

The Author. locking ; with long bogie-stock on sharp curves this was especially noticeable. From the latest information available the working-expenses of the railway were about 3s. 5d. per train-mile, and the expenditure of fuel was 115·17 lbs. per train-mile.

Correspondence.

Mr. Berg. Mr. S. J. BERG observed that the following system of railway location on difficult ground was frequently used in Switzerland. The ground was roughly surveyed to get a contoured map, to a scale of $\frac{1}{2000}$ or $\frac{1}{5000}$ of a fairly broad belt of ground along the probable route. When study of this in the office had resulted in the choice of a suitable line, a traverse approximately fitting the location of this line was run on the ground, cross sections were taken, and a new contoured map to a scale of $\frac{1}{1000}$ was made, steep places being mapped to a suitable larger scale. On this map the final line was carefully selected and afterwards staked out, and final cross sections were then taken. This method seemed expensive, but, as a rule, money well spent on surveys was a first-rate investment, and with difficult ground it was, as a rule, impossible to arrive in any other way at the most satisfactory solution of the different questions arising in the location of the line. Very often the valley slopes were flatter near the bottom of the valley, which indicated that the line ought to be located as low down as possible, with due regard to the other factors in the problem. With regard to retaining-walls on sidelong ground, experience had shown that these ought to be replaced by masonry viaducts when they were as much as 25 feet high, the cost of wall and viaduct being then equal. A retaining-wall 63 feet high cost more than twice or three times as much—according to circumstances—as the corresponding viaduct, and was a source of much greater danger where the ground was somewhat difficult. In many cases, however, it was possible to employ viaducts where the use of retaining-walls would entail danger of slipping. The viaduct left ample room for drainage, and did not require a continuous cut in the ground, merely needing excavation for the foundation of the piers. Where possible, the bridges ought to be of masonry and not of metal, and, judging from the prices mentioned by the Author, masonry bridges, and in particular hillside viaducts, had not received full consideration ; though of course it was not easy to judge Indian matters from a European point of

view. On the Albula Mountain Railway in Switzerland, in course **Mr. Berg.** of construction, there was, out of more than forty viaducts and bridges of importance, only one of iron, with girders of $262\frac{1}{2}$ feet span; all the others were of masonry, and spans of even 131 feet (40 metres) were employed. The principal ground for preferring the masonry was economy. The arrangement of central masonry bench-marks on the balance-points was certainly an excellent practical idea. It was always found to be a tedious matter on difficult ground to secure the centre of the line in a practical way. The Author's concluding remarks might be considered as quite true and to the point, and, as far as Mr. Berg was aware, his views were certainly identical with the opinions of the leading engineers of Switzerland.

Mr. F. C. FAIRHOLME remarked that, having had the pleasure in **Mr. Fairholme.** 1896 of going over the Nilgiri Railway during construction, he was glad to bear witness to the excellent manner in which the great difficulties of location had been overcome, and to the careful and substantial construction of the very heavy works of the line. The Paper was of special interest, as describing the first practical case of the adoption of the Abt rack-system in India, a country offering many other similar problems of railway construction which would sooner or later have to be dealt with, and for which the successful working to which the Author testified should afford a valuable object-lesson. It would add materially to the value of the Paper for purposes of comparison if the Author could give some figures as to cost of traction, etc. The Nilgiri Railway was also, as the Author had remarked, the first Abt rack-railway of English manufacture, and it was a source of much personal satisfaction to Mr. Fairholme that he might claim to have been instrumental in this respect, and he thought his firm (Messrs. Cammell & Co.) might take pride in the result as regards the rack-material. There were, however, one or two details in the design of the permanent way in which he thought the example of the Nilgiri Railway should not be too closely followed in any other instance, one being the departure in this case from the practice (which experience on other similar Abt rack-railways had established generally) of having a standard distance between centres of sleepers of 900 millimetres (2 feet $11\frac{7}{8}$ inches), and making the individual rack-bars of a length to reach over two bays of sleepers. This departure had been due, he believed, to the fact that, when the permanent way for the Nilgiri (then known as the Coonoor) Railway was first being designed, the promoters had desired, whilst maintaining for the rails the standard section of

Mr. Fairholme. $41\frac{1}{4}$ lbs. per yard employed for Indian metre-gauge lines, to increase the load to be put on the axles, and this had necessitated a reduction of the sleeper distance to the next practicable multiple of the pitch, namely, 780 millimetres (2 feet $6\frac{3}{4}$ inches), making the length between joints of rack-bars $780 \times 2 = 1,560$ millimetres. When the line had come eventually to be constructed under other auspices, the weight of the rails had been increased to 50 lbs. per yard, but the distance between centres of sleepers had remained unchanged, the individual rack-bars being given a length equal to four times this dimension, or rather over 10 feet; and thus they compared unfavourably, in his opinion, with the normal length of about 6 feet, both from the point of view of facility of manufacture and laying, and because of the consequent greater variation in the pitch at the joints of the bars through expansion and contraction, as referred to by the Author. Another departure from normal practice on rack-railways to which exception might be taken was the use of wooden sleepers. The Author claimed for these, *inter alia*, the advantages of cheapness and of giving a more flexible road, but the latter quality, in the case of a rack-railway, was in Mr. Fairholme's opinion by no means an unmixed advantage; whilst he thought that economy in first cost might be somewhat dearly purchased if it led to increased expenditure for maintenance; and this he thought would prove to be the experience of the Nilgiri Railway in regard to sleepers, especially with the peculiar method adopted of cutting recesses therein to receive the projecting portion of the bottom of the chair (as shown in Fig. 8, Plate 1), and, in some cases, for the end of the fish-plate, which recesses, by catching water, would be liable to lead to decay of the timber. The general experience on rack-railways agreed with that of Sir Guilford Molesworth,¹ viz., that rolled steel sleepers, when not of too light a design, were most satisfactory; and he thought that the increased grip of the ballast which their shape gave them, as compared with flat wooden sleepers, was also a point of some importance for mountain railways. Another advantage of steel sleepers, as adopted on the majority of Abt rack-railways, was the possibility of accurately adjusting at any time, for widening gauge on curves, the distance from the rack of the adhesion-rail on either side. The experiments made by the Author as to the positions taken by the pinions when passing round curves, and as to the possibility of the pinion mounting the rack, were, in Mr. Fairholme's opinion, of special

¹ Minutes of Proceedings Inst. C.E., vol. cxx. p. 55.

interest and value, and he thought that all engineers connected with rack-railways would be grateful to the Author for his practical demonstration of the fact that, provided the line was properly laid and kept in order, there was even less likelihood of the engine of an Abt rack-railway leaving the road than an ordinary engine on an adhesion-railway. He thought the Author was under a misapprehension when, in alluding to the Abt design of rack-engine, he stated that all the power was transmitted by one pair of pinions only, as in all the locomotives of Abt design which Mr. Fairholme had seen, the two pairs of pinions were coupled and driven direct, and the pressure on the rack-teeth was thus equally distributed without the disadvantages of intermediate gearing. He thought it might be of interest to draw attention to the fact that the Author's contention that the ruling coefficient of adhesion on mountain railways should not, as a rule, be calculated at more than one-seventh was confirmed in a very careful review of the question in the Journal of the Association of German Railway Administrations, an abstract of which had been published in the "Proceedings."¹ He could not agree with the Author that, on a falling gradient, the rack might begin slightly below where the incline commenced. He thought an element of danger would be introduced unless the rack (not counting the entrance-tongue) started at least the length of the locomotive before the commencement of the gradient, so that the train should always be well in hand.

Mr. JOHN B. FELL remarked that the Author had referred in his interesting Paper to the "Fell centre-rail system" as having at one time been under consideration by the company's engineer along with the "Abt rack-system"; and, as he had supplied the company with the information required for making a comparison of the respective advantages offered by the two systems, he would like to make some observations thereon, first, with regard to the cost of construction, and, secondly, upon the most important question of security and safety in the working of the Nilgiri Railway. With regard to the cost of construction, which was stated to have been £15,000 per mile, this was much in excess of the cost of the Mont Cenis Summit Railway, which had been constructed on the centre-rail system at a cost of £8,000 per mile, including a length of over 10 miles of avalanche-galleries and covered ways through the deep snow-drifts at an elevation of between 5,000 feet and 7,000 feet above sea-level. The cost of the centre-rail per-

¹ Minutes of Proceedings Inst. C.E., vol. xcvi. p. 408.

Mr. Fell manent way was less than half the cost of the rack-and-pinion. There was the advantage of having the wider gauge of 1·10 metre in place of only 1 metre, and the further advantage of being able to adopt curves of a radius of 40 metres, in place of 100 metres, whereby a great saving was made in the cost of the works, bridges and tunnels; and these savings collectively would go far towards accounting for the excess of £7,000 per mile in the cost of the Nilgiri Railway, the cost of equipment, stations, &c., being in both cases included. With regard to the Author's observation that, to guard against certain dangers in the working of the line, it was essential that a rack line should be laid with the greatest care and accuracy and be kept in perfect order, it would be difficult, and perhaps impossible, that these conditions should always be strictly complied with; whereas during the five years' working of the centre-rail system on the Mont Cenis Summit Railway, with a day-and-night service, carrying the Indian mail all the year round, and all the international traffic of passengers and goods over a distance of 50 miles, no passenger had ever received an injury of any kind; and the King, when, as Prince of Wales, he made a journey over the line in May, 1869, had written to the late Duke of Sutherland:—"I was delighted with the Mont Cenis line, and so was the Princess; the scenery was splendid, and the line not at all 'jumpy,' in fact it seemed to me the safest railway I had ever been on." It was evident that if the Nilgiri Railway Company had adopted the centre rail in place of the rack-and-pinion system they might have saved over £100,000, and have avoided all the otherwise unavoidable dangers of the rack-and-pinion system for passenger traffic. On one of the New Zealand Government railways, built over 20 years ago, on which the centre-rail system had been adopted for the crossing of a mountain range, the engineer reported that a saving there of £100,000 had been effected by the adoption of the centre-rail system. It would therefore appear that of the two systems the centre-rail was better suited for steep gradients up to 1 in 10, and the rack-and-pinion system for steeper gradients.

The Author. The AUTHOR, in reply to the Correspondence, explained that the reason given by Mr. Fairholme for not adopting the ordinary sleeper distance of 900 millimetres (2 feet $11\frac{7}{8}$ inches) was not quite correct. The standard distance for metre-gauge railways fixed by the Government of India was 2 feet $8\frac{3}{4}$ inches, with a maximum engine axle-load of 8 tons, but as it had been intended to increase the axle-load to 13 tons, it had been considered desirable to decrease the sleeper distance. The most convenient

dimension to adopt was 780 millimetres (2 feet $6\frac{3}{4}$ inches). The The Author.
question of the relative merits of wooden and steel sleepers must ever remain debatable. It was difficult to follow Mr. Fell's reasoning that, as the Mont Cenis temporary line had cost only £8,000 per mile, if the Nilgiri Railway had been built on the Fell system it would have cost the same, especially when it was remembered that the only Fell railway in existence had cost £28,160 per mile. Mr. Fell's quotation from the Paper by Mr. J. P. Maxwell was not quite correct. The Author of that Paper had not stated that the adoption of the centre-rail system had resulted in a saving of £100,000, but that the adoption of the gradient of 1 in 15 had done so.¹

¹ Minutes of Proceedings Inst. C.E., vol. lxiii. p. 53.
