

Discussion.

Sir DOUGLAS FOX, President, said that the members had listened with great interest to the Paper, partly historical and partly practical, which had been placed before the Institution. They were very pleased to see Sir Lowthian Bell there that evening, and felt that he had made a valuable contribution to the "Proceedings" of the Institution, as he had been closely connected with the matters dealt with in his Paper, from the early days of railways. The members, therefore, not only had a little insight into the inner history of the subject, but also had the opinions of a gentleman whose experience was as large as that of anyone else upon the very important matter of the manufacture and use of rails. He proposed a very hearty vote of thanks to Sir Lowthian Bell for his Paper.

With regard to Mr. Andrews' Paper, the members would agree with him that it was a valuable contribution to experimental research in connection with the qualities of steel rails, and he begged to move a vote of thanks to the Author for his communication.

Sir WILLIAM ROBERTS-AUSTEN, K.C.B., in view of the fact of so many wishing to take part in the discussion, would pass over the historical part of the Paper, which Sir Lowthian Bell's vast experience and great knowledge had enabled him to deal so effectively with, merely thanking him for that contribution to the history of metallurgy. He would like to ask a question with reference to the rate of wear in the case of iron and steel respectively. How much did Sir Lowthian think was due to attrition, and how much to oxidation and corrosion in such cases? Might it not be in the case of steel, which contained carbide and ferrite, that the carbide and ferrite set up an electric couple, which promoted corrosion in the case of steel as compared with iron, and hence the wear was greater? Then again, with reference to the question of turning rails, he had recently examined a great number of worn rails with the microscope, and he found that very many of them had incipient flaws. He considered that it was a highly dangerous practice to turn a rail, but he was bound to say that he had had no practical experience of the wear of rails on a road. Sir Lowthian had referred to the change of structure in rails after prolonged use. He thought Sir Lowthian had in view

Sir William Roberts-Austen. the mysterious appearance of martensite in the St. Neot's rail, which was thought to be due to a molecular change during the use of that rail. The appearance of that martensite had not as yet been absolutely and satisfactorily explained, for although the result had been closely imitated, the conditions were hardly such as could have obtained in the actual use of the rail on the road. With regard to the point in Mr. Andrews' Paper as to the wear of rails in dry tunnels as compared with that in wet tunnels, it seemed to be an interesting suggestion that the water in wet and in badly ventilated tunnels might absorb the corroding gases, and in that way take them out of the sphere of mischief. Without suggesting that Mr. Andrews' drawings were not absolutely faithful, he wished he could induce him to come over to the side of those who discarded drawing and employed photography with so much success in the examination of steel and of alloys generally.

Mr. Inglis. Mr. J. C. INGLIS remembered with pleasure discussing the question raised in the Papers on a previous occasion, when Sir Lowthian promised the Paper to which the members had now had the pleasure of listening. He then expressed his feeling that the greater the number of cases to be dealt with, the more perplexing, apparently, the problem became. But he thought he might fairly say that one point seemed to crop up now and again from the chaos, viz., that in making steel rails, cleanliness in keeping the rails free from scoriæ and other extraneous matter seemed to be the most important point in obtaining uniformity of strength, even in Bessemer steel. He had had to examine, with the assistance of those who advised him, a large number of cases of fractured rails, where, on testing, the behaviour of the steel on both sides of the fracture was found to be entirely satisfactory. Fracture in such cases could only be explained as the result of an incipient flaw. Occasionally there were indications of such a cause; in other cases no indications were found and the cause was assumed. At any rate there was some such cause, which largely detracted from the credit fairly due to Bessemer steel if manufactured with greater attention to the exclusion of foreign matter. He only said that in passing, as it appeared to him to be some little explanation of many of the difficulties which had to be faced in accounting for failures of steel rails. Sir William Roberts-Austen had spoken of the difference in wear of iron rails as compared with steel rails. He had ventured to make a similar suggestion some time ago, and was rather severely handled for doing so. He had said then that under moderate traffic an iron rail would last quite as long as a steel rail, and that he thought the extra wear

was due, as Sir William Roberts-Austen had suggested, to the fact Mr. Inglis. that, for some reason or other, oxidation was more rapid in steel than in iron. It was well known to those who built dock-gates that it was always wise to have iron plates and not steel plates, and that was a little indication of how the wind blew in that matter. Then there was the question of attrition. Steel rails undoubtedly seemed to pulverise, if he might use that term, in a way which iron rails did not. That was really the only explanation he could give of it. He quite agreed with Sir Lowthian Bell's remarks as to the Siemens-Martin process, although his experience was small as compared with the Author's. But having made a good many experiments, both practically and in the laboratory, he had no doubt of the superiority of that steel. At present the Great Western Railway Company were using it for fittings, and he had not the slightest hesitation in saying that if ever the price of that kind of steel approached the price of Bessemer steel, there would be no hesitation in using it more frequently. By its use a more reliable rail would be obtained, doubtless on account of the longer time which was occupied in its manufacture, so that there was greater power of eliminating defects. An experiment which he had introduced proved that the rail was at once tougher and stiffer than a Bessemer rail, and the fact that the Great Western Railway felt it was quite worth while using a particular sort of steel in fittings—subjected, of course, to a great deal more wear and tear than an ordinary rail—showed that that statement was correct. He noticed with a certain amount of satisfaction the observation in the Paper that at a certain station near Penrith there had been a great many breakages at one place, which had been explained as being due to a heavy fall of snow. He believed that a good many breakages of rails arose from movement of the sleepers—the very cause which was found in that particular instance. Engineers often talked learnedly about the quality of the steel when the fault was in fact inefficiency in maintenance, and he believed that particular cause of fractures would increase instead of decrease as manufacturers went on making rails heavier; at any rate, he felt sure it would so far as the joints were concerned, because the more unbending and rigid the structure became, the more likely it was, if there was a deflection in the rail, to get at certain points very severe twists and reciprocating stresses which would produce fracture. It would appear from Sir Lowthian Bell's Paper that the Board of Trade now absolutely refused to certify a new line for passenger traffic if that line was laid with rails which had been in use in other parts of the line. He hoped the Board of

Mr. Inglis. Trade would never get to that advanced stage of consideration for public safety. He thought if they did they would be somewhat illogical. At any rate, he would be a sinner in the matter, if the Board of Trade took it into consideration. His Company were now making a railway for passenger traffic and goods traffic—it was true it was a light railway—and there the Board of Trade had inserted a clause in the Bill providing that worn rails might be used if they were not lighter than 60 lbs. per yard when laid. That was an indication of what the views of the Board of Trade might be about light railways; but he did not think such a regulation as that mentioned by Sir Lowthian Bell would be quite fair. He had a case now, for instance, where, on the main line, with very heavy traffic, the spacing of the sleepers was perhaps wider than he would like it to be. The ballast was not quite satisfactory, and would have to be taken up, and the sleepers required to be re-spaced. The rails were 7 years old, and were almost at their best, or, at any rate, in quite good working-order. A railway company might desire to put down a type of road which was adjacent, and might take up those perfectly good rails and the sleepers, and move them to another line less frequented and carrying lighter traffic than the main line; and if the Board of Trade prevented such an operation as that, he thought they would only perpetuate the jolting of the British public in express trains; because, if the Board of Trade would not allow it, the simple result would be that the company would have either to leave the rails until they were considerably more worn, and so perpetuate the unsatisfactory running for a series of years, or to take up the whole at a greater cost, re-space the sleepers, shift their old beds, and produce an unsatisfactory road—at any rate, for the first 12 months after it was laid. He thought the Board of Trade ought not to be encouraged in any such very safe method as was suggested in the Paper.

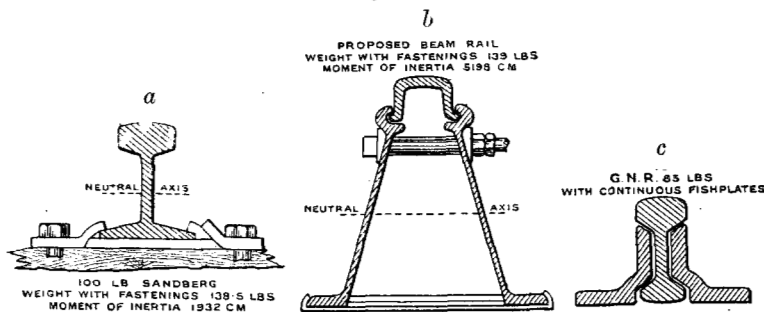
With regard to the second Paper, he had had some very careful observations made on the rails taken from the Box Tunnel, where there was excessive wear. He compared carefully a section of the rail as it was taken out with the original section, and in the case of maximum wear it appeared that just about half the loss was due to oxidation, and the other half due to attrition, or the wearing away at the top. In the majority of the instances there was more loss from wear than from oxidation, but there were one or two cases in which the one approached the other. He felt convinced that in most tunnels, especially in certain cases where the tunnels were not moist but badly ventilated, a greater wear occurred on the top of the rail than was the case in rails outside;

because, apparently, when trains had passed over, the top surface Mr. Inglis. was left bright, the deleterious gases were able to attack it, and there was a certain amount of oxide formed which was removed by the next train that came along. The process of wearing down the top of the rail was thus considerably expedited. He believed the determining factor in the wear of rails in tunnels was the ventilation—and by ventilation he meant the introduction of fresh air, and the removal, as far as possible, of moist air. But in the Severn Tunnel, for instance, assuming a train was running from Cardiff, it ran down into the tunnel on a gradient of 1 in 90, and came up on the other side on 1 in 100. In 32-foot rails put down in the sleeper-road 6 years ago, the wear on an 86-lb. rail in 6 years at the Welsh end of the tunnel was 1·69 lbs. per yard; 10 chains farther on the wear on a similar rail was 3·94 lbs. per yard; 10 chains farther on 7·51 lbs. per yard; and 10 chains farther on, or 30 chains from the face, it was 10·22 lbs. per yard, showing a steady progression of the rate of wear of the rail on entering the tunnel, where of course the ventilation was not so good, or where the passage of the gases over that particular part was greater. He had not calculated the wear per yard per annum, but it could be obtained exactly from the figures. At the east end of the tunnel, coming up the 1 in 100 gradient to come out of the tunnel, at 32 chains from that end, with rails of the same weight—86 lbs.—which had been laid 6 years, there was a loss of 11·63 lbs. per yard; 10 chains nearer to the mouth it was 10·69 lbs. per yard; 10 chains nearer again, for some reason or other, it was 11·63 lbs. per yard; and at the mouth it was 6·38 lbs. per yard, showing, as suggested, like the first series he had given, that there was the same tendency to increased wear as a less well-ventilated part of the tunnel was approached. The trains ran down without steam in the first place, and came up at the other side with all the steam on that could possibly be obtained, perhaps also letting down a little sand.

Mr. Gribble. Mr. T. G. GRIBBLE remarked, in reference to the deflection-trials mentioned in Sir Lowthian Bell's Paper, that it was not stated whether the deflection was that of the rail-joint, or of the adjacent section between chair-supports, or of the whole rail. The deflections stated, if occurring at the rail-joint or between any two sleepers, would seem to indicate impossible fibre-stresses in the rail. In some rather crude experiments on deflection he had made, with a pair of folding wedges on which the travel measured the deflection, he had obtained results which, although very different from those in the Paper, indicated much severer stress than was

Mr. Gribble. ever worked to in bridge-structures, or, indeed, than was allowed by the Board of Trade. The rail was an 85-lb. bullhead, and the load was a 16-ton pair of driving wheels at a standstill. The joint was tried both fished with ordinary fish-plates, and also with the fish-plates removed. The general conclusions arrived at were as follows:—1. That the stresses on the extreme fibre of the rail were from 3 to 5 times as great as the stresses worked to in bridges. 2. That the joint with ordinary fish-plates was statically much weaker than the rest of the rail, apart from wear and tear due to hammering, etc. 3. That the fish-plates did not prevent the rails at a joint from acting almost entirely as a pair of cantilevers. 4. That the adjacent sections of the rail between chair-supports did not act as portions of a continuous girder but as if they were supported beams, probably because a very slight settlement in the sleepers was sufficient to alter the reactions.

Figs. 1.



To illustrate how far the heaviest and stiffest rail in use, the Sandberg 100-lb. rail, with steel bearing plates, *Figs. 1, a*, was from coming up to Board-of-Trade requirements for structural steel, he had formed the same material into an attenuated A beam with removable rail-head, shown in *Figs. 1, b*, so as to reduce the flange-stress to $6\frac{1}{2}$ tons per square inch. If, therefore, rails were to be brought up to the standard which was considered none too safe for bridge-structures, let alone hammering, attrition, and corrosion, which were much more aggravated in rails than in bridges, it was plain that they would have to be radically altered. Whatever might be the relative imperfections of the Bessemer process as compared with the Siemens-Martin process, it was not clear to his mind that rail-fractures were as much due to that cause as to the fact that the rails were structurally weak. The illustration of a Bessemer rail given in Mr. Andrews' Paper seemed to bear

strongly in favour of the tenacity and ductility of that particular rail, in spite of its tremendous punishment. Until much heavier rails could be afforded the principal point to strengthen was of course the joint. *Figs. 1, c*, showed the continuous fish-plate used on the Midland and Great Northern bridges where the road was "tied." The weight was doubled, but the combined moment of inertia was about $1\frac{1}{2}$ times that of the rail. This continuous fish-plate had been used also in shorter lengths to bridge a pair of sleepers, and formed a very safe joint. Mr. Gribble.

Mr. J. A. McDONALD could hardly agree with the conclusion drawn in the Paper on the question of the life of iron rails as compared with steel. Whenever he had had the opportunity of judging between iron and steel in similar circumstances over sufficiently long periods, the result, with one exception, had always been in favour of steel. That exception was in the West of England, where an old iron road was laid on an extremely soft formation, making the road very elastic, and it lasted about 28 or 29 years. Everywhere else his experience had been that, where sufficient time had elapsed to enable a judgment to be formed, steel rails had stood better than iron. He remembered one case in particular, in Derbyshire, which showed, he thought, a reason for the iron rails fracturing so quickly. It was on magnesian limestone rock formation, and at the end of 16 years the rails broke in the most unaccountable way. When they were examined it was seen that the fractures showed like very bad pig-iron, somewhat similar to cinder pig-iron, and he believed this was due to the extremely hard formation on which the rails were laid. With regard to wet and dry tunnels, he had had a great deal of trouble, as all engineers had, with rails wearing out in tunnels; but, without any exception, the worst tunnels had been the wet ones. He could mention half-a-dozen notable instances where the tunnel was over a mile long, and in the wet portion of the tunnel the rails had lasted only $3\frac{1}{2}$, $4\frac{1}{2}$, or 5 years, while the rails in the dry portion had lasted nearly double that time. He thought the rapid wear of the rails in those tunnels was due not so much to the actual wear on the face of the rail as to the corrosion all round. Some 8 or 9 years ago Mr. Francis Stevenson of the London and North Western Railway had tried the experiment of painting his rails. Mr. Stevenson had been kind enough to show him what he had done and the result, and about 6 years ago he had adopted the same system, and now he was painting the rails in all tunnels that were at all wet or more than half-a-mile long. He painted them with four coats, three before they were put in and one after they were in the road, the paint used being red lead and boiled oil without Mr. McDonald.

Mr. McDonald. anything added to it. Where the rails had been in long enough to judge, he had found this practice to result in lengthening their life by between 30 and 50 per cent. He had one case where the rails were in good order, and they had now been in longer than the rails which had been in the tunnel previously. He quite agreed with Mr. Inglis in hoping that the Board of Trade would not make a mistake with regard to prohibiting the use of worn rails, for light railways in particular. Of course it was known that the Board of Trade "had never made a mistake," and he hoped they would not make a mistake in that instance. The practice was a means of providing, at rather less cost, a very much stronger road than would be provided in any other way. He had a light railway in mind at the present moment, where between 8 and 10 miles of road were required, and the engineer who was constructing it had asked him to supply worn 85-lb. rails. The Midland Railway Company, of course, did not wear the rails down to the same extent as those mentioned by Mr. Andrews. In his experience, 85-lb. rails in the ordinary main line came out when they weighed about 76 lbs., and rails of such weight that were originally 85 lbs. were very much better than the ordinary 60-lb. rail which would be used for a light railway.

Sir Benjamin
Baker.

Sir BENJAMIN BAKER, K.C.M.G., Past-President, thought he might reassure his friends Mr. McDonald and Mr. Inglis on the point which had been raised about the views of the Board of Trade on the question of using old rails. One of the first remarks that he had made when he was on the Light Railway Commission of the Board of Trade was to protest against what might be called the definition of a light railway as a railway which had a certain limited weight on the driving-wheel or which had light rails. He said if there was to be any extensive introduction of light railways it could only be through the help and assistance of the leading railway companies, and questions of economy would be the first consideration. Therefore, one of the very first conditions would be that the railway companies should be able to take out their old rails and use them for light railways, and should be able to take their old rolling stock and engines which were obsolete for main-line service and put them on light railways. There was not a word of protest from any of the Board-of-Trade officers present, and he did not think any fear need be felt about putting the old rails of main lines on light railways. It would be regarded as a common-sense matter which all Englishmen, including the Board of Trade, would accept as proper. He was certainly not going to criticise in any way the Paper of his dear old friend, Sir Isaac Lowthian Bell. From his very earliest days of pupilage he had

been accustomed to look up to Sir Lowthian with the same amount of respect that he looked round at the names of Cort, Rumford, Bramah, and others on the walls of the Institution. His earliest associations with the blast furnace and with the chemistry connected with it had been linked with Sir Isaac Lowthian Bell, and it was really not only with personal feeling, but with the more general feeling shared in by every member of the Institution of Civil Engineers, that he was delighted to see Sir Lowthian sitting there that evening after the many years' service he had rendered to practical science. It was wonderful, he thought, that, after Sir Lowthian had passed his fourscore years, he was taking the same keen interest in the engineering profession that he did in his earlier days. He had said before that in the Institution of Civil Engineers the old members were beloved, and there was no one, he was sure, who was appreciated more than his old friend, Sir Lowthian Bell.

Mr. RICHARD JOHNSON was very glad to find that the Board of Trade objected to turning rails. That objection had been sustained, as might be remembered, by a very bad illustration of the effects of turning rails between Tunbridge Wells and Tunbridge. He was very glad to know that that practice had been stopped. Sir Lowthian Bell had mentioned the fact of rails being turned upon the North Eastern Railway, but there Mr. Thomas Elliot Harrison had adopted a cushion, and that helped very much to save the rail before it was turned. He thought Mr. Copperthwaite had continued the practice until he had put into work the bull-headed rail. He was very glad to learn from Mr. McDonald that he had adopted a plan of painting the rails in tunnels, and he believed it would be found very successful.

Mr. F. E. ROBERTSON wished to ask one question on which Sir Lowthian Bell's opinion would be valuable. There was an impression abroad, which was found reflected in the American journals, that steel rails as made within the last few years were much softer than they used to be, that they showed signs of wear and wore out sooner, especially at points and crossings. Where there was so much smoke there was probably some fire, but he did not know that the fact of the rails being softer had ever been established. He had asked some of the men in India who complained of the rails being too soft to send samples home so that experiments might be made to test their physical hardness. Assuming that they were softer, it was scarcely probable that rails made under the same inspection and to the same specification were softer on chemical grounds, and the reason was there-

Sir Benjamin
Baker.

Mr. Robertson.

Mr. Robertson, fore to be sought in the process of manufacture. There was no question, he believed, that in former days the ingots were much more gently treated, and the rails were rolled more easily and finished at a much lower temperature. Nowadays an ingot was stripped as soon as it could stand upright, it was hauled off to the soaking pits, and it went through the rolls and was turned into a rail at as high a temperature as it could stand at. What he would like to ask Sir Lowthian Bell was, whether it was not possible that the great speed at which the work was done now, and the higher temperature throughout under which the rails were finished, might be the cause of their softness at the present day?

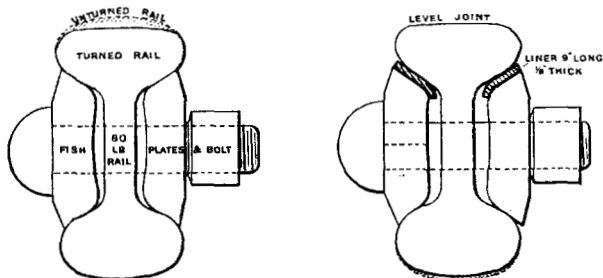
Sir Lowthian
Bell.

Sir LOWTHIAN BELL, Bart., in reply, observed he had brought some illustrations of the various stages of making iron, which were on the table and which members might be interested in looking at after the meeting. With regard to the turning of rails, a statement had been made about a plan introduced by Mr. Harrison of having a cushion under the rails, and no doubt that was a most useful addition. A cushion was laid under the rail between it and the chair. But, in addition to that, steel liners were now used so as to bring the top of the rail exactly on a level with the tops of the adjoining rails. The plan adopted was illustrated in *Figs. 2*. As regarded the length of the line upon which that trial was made, namely, between York and Darlington, probably the busiest part of the North Eastern system, there were nearly 1,000 tons of rails which had been turned, against something like 3,000 or 4,000 tons of rails which had not been turned, and on weighing those rails there was absolutely no difference whatever in loss of weight. The turned rails were lasting as well as those which had not been turned. With regard to the regulations of the Board of Trade, he quite agreed with Sir Benjamin Baker as to the futility of such a line of conduct as that mentioned, yet he might state his own experience. The company with which he was associated laid the Wear Valley line, running up to the neighbourhood of Stanhope, and then approaching the lofty hills of Austin Moor. When the inspector found that the line was being laid with rails which had been removed from very severe portions of the North Eastern line, he said: "I object to this. As it is done I will pass this line; but I will never pass any more lines which you lay down with old rails." As a matter of fact there was a small branch the North Eastern Railway Company were now making between the works of Messrs. Bolckow, Vaughan & Co.

and their cottages, where the line ended ; and they were prevented from laying down old rails upon that portion, with the result that it was being laid with new rails. With regard to deflection, in the diagram given in the Paper (*Fig. 5*) the curve represented the deflection caused by the engine and tender of a train running from right to left. It would be observed that there was a well-defined point, and he reckoned that going at the rate of 45 miles an hour, which was a long way short of the regular speed for express trains—practically 60 miles an hour—the engine went over the point of greatest pressure in an inconceivably small fraction of a second, and therefore the cumulative vibration spoken of by Sir Andrew Noble could not be said to have much effect on the general conduct of the rail itself. The diagram would be seen to be irregular, oscillating slightly according to the nature and work of the engine itself. The locomotive could not be balanced so exactly as not to cause a slight blow, and

Sir Lowthian
Bell.

Figs. 2.



consequently the lines on the diagram were in a sort of saw-toothed form, until the whole of the heavy part of the train, *i.e.*, the engine and tender, had passed the indicator, when the carriages alone could affect the readings of the instrument. With regard to the rusting of rails, it was a well-known fact, and he had never heard it disputed, that if an iron rail was laid down alongside a running rail, the oxidation of the unused rail was much greater than that of the rail in use. Cases had occurred where rails had been overlooked and left for many years, and the amount of corrosion of those rails, which had never been used at all, was very great. He remembered quite well that when it was first proposed to lay rails of malleable iron the objection raised was that malleable iron corroded much more rapidly than did cast iron. Referring to the action on rails in tunnels, and in fact near any centre where the atmosphere was polluted by chemical fumes, he might mention that the rails and the telegraph lines

Sir Lowthian Bell. near the chemical works in the neighbourhood of Newcastle, for instance, were very much corroded, and rails were taken out of a tunnel near Leeds, where in 7 years they had lost 21 lbs. per yard in weight. He was very glad to hear that the extreme corrosion of rails in tunnels could be stopped by painting them, and he would carry away from the meeting an impression which would induce him to try that plan. He would like to say one word on the subject of the two processes of making rails, the open-hearth and the Bessemer. In the latter process something like 15 tons or 20 tons of metal was run into the converter, and in less than as many minutes it was converted into steel. It was idle therefore to talk of making any examination of the condition of the contents of the ingots where the time was so short; whereas with the open-hearth furnace a very different state of things prevailed. Practically it might be said that the charge was in the open-hearth furnace for nearly 10 hours, and the practice was to take out a certain quantity of steel, beat it under the hammer into a flat plate and then bend it. It was then a circular plate, and was bent a second time when cold. Unless it stood that test without breaking, the product would be rejected. The workmen by experience could read the lesson that was taught them, and there was opportunity in the open-hearth process, from the length of time during which the operation lasted, to introduce modifications. If the product was deficient in carbon, carbon could be added, or if it was too high in carbon or sulphur, those things could be corrected in the furnace itself before the product was run into the ingot moulds and formed into steel. He was hopeful that the day would come when, in order to secure a rail of uniform quality and of the highest possible strength, railway engineers would specify that all rails should be made in the open-hearth furnace.

Mr. Andrews. Mr. THOMAS ANDREWS said he had greatly enjoyed Sir Lowthian Bell's Paper both from its retrospective character and from its bringing one into touch with things of the past and with modern requirements. One part of the Paper especially struck him as being important, namely, the different deflection and strength of rails taken from various parts of the same ingot. He thought there was a danger at the present time of cutting too little from the top of the ingots from which modern rails were made. There was a considerable amount of impurity always located in the top part of an ingot, and if sufficient was not cut off there was a liability of the rail which represented the top of the ingot being in a somewhat brittle and dangerous state. With regard to Sir W. Roberts-Austen's remarks, he was not at all prejudiced in favour of drawings in preference to photography in microscopical work, but

believed in the use of both, some for one purpose and some for Mr. Andrews. another. He hoped to show specimens of each.

Mr. Andrews subsequently exhibited a series of lantern slides showing the chemical composition of steel rails and fractures and flaws in rails.

Correspondence.

Mr. W. L. JORDAN observed that Sir Lowthian Bell had given Mr. Jordan, a clear explanation of the manner in which a fast train might run in safety over a fractured rail which could not carry the same train if moving slowly; he presumed, however, that it was nevertheless generally recognised that the vibration caused by a fast train might break rails, or shake to pieces girders, which would not be injured by the passage of the same train moving slowly. He alluded to this for the purpose of suggesting that Sir Lowthian Bell might perhaps be able to add some further information to the interesting statement he gave regarding the relative number of rails broken on different parts of the North Eastern line. A point of special interest in connection with the subject seemed to him to be as to whether the same rule for spacing sleepers prevailed all over the Company's lines, or whether any particular rule for spacing prevailed in the areas in which breakages were most numerous.

Mr. J. E. STEAD considered it a great triumph in metallurgical Mr. Stead. research when Professor Arnold proved that the sulphur in steel, or at least the greater part of it, separated out in combination with iron or manganese, and did not remain in combination with the mass of the steel in the way phosphorus did, but was thrown out of solution and appeared as envelopes to the crystalline grains of steel under certain conditions. Mr. Stead had noticed they were more usually in the form of minute globules in large ingots. When the steel ingots were rolled out into rails, these globules were elongated and appeared in longitudinal section as lenticular forms; but in reality, as he had shown in a Paper¹ on the causes which tended to produce fracture in iron and steel, they were of torpedo or cigar shape. When the original section of the ingots was greatly reduced, these sulphide globules were rolled out and became elongated threads. He had observed that they

¹ Proceedings of the Cleveland Institution of Engineers, 1898-99, p. 12.