

gestion of the shafts bringing in the water, as a matter of fact Mr. Parry. there was not so much water at the Totley end of the tunnel as there was between No. 4 shaft and Padley. The great difficulty was the large quantity found some 200 or 300 yards west of No. 4 shaft, which stopped the work for some time, while the dam was being put in to enable a drain to be laid through to carry the water away. He would not conclude without saying how admirably the work had been executed by the contractor, who had, under great difficulties, succeeded in carrying it out, and must be heartily congratulated upon its completion.

Mr. ALFRED GILES, President, said the Institution was to be Mr. Giles. congratulated upon the profitable discussion on the great work that had been described; and thanks were specially due to Mr. Parry for having afforded information upon the points as to which the original communication was not sufficiently explicit.

Correspondence.

Mr. BENNETT H. BROUGH remarked that, as there were but few Mr. Brough. published records of surveys of tunnels, the information given in the Paper could not fail to be of value to all interested in underground surveying. The results obtained when the two headings met were very satisfactory and compared favourably with others recorded elsewhere, as was shown by the following tabulated statement:—

Tunnel.	Length.	Error at Junction.	
		In Alignment.	In Level.
	Fect.	Inches.	Inches.
St. Gothard	48,872	12·99	1·97
Mont Cenis	40,081	Nil.	12·00
Hoosac, Massachusetts	25,031	0·03	0·23
Ernst-August adit, Hartz (Division 2) .	23,760	1·20	0·09
Totley	18,687	4·50	2·25
Cowburn	11,106	1·00	
Croton aqueduct, New York (Division 1)	6,400	0·09	0·01
Nepean, New South Wales (Division 2) .	4,341	0·42	0·25

It was possible that the Author might have obtained even better results if he had adopted more precise objects for sighting

Mr. Brough. upon than the lamps shown in *Figs. 10 and 11*. Mr. Brough's experience in mine-surveys tended to show that for short distances it was advisable to sight a plumb-line. This was distinctly seen as a black line upon a white ground, if a sheet of paper dipped in oil was held behind it and illuminated from behind by the flame of a candle. A sheet of paper rendered transparent in that way was visible at a much greater distance than a sheet simply illuminated from the front. In setting out tunnels it was often difficult to distinguish the centre-line wires, as the cross-hair of the telescope and the two plumb-lines appeared so nearly alike. In order to obviate this difficulty, Mr. F. W. Watkins had devised for use in the Croton aqueduct an illuminated-slip apparatus to replace the wires. It consisted of two vertical strips of brass (3 inches in height) attached to separate horizontal bars moving in guides and provided with a tangent-screw motion, by which one or both could be moved right or left and the vertical aperture between them made as small as desired. One of those instruments was screwed to a plank-bracket, close behind each plumb-line, and so placed that the farther one could be seen through the telescope in line just above the other. When the slits were adjusted to be directly behind the plummet-wires, the latter were removed, and lights were placed behind the slits. In that way two fixed and illuminated points were substituted for the wires. The results of tests of the alignment thus effected showed that the accuracy attained in the surveys was very remarkable.

Messrs. Lar-
muth & Co.

MESSRS. THOMAS LARMUTH & Co., of Manchester, stated that the most rapid boring accomplished by the "Hirnant" rock-drill had been done in the Moorhowe tunnel of the Thirlmere Water-works, where, in the presence of the Manchester Water-works Committee, eighteen holes, each 4 feet 6 inches deep by $1\frac{1}{2}$ inch in diameter at the end, were drilled in three hours thirty-five minutes, by two $3\frac{1}{2}$ -inch cylinder "Hirnant" rock-drills, mounted on a carriage—the time including two changes of drill-bits to each hole, and the shifting of the drills on the carriage in various positions for a face 8 feet 6 inches wide by 7 feet 3 inches high. That afforded a record which had probably never been equalled.

Mr. Twin-
berrow.

Mr. J. W. TWINBERROW observed that though there did not appear to be anything novel about the methods adopted for setting out the Totley tunnel, it was instructive to learn how the difficulties which arose had been overcome. At Totley, the length of the sights necessary, and the boisterous nature of the weather on the top of the moor seemed to have been the chief difficulties encountered. The former had been met by the use of a 30-inch

transit instrument; less trouble from the latter might possibly have been experienced if the observatories had been built more solidly and had been constructed on a wide footing built tight up to the excavation to ground-level, instead of on footings stepped back in courses as the drawing showed. He presumed that the platform was quite independent of and in no way connected with the observatory. It was stated in the Paper that at its western end the Totley tunnel was on a curve of 40 chains radius for a distance of 100 yards; so that, in order to sight the straight into the tunnel from observatories Nos. 3 and 4 west, the heading must have been driven for some distance beyond the side-wall of the tunnel. No doubt the length of base thus obtained justified the slight additional expense, but with care there need not have been any risk of an unsatisfactory junction in working in from the curve, especially as the headings could be pushed well ahead of the last working-faces. In the case of the King's Cross tunnel completed by the Great Northern Railway Company in 1892, no heading was allowed to be driven through until the faces were within 18 feet of meeting; but in every instance the junction was made without appreciable error, though the base worked from was only 6 feet in length. The observatories had to be fixed to the roofs and chimneys of houses, in which situation they were particularly sensitive to vibrations due to wind and passing traffic. The smoky state of the atmosphere was also a constant source of trouble.

Mr. Twin-
berrow.

The system advocated by the Author for expediting the progress of headings by means of overhead travelling skips suspended from the head-trees would be accompanied by many difficulties in practical application, as the timbering of a heading had usually quite enough to bear without being subjected to the risk of displacement from moving loads. The failure of 1,000 yards of heading in Cowburn tunnel showed that was the case there. Also, unless specially designed wagons were employed, the height of the heading would have to be increased with a corresponding diminution in the rate of progress of mining. If it were worth while to employ special wagons, he thought that it would be best to construct them with a frame, by means of which the moving load might be supported over the body of the wagon. But only in exceptional circumstances could a contractor be expected to incur such additional expense. On the whole, the rate of progress of the headings of the Dore and Chinley tunnels appeared to have been by no means unsatisfactory. The 2-foot gauge adopted for the temporary roads in Totley tunnel must have been a source of

Mr. Twin-
berrow. expense from the mixed plant necessary, and of trouble due to the break of gauge, irrespective of the fact that the single road of 4 feet 8½ inches gauge proved in practice to be of greater capacity. He wished to ask whether the narrow gauge had been tried also in Cowburn tunnel.

It was interesting in the case of such long tunnels to note the quantity of excavation and of brickwork in the sweets. The total quantity of the former must have been about 30,000 cubic yards, and that of the latter 15,000 cubic yards. Assuming roughly the cost of the former to have been 8s. and of the latter 30s. per cubic yard, the very large sum of £34,500 resulted; the greater portion of which might, he thought, have been saved by the adoption of some such system of tunnelling as that described in his Patent (No. 19,679), or that invented by the late Mr. Jennings, which was used with success in the King's Cross tunnel.

Mr. Walker. Mr. CHARLES R. WALKER observed that the western end of the Totley tunnel was stated to be on a 40-chain curve extending 100 yards into tunnel. The offset would be more than the half-width. He would like to know how this was provided for. Apparently the heading was driven on the straight line. As to drainage, he agreed that the heading should be driven as low as possible; where there was an invert the heading should be driven at the top of it, to allow the temporary road to be laid over the brickwork. In heavy ground a grip 3 feet 6 inches deep could not be cut below the bottom of the heading. Locomotives were used by the late Mr. T. A. Walker in the headings on the Dover and Deal Railway, but when the break-ups were proceeding, the fumes from the locomotive drove out the miners on several occasions. With regard to the Author's proposal to use large wagons and a light overhead road at the face, for removing the earth in skips to be tipped into the wagons, he did not think that would be satisfactory in practice. It would necessitate two temporary roads, one above and one below. In an ordinary heading there was only about 1 foot between the wagon and the side-trees, which frequently yielded in heavy ground and blocked the road. The weight of the wagon would give rise to grave difficulty in cases of derailment. There was also an objection to special plant for tipping. In the Severn tunnel and in the Wenvöe tunnel on the Barry Railway, the late Mr. Walker used skips containing 1 cubic yard, running on a 1-foot 9-inch road. In the Severn tunnel two roads were laid. In the Wenvöe tunnel three roads were laid in the heading, and the haulage was chiefly effected by ponies. The roads were connected by frequent crossings. The

third road offered great advantages in the break-ups, chiefly as a Mr. Walker. means of avoiding the removal of half-filled skips; the skips were run out to the tip, and could be readily lifted by hand when off the road. A double road would admit the introduction of wire-rope haulage. This was used in the Severn tunnel, where $1\frac{1}{2}$ mile of tunnel was completed in about three years, all material up and down being passed through one shaft. He believed that plant of that description would be more useful than the heavy plant suggested by the Author.

Mr. EDWARD PARRY, in reply to the correspondence, said the Mr. Parry. suggestion for expediting the progress of the headings by means of overhead travelling skips suspended from the head-trees could not, owing to the death of the Author, be further explained. It was not so much the cost of the mixed plant, rendered necessary by the adoption of the 2-foot gauge for the temporary roads at the Totley tunnel, which caused their abandonment, as the impossibility of removing the spoil from the heading and break-ups fast enough to permit of the work to be carried on without interruption. The narrow-gauge was used at one end of the Cowburn tunnel, but the work there did not proceed nearly so rapidly as at Totley, and was not complicated by the working of a large number of break-ups during the time the heading was in progress. The method of tunnelling invented by the late Mr. Jennings had been already successfully employed, and would probably be more used in the future; but, for various reasons, it was not thought desirable to introduce it into either the Totley or Cowburn tunnels. The heading at the Totley tunnel was driven through on the straight, but was extended for so short a distance at the tunnel entrance beyond the section of the tunnel, that the slight additional cost incurred was justified. With a short tunnel, it might have been sufficient to have worked from the curve, but it would have been unwise to have risked an improper junction at the centre when the means of accurate setting-out were obtained so readily.

30 January, 1894.

ALFRED GILES, President,
in the Chair.

The discussion of the Paper on "Tunnels on the Dore and Chinley Railway" occupied the evening.