at the level of and on the north side of Argyle Street. The circumstances were such that physically this would have been almost impossible, and such a cab-rank would have been quite inconvenient. The main difficulty arose in dealing with passengers' luggage. With no luggage accompanying the passenger, a cab-rank inside a terminal station was unnecessary, and platforms might be made narrower and, if need be, more numerous. Had there been no need for a cab-rank inside Glasgow Central Station, the number of platforms could have been considerably increased, without much, if any, additional expenditure. The expediency of having a cab-rank inside a city terminal station was, therefore, a matter of much economic importance. As to the access to the cab-rank, it was impossible to provide the orthodox access at the extreme south end, the difference of level between Broomielaw Street and the platforms being such that too much space would have been taken up by the inclined approach. The "corkscrew" entrance, as it had been called, for empty vehicles, interpolated between the floors of the hotel, saved a great deal of space, and was found to be quite convenient. There was one apparent objection in respect of the crossing of the full and empty cabs in the cab-rank, but that had not been found to be detrimental in practice. The means of egress from the cab-rank had worked well by reason of the fact that Hope Street was a very wide street, with not a great deal of traffic, and there was no blocking of the street or reflected congestion in the station. It was an important thing to save space by having accommodation on more than one floor, and in this connection he submitted that there was justification for having the winding inclined access to the cab-rank. The commercial aspect of the premises of the substructure, which were not required for service purposes, had been carefully kept in view in the scheming,

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The Author. and the substructure was specially planned accordingly, much consideration being given to the all-important work of waterproofing, and the no less necessary means of ventilation, desiderata which experience in maintenance work had shown were not always borne in mind in design and construction. Such parts of the substructure as were not required by the company were let at remunerative rents, although in these days when there was so much accommodation of that character in cities, the return on the capital expenditure stated by Sir John Wolfe Barry at 6 per cent. on the cost of the substructure of Cannon Street Station, and by Mr. Blyth at 9 per cent. on the cost of the substructure of the original Central Station, had not been reached. Apart from the high rents of the shops with street-frontage, the rents received from the letting of the parts of the substructure of the Central Station ranged from 4*s.* to 5*s.* per square yard per annum. The premises of the substructure of a terminal station could also be utilized to great advantage for service purposes, although, on the score of inconvenience of access, the situation of the main lavatory accommodation for men in Glasgow Central Station had been adversely criticized but, the Author thought, unjustly. The only alternative site at platform-level for main lavatory accommodation was on one or other of the extreme sides of the station, the inconvenience of access to which would have been greater. Of two evils, the lesser had been chosen, and that with much advantage, as results had proved. The lavatory had been alluded to as a "palace," but inspection would show that the inside finishing was of tile work similar to, and no more costly than, that of the ordinary underground lavatory of the London street. The accommodation for parcels had been criticized—in respect of size and relative position—but experience of the working of the parcels-traffic, which had recently rapidly increased—until now, exclusive of newspaper parcels, about $3\frac{1}{2}$ million parcels were dealt with per annum—showed the necessity for spacious premises, and there was of course consideration of the future. In regard to the situation, it was thought essential that the accommodation should so be placed that the hoists providing communication between the station proper and the parcels premises should be in such position as to preclude the necessity for parcels being wheeled through the "concourse," and this was effected by having the hoists in the vicinity of the ends of the several platforms as shown in Figs. 2 and 4, Plate 1. The statement made by Mr. Blyth that the concourse at Glasgow Central was merely a place of shelter for Glasgow people in wet weather was quite unfounded, and such criticism of this accommodation was well answered by the observations of other speakers who, without exception, strongly advocated the necessity of providing a spacious concourse. It was

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imperative that there should be a proper assembling-place for passengers, as on holidays and other occasions it was not always possible to provide trains as quickly as passengers arrived. With respect to the position of the train-information indicator in the "concourse" of the Central Station some explanation might be desirable. In the old station the train-information indicator was placed close to the ends of the platforms, and at right angles to them. The result was that on busy days, with a crowd in front of the indicator, it was quite impossible for passengers to pass it and gain access to the platforms. In the new station the indicator was so placed that even if a large number of people were waiting until information in regard to their train was posted, other passengers, such as season-ticket holders and frequent travellers acquainted with the starting-platforms, could readily find their way past. The size of the lettering on the train-information board was such that passengers stood well back from the indicator and thus left a thoroughfare immediately in front of it; and there was also a passage behind the indicator, which, while mainly for the use of outgoing passengers, was also used by those ingoing passengers who knew their way and of whom there were, of course, a very large number. In the matter of the grouping of the "concourse" buildings, it had been found difficult in the terminal stations of British railways to have these all at the extreme end. To have them entirely at the extreme end would in most cases have necessitated that the booking-office and other accommodation should be on a low level relatively to the main "concourse," similar to the arrangements at the St. Lazare Station and the Broad Street Station, Philadelphia. The method of dealing with luggage in Great Britain rendered such an arrangement prohibitive.

The arrangement at St. Pancras, where the main entrance and the booking-office and relative accommodation was situated at the side as well as at the end of the station, with direct access to the concourse, appeared to be a method of planning intermediate between the ordinary practice of having the entrance, etc., entirely at the end and having it entirely at one side as at Paddington. The arrangement at St. Pancras had its advantages, but, as had been indicated by Mr. Jacomb-Hood, there appeared to be no benefit attending the arrangement at Paddington. It might be, however, that the placing of the main entrance and the booking-office at the side of the station in the case of Paddington was another example of Brunel's keen foresight. Doubtless he had regard to the desirability of building the station as part of an ultimate whole from the point of view of the probable prolongation of the railway through the station with the object at some future

The Author. time of joining it up with a railway coming into London from an opposite direction.

In the matter of the signalling, it was satisfactory to know that the installation of a system of power working at the Central Station had met with the approval of such authorities as Mr. Siemens and Mr. Willox. The former speaker might have some justification for suggesting that the Paper had advocated the installing of power working at terminal stations only, but reference to the text would show that the decision come to was that "there could be no economic advantage in the installation and operation of a power plant anywhere except at certain larger terminal or through stations where the state of things was such as absolutely to demand it." In other words, power working of points and signals did not appear to be economical except at very important stations. It had been said by Mr. Acfield that the all-electric system which Messrs. Siemens had installed at Derby was more costly to maintain than the ordinary manual system. Contrary, therefore, to the opinion expressed by Mr. Jacomb-Hood, as well as the opinion of Mr. Siemens, the statement that the maintenance of a power system cost more than the maintenance of the ordinary manual system appeared to stand; although it might be that there had not yet been time to collect proper statistics, owing to the comparative newness of important installations of power working in Great Britain. In the working, the installation at the Central Station was very quick and very satisfactory, having stood the test of all kinds of weather, including heavy snowfall. In regard to the experiments at Glasgow Central Station before the selection of the electro-pneumatic system was made, the Siemens all-electric system was one of the five systems which were tried. All the five systems were tried simultaneously and under exactly similar conditions. The trials were very exhaustive and the electro-pneumatic system was found to meet the requirements of the Central Station best. As against the extra cost of maintenance the advantages of power working were clearly stated in the Paper.

It had been recorded by Mr. Blyth that the cost of the roofing of the original Central Station was at the rate of £2 9*s.* 2*d.* per square yard. That was for an absolutely rectangular and symmetrical roof, every main girder and all the other parts being identical. The site of the extension of the station was such that the new roof was only rectangular and symmetrical for about one-half its area—that was, south of Argyle Street—and to that extent only was it comparable with the roof of the original station. The cost of that portion of the new roof was at the rate of £2 5*s.* per square yard. The lower cost was probably accounted for by the span of the new roof being

less than that of the old one, and this pointed to the inexpediency of having long-span roofing. To the north of Argyle Street, where the site was irregular and every girder was of a different length, the cost of the steelwork of the roofing was about £2 per ton higher than on the south side of Argyle Street. Terminal station work in a great city was always costly, but, notwithstanding this, there were many terminal stations which would have to be extended sooner rather than later. Although the reconstruction and enlargement of terminal stations had appeared to synchronize with the abnormal increase of suburban traffic of recent years, it had undoubtedly in a large degree been rendered necessary by the requirements of the much more important and ever-increasing long-distance traffic. If there was excessive congestion in a city terminal station due to suburban and other short-distance traffic, the remedy alternative to reconstruction and enlargement appeared to be the diversion of suburban traffic into a separate station. Electrification was not the panacea. The Author.

The PRESIDENT thought the members would agree with him that, valuable as the Paper itself was, they had seldom listened to a discussion so valuable and covering so wide a range of ground. It had dealt with both the engineering side of the subject and the political or social side, and just at this time it was more than ever necessary to look at the two together. If nothing else had been done than elicit the strong observations on both sides on the treatment of corporate bodies like railways, it would do a great deal of good. From his point of view the matter discussed was the most important that had to be dealt with in years to come in great cities, namely, the planning of the points at which the railway systems discharged their passengers. He was sorry to note the tone which pervaded the views put forward from the side of the London County Council, because he was certain that, without sympathy and a feeling that the Council and the railways were trying to solve the same problem, nothing but muddle would occur and nothing but difficulty to the citizens of London in respect of transit. Tramways would not cure the problems of great terminal stations, neither would electric railways. The one business was being differentiated rapidly from the other. It was not a satisfactory position of affairs, and though it was impossible to prevent it for a time, the pressure of circumstances would eventually become so great that it would be possible to get along only by active co-operation and sacrifice on both sides. He thought the discussion was particularly valuable in ventilating that point in such an assemblage as The Institution, and he thought it was likely to bear fruit. The President.