The Author. Paper, been adhered to throughout, instead of experimenting with other compounds; especially as these ploughs had been subjected to a much more severe strain than was considered expedient elsewhere, in that the car- and repairing-sheds had not been so well equipped for treating the ploughs. While he did not suggest that the Tooting plough was incapable of improvement, and thought that efforts in this direction should be devoted chiefly to reducing the number of parts, and to securing a plough which required no dipping, he did maintain that, given systematic treatment, the present plough was a workable article, capable of giving excellent results, as had been abundantly proved during the 10 years it had been in use elsewhere. As to the cost of cleaning, this was given as ranging from £5 10*s.* per annum per mile of single track in Washington, where the streets were well kept and the cleaning-chambers numerous, to slightly over £100 in Paris, where the streets were flat and badly kept, and the cleaning-chambers were at long intervals. Paris might be regarded as abnormally high; because at Bournemouth, with somewhat similar construction, but with undulating, well-kept roads, the cost was estimated at about £20 per annum. The greater cost of working conduit than overhead tramways seemed to vary between 0·2 and 0·55 per car-mile; but this was not a good basis of comparison, as the car-mileage varied so materially.

Correspondence.

Mr. Howard-Smith. Mr. W. HOWARD-SMITH remarked that the capital cost of a tramway was so largely represented by the permanent way, and in particular by the rails, upon which all the money had to be earned, that it was of primary importance that these should be as perfect as possible in every detail of design as well as manufacture, in order that the longest practicable life might be attained. In the design of the track-rail (Figs. 17 and 18, Plate 2), there were somewhat unusual features, and in particular the wide fishing-angle of 30°, 15° each at top and bottom—was quite a departure from prevailing methods in British and foreign electric tramway practice: it would appear rather to favour a return to the wide fishing-angles usual in the earlier tramway rail-sections, but which had been discarded soon after the advent of electric traction. For railway-rails it was usual to adopt wide fishing-angles, but the conditions which made this essential did not prevail in

Mr. Howard-Smith.

street-tramways. For instance, on railways it was customary to allow freedom of rail-movement in expansion and contraction. Again, the fishplates were accessible, and the bolts could receive attention whenever required. With tramways on public roads the conditions were quite different, as the fishplates were embedded in the paving, and generally remained untouched for considerable periods; and, as the same amount of provision for expansion and contraction was not necessary, it was usual to adopt somewhat flat fishing-planes, in order that the support afforded by the fishplates might be as direct, and the stress upon the fish-bolts as little, as possible. Fishplates with narrow fishing-angles could be jammed in fairly tightly, and would probably remain so for a long time, a little stretching of the bolt or slacking of the nut not appreciably loosening the joint; whereas with wide angles of contact the fishplates were apt to work loose much more quickly, thereby leading to deterioration in the rigidity of the rail-joint. Even in railway-rails it was not considered desirable to have as wide fishing-angles for flanged, or flat-bottomed, rails as for bull-headed rails, and recently there had been a tendency to make the angles of the latter less than heretofore. For bull-headed railway-rails a combined fishing-angle of about 40° was now generally favoured, while for flanged rails 24° to 28° was usual; the Committee on Standard Rail Sections appointed by the American Society of Civil Engineers recommended not more than 26°. A main reason for this difference was the greater lateral rigidity imparted to flat-bottomed rails by having a flange about 5 inches in width—for, say, a 90-lb. rail—as against an overall width of 2½ inches in a bull-headed rail. The girder tramway-rail, shown in Figs. 17 and 18, had still greater lateral rigidity due to its 7-inch flange and a head about 4 inches wide. If, therefore, 40° was the best angle for a bull-headed rail having a width of 2½ inches, and, say, 28° the best angle for a flat-bottomed rail with 5-inch flange and 2½-inch head, then, for a tramway-rail with 7-inch flange and 4-inch head, the fishing-angle should, following the foregoing considerations, be proportionately less: and this was generally the case in practice, the angle adopted being, as a rule, 17° to 20°. In the British Standard tramway rail-sections, a bottom angle of 7° and a top angle of 12°, giving a total fishing-angle of 19°, had been adopted. As an indication that this latter angle did not at all verge towards an extreme in narrowness, might be cited the fact that for the Burton-on-Trent tramways, recently opened, the rail had a combined fishing-angle of only 12°, namely 6° each top and

Mr. Howard-Smith. bottom. So narrow an angle as this was not, however, to be advocated. With the particular form of rail-joint described in the Paper as having been used in the straight portions of the track, which made it possible for the raised fishplate to receive impact directly from the car-wheels, as also from road-vehicles, it would certainly appear desirable that the foot of such fishplate should rest upon as flat a plane as practicable, rather than bear, almost upon tip-toe as it were, upon a slope having an inclination as steep as 15°. Another peculiarity of this fishplate lay in the departure from the usual rule that the maximum amount of support should be afforded to the rail-head by fishplates having as wide bearing-surfaces as practicable; although at the same time there was little gained by one wing of a fishplate having a greater fishing-surface than the other, and, generally speaking, it was desirable that the bearing-surfaces of both fishplates should be approximately equal. In the rail shown in Fig. 17 the raised fishplate had a top fishing surface only about $\frac{1}{4}$ inch in width to support the underside of the rail-table; and even this width was theoretical; probably the actual bearing would be even less. In practice it was found that this particular part of a fishplate was subjected to the greatest wear from attrition, due to the vertical and vibratory movements of the rail-ends; and such a narrow surface was liable to become quickly worn down, especially as, from its peculiar shape and situation the fishing-shoulder was likely to be continually fed with gritty particles and moisture passing down the $\frac{1}{16}$-inch opening between the rail-table and the raised fishplate. Again, if the rail-table was rolled even the slightest degree deeper, or the fishplate the slighest degree wider between fishing-angles, than was theoretically required; or should the slot in the rail-end not be planed out absolutely clean in the corners, or the fishplate itself be a trifle too long, or not cut absolutely square—not at all impossible contingencies; then the fishplate would not go home tightly to the underside of the rail-head, but would merely touch at a point, thus depriving the head of proper support and increasing the tendency to wear. If, moreover, the height of the fishplate between fishing-angles were increased by only $\frac{1}{64}$ inch, or the fishing-opening of the rail were diminished by a similar amount, the effect would probably be to make the vertical space as much as $\frac{1}{8}$ inch in width, instead of the theoretical $\frac{1}{16}$ inch. The fishing-surface at the bottom of the raised fishplate had a width of $\frac{5}{8}$ inch, while the fishing-width at the top and bottom of the small fishplate was $\frac{1}{2}$ inch in each case: the No. 4 British Standard section had a fishing-surface $\frac{13}{16}$ inch wide at all four bearings. Again, the double-taper angle of the top surface of the flange (Fig. 17) was not liked by rail-makers, as the outsides of the flange were so very flat (namely about 4° angle), that it was difficult to squeeze the steel into the rolls in the squabbing pass so as to ensure flanges of full width and perfect shape at the toe. Mr. Howard-Smith.

Mr. W. H. PRETTY observed that from the experience of railways it would seem to be essential for continuous and steady running that the rails should be of the nature of continuous girders, and the joints should be of the same order of rigidity and durability as the remainder of the rail, which behaved like an elastic bar under the succession of transverse loads brought upon it as the trains passed. A fairly rigid track would entail a correspondingly rigid joint for smooth running, and no mechanical joint using bolts for fastening was likely to satisfy this condition. It would be interesting to have some exact particulars of the expansion and contraction of welded tracks buried after the manner of street tramways, which might also seriously affect the durability of mechanical joints. The fishplate shown in Fig. 17, Plate 2, where one plate was level with the surface of the rail, was obviously bad, since the rail, which was of considerable mass, was relatively not so free to move as the parasitic plate which, with its attachments, behaved somewhat like an elastic body attached to a rigid mass, and was therefore likely to receive all the hammering effects of the car-wheels. The helical nut was a doubtful servant and might defeat its object, should a workman not grip the helix immediately next the fishplate when tightening up. He was inclined to think, that in the hands of a good platelayer, the solid, tight-fitting nut was to be preferred. In connection with mechanical joints, it might be interesting to note that oxidation between iron and steel plates produced a pressure within the joint, which was sometimes useful and sometimes detrimental. The following Table was suggestive of Mr. Pretty.

—	Specific Gravity.	Relative Volume.	Increase in Volume.
			Per Cent.
Hematite—Oxide of iron (Fe_2O_3)	5·23	1·49	49·0
Göthite—Hydrous oxide of iron ($Fe_2O_3.H_2O$) . .	4·2	1·86	86·0
Limonite—Hydrous oxide of iron ($2\,Fe_2O_3.3\,H_2O$)	3·8	2·05	105·0
The unit of volume being steel of	7·8	1·00	..

Mr. Pretty. possibilities which might arise on account of pressure thus produced between plates, at places some little distance removed from a bolt or rivet. So far as his observations had gone, a definite pressure could be exerted by these oxides of iron, which in the course of time might ruin structures; evidence of such destructive action was seen in many fine examples of ornamental ironwork and occasionally in joints of tanks, gasholders, etc., when the riveting was somewhat sparse. The degree of hydration appeared to depend upon the pressure exerted by the plates and would vary in the same joint, the part most rigidly held approaching nearer to the anhydrous state. The flexible joint of the steam locomotive railway was indifferent to corrosion, while the pressure thus produced assisted in locking the solid nut upon its bolt; but the arrangement shown in Fig. 17 would defeat any benefit likely to accrue from increased rigidity in a rigidly laid track, and would assist in the formation of oxides tending to separate the fishplate and rail in the case of tracks laid down some years prior to their use for heavy traffic. Oxidation in cast-iron chairs appeared to take the form of weathering. He had seen very old railway chairs weathered to a depth of $\frac{5}{8}$ inch, and quite recently some tramway chairs taken up from the old horse-tramways at Leicester had shown a weathering to a depth of $\frac{1}{8}$ inch; others which were embedded in pitch, or in material of a similar nature, had a well-preserved structure in the cast-iron section and quite near to the skin of the castings. The conduit system was a step towards ideals in street-tramway work; possibly the ideal would be reached when the track represented the stator, and the train or car the rotor, or rotor element, respectively, in a polyphase transmission. Were Arago alive he might not be quite satisfied with the progress made in this direction.

The Author. The AUTHOR, in reply, observed, in reference to Mr. Howard-Smith's remarks on the fishing-angle, that it could not be disputed that the flat-bottomed rail was rigid; but that this rigidity should be considered to apply equally to the joints was quite a different matter: and much might be said in favour of maintaining if not increasing the fishing-effect in the heavier sections of tramway-rails, which were liable to severe shocks, causing vibration. Accepting, however, the contention that a high value should be attached to lateral stiffness, it was obvious that the value which had been accorded it in the examples quoted by Mr. Howard-Smith could not extend much farther, as, were this done, with a very slightly wider flange there would be practically no fishing-angle, and, worked out on an arithmetical basis, fishing would disappear altogether at $10\frac{1}{2}$ inches. Whatever the basis of working, arithmetical, geometrical, or empirical, a stage must come when the high value attached to stiffness must be set aside, and other factors must be considered. For example, taking variation in section and considering the effect produced (*a*) on joints of the standard British section with combined fishing-angle 19°, and (*b*) on the section given in Fig. 17, with a fishing-angle of 30°, by the $\frac{1}{64}$ inch variation allowed by the standard rail-specification in the total height between the fishing-surface, and dealing with the case where one rail was normal and the other $\frac{1}{64}$ tight in the fishing-surfaces; in case (*a*), when the fishplate was bolted up hard to the tight rail, it would require to be bent inwards about $\frac{1}{16}$ inch before it bore on the fishing-surfaces of the other rail. It was manifestly impossible for the fishbolts to do this exactly opposite the joint, with the strong section of fishplates at present employed; and the result was that, although a good bearing might be secured at the second and third bolts, no bearing was obtained at the rail-end opposite the first bolt, where it was most needed. In case (*b*) the effect was much less, as the fishplates only required to be bent $\frac{1}{32}$ inch in order to gain contact. Other reasons, such as increased life, uniformity of top and bottom fishing-angle, might be brought forward in favour of the London section; but the foregoing illustration might show that there were distinct advantages with the steeper angle, which might outweigh the advantage of greater support given by the standard section. Mr. Howard-Smith had pictured various complications which might produce bad results at joints, but none of the cases connected with the preparation of the joint did occur, for the simple reason that the sleeve was milled out and checked by gauge; and Mr. Howard-Smith's other general remarks about fitting were equally applicable to all joints. Regarding the restricted width of fishing-bearing under the head, with the Dicker joint this was a disadvantage, but the Author had had frequent opportunities of examining rail-joints of different forms, and in the great majority of those inspected he had found that only a limited width of the fishplate actually bore on the rail. For example, in a fishplate with a top 1 inch wide, on an average only $\frac{3}{8}$ inch width would be touching. It was true that the double-angle flange was not so easy to roll as the ordinary flange; but the difficulty was a very small one, and rarely, if ever, was a rail rejected on account of faulty angles. He was disposed to agree with Mr. Pretty that it would be an improvement if the fishplates were The Author.

The Author. more rigidly held. With regard to oxides of iron gathering in the crevices of the joint, and attaining sufficient strength to force out the fishplates, he was convinced that the vibration in a rail-joint would render this impossible.

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19 January, 1904.

Sir WILLIAM H. WHITE, K.C.B., D.Sc., LL.D., F.R.S., President, in the Chair.

The discussion on Mr. A. Millar's Paper, "The Electrical Reconstruction of the South London Tramways on the Conduit System," occupied the evening.
