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The Paper is accompanied by eleven photographs and one sheet of drawings, from which the half-tone page plates and the Figures in the text have been prepared.

Discussion

The Author introduced the Paper with the aid of a series of lantern slides.

Mr M. G. R. Smith considered the case of a gang of six men maintaining a normal length of, say, 3 miles of double track (6 miles of running line, and ½ mile of sidings) and considered their weekly work in man-hours at present and in the future. Assuming that the rail was bull-head, and applying the Systematic Maintenance Chart which had recently been issued, the total number of man-hours per week, 264, for a 44-hour week for the six men could be sub-divided on an average in the following ratio :—

	Per cent.	*Man-hours*
Ballast cleaning	9	24
Coach screws or chair bolts and keys	15	40
Packing sleeper and timbers	25	66
Ballast trimming	4	10
Turning and oiling fishplates	8	21
Weeding cesses, etc.	5	13
Cutting grass	6	15
Hedging and fencing	8	21
Ditches and drains	6	15
Miscellaneous duties	14	39
	100	264

Those figures were found to agree very closely with the actual average in practice.

The introduction of flat-bottom track on the gang's work meant that there would no longer be any coach screws, chair bolts, or keys on the plain line, so that there was a direct saving of 15 per cent. of the gang's time, or 40 man-hours. That was slightly reduced by the continued need to maintain the fastenings in the point and crossing work ; that reduction, however, was more than offset by a saving in the packing of sleepers, due to better spreading of the live load since the flat-bottom rail was stiffer than the bull-head rail. In his opinion, the result of substituting flat-bottom for bull-head track would be a saving of more than 15 per cent.,

or at least 44 man-hours, which represented a saving of one man or about £330 per annum on a length of 6 miles of running line, or £55 per mile.

As for the future, the greatest proportion of the gang's time—25 per cent., or 66 man-hours weekly—was spent on packing. Of that figure, about 60 per cent., or 39 man-hours, was spent on the rail joints, which were the weakest part of the track. There was therefore a very good argument for the elimination of rail joints by welding. If joints in plain line could be eliminated entirely, then, in addition to saving the 39 man-hours on packing, there would be the saving of the turning and oiling of fishplates and adjusting rail creep, which represented a further saving of 8 per cent. or 21 man-hours per week, making a total saving of 60 man-hours weekly. Rail failures could be reduced by 56 per cent., since, according to Western Region figures for 1950, that was the percentage of failure of rails which occurred at the rail ends. There would be yet another saving by the elimination of the fishplates and bolts, of which even the annual replacement due to breakages was of a very high order. To what extent could joints be eliminated? A definite answer to that question was needed and should be obtained by trial with gradually increasing lengths of welded rail under test conditions.

Mechanization, which in the past had been merely a desirable means of achieving economy and relieving arduous labour, was rapidly becoming an urgent necessity in certain areas owing to the manpower shortage. Electric generators gave the greatest and most convenient source of power in relation to their size and portability, and electric tools were light and easy to work and were therefore popular. It seemed that the three sizes of generator most likely to prove generally useful were: (*a*) 1-kilowatt, weighing 3 cwt., for very light hand tools and for flood-lighting; (*b*) 1½-kilowatt, also weighing 3 cwt., for driving a pair of Kango "E" hammers; and (*c*) 3-kilowatt, weighing 3½ cwt., for general hand tools such as wood augers, steel drills, and saws. There was a great future for the Kango "E" hammers for crossing and other work, owing to their ability to work in the narrow space between crossing timbers. All those generators should work off 110 volts and tools and lighting would therefore be interchangeable.

As an example of the wrong type of mechanization he mentioned the case of a set of six heavy self-powered tamping tools which had caused a great deal of complaint from the men who were expected to use them; to such an extent that, after having been in use for only a few weeks, they had the misfortune to find themselves in a small wooden tool-shed, which also happened to have the misfortune to be burned to the ground—no doubt due to the spark from an engine!

Mr L. G. B. Rock referred to the method of operating the "Kango" hammer, which in *Fig. 1* was shown being used at a fairly flat angle. He assumed that those hammers were operated by two men working in opposition, and in circumstances such as closely-spaced switch and crossing

timbers, where it was stated in the Paper, and in his opinion rightly, that the advantages of those tools were most manifest, he thought that it would be necessary to operate them in a far more upright position; but there was always a risk, if there was not a great depth of ballast, of forming a water pocket under the timbers.

In the Paper it was assumed that 30 per cent. of a gang's time on track maintenance was spent in dealing with rail joints. That seemed to be a little high; an earlier estimate of his own, which had been confirmed by an investigation covering quite a number of recorded times, suggested that the figure would be nearer 20 per cent. Nevertheless, it was quite an appreciable percentage, and if welding could be shown to be practical and economic, bearing in mind the extra cost of laying in welded rails, which would have to be commuted over the life of the track, the subject deserved the most careful investigation. He thought that far more benefit would be gained by confining the length of welded rail to something like 180 feet, and in any case not more than 300 feet, because it was obvious that the longer the length the smaller became the increase in the proportion of joints eliminated. With track electrified in the third-rail system there was an additional saving due to the elimination of copper bonds for traction current.

Mr Rock was aware that abrasion had occurred in the underside of some concrete sleepers, but he thought that that was a defect in the materials used; there was evidence of some sleepers which had been in the track for 22 years and where it was still possible to see the marks of the moulds on the underside.

Reference was made in the Paper to renewing the rails in tunnels at intervals of half the estimated track life. If the estimated track life were taken as being the estimated life of the chairs on the sleepers, having regard to galling or the tendency for the jaws to burst open by corrosion, there was not a strong objection to that practice. On the Southern Region, in most of the tunnels the rails lasted for periods of from 4 to 8 years; in those tunnels it was the practice to re-rail after the fourth to eighth year, and the life of the second rail would take the sleepers to a life of between 8 and 16 years. Even the 8-year sleepers were then taken out, with no attempt to re-rail a second time, because by that time the corrosion effect on the chairs was such that there was a risk of the chair jaws breaking.

A number of variations of the normal practice of crane renewal were also mentioned in the Paper, and methods (2) and (3) struck him as interesting. He did not see in what circumstances the old track would be lifted out in complete sections and the new track laid in by hand, or alternatively when the old track would be broken out by hand and the new track laid in in pre-assembled lengths. It appeared that a great advantage was lost in having a train of wagons brought to the site with new pre-assembled material—thus being available for the old—and not making use of them.

The advantages due to the faster rate of progress achieved by the use

of mechanical methods when re-laying were sometimes restricted by certain factors which were outside the control of the civil engineer. If the overall length of speed restriction were limited for operating reasons, it automatically limited the rate of progress of re-laying, however efficiently the work had been organized. It would be of interest to learn from the Author what was the maximum length of speed restriction normally allowed on the main lines of the Western Region.

Mr P. S. A. Berridge observed that the Author, referring to flat-bottom track, had stated that the practice in Great Britain had been to use one fastening to hold the rail to the base-plate and the base-plate to the sleeper, namely spring spikes. The small number of components was claimed to effect an economy, but there were two drawbacks to the use of spikes, whether spring or dog spikes, to hold the rail to the sleeper. They did not hold the rail against creep, and, through damage to the holes every time a rail was taken out, they shortened the life of the sleeper. It was unlikely that any spike relying on vertical pressure on the rail would ever hold creep. A spring spike might do so when the track was new, but sooner or later it would lose its original holding force. Recent observation on a British Railways main line had shown seventeen Fair-type rail anchors on a 60-foot length of flat-bottom rail where the rails were secured with spring spikes. Those rail anchors should not be overlooked when counting the number of components in the track. The jaw-and-key type of fastening appeared to be much more effective in resisting creep, and, since the fastening of the rail to the bearing-plate by keys was independent of the spiking of the bearing-plate to the sleeper, the sleeper suffered no damage, no matter how many times the rail had to be changed.

In the jaw-and-key type of bearing-plate in use on the North Western Railway in India, the jaws were incorporated in the cast-iron bearing-plates and the keys driven in the direction of creep.

Mr M. G. Maycock disagreed with the Author's opinion that "all point and crossing work should be designed and purposely made to suit conditions at the site . . . ," since that might entail extensive use of points and crossings of special angles and lengths. Perfectly good lay-outs could be designed by making use of standard sizes of points and crossings, and Mr Maycock considered that that should be done to the greatest extent possible, although, admittedly, there were places where it was essential to use special units at times. Standard sizes permitted mass production, reduced the cost of manufacture, and also made replacement easier in an emergency. He thought that economy lay in that direction rather than in the practice advocated by the Author.

With regard to the man-power required for renewals carried out by hand and by various mechanical means, it was not clear from Table 1 whether time had been taken into account, and if so in what way. It seemed obvious, for instance, that the two-crane method was nearly twice

as quick as the one-crane method, and, in spite of requiring five more men, the total time and therefore the total cost should be less. For the purpose of comparing costs and judging the real economies of the various methods, it would have been of interest if Table 1 had included a comparison on the basis of man-hours.

Of the various mechanical methods of laying pre-assembled track, namely the one-crane and two-crane methods and the new track-laying machine, none was applicable to a single line. In view of the large mileage of single-line track in Britain, and of heavily-worked double lines, where diversion or interruption of traffic could not easily be arranged, there was scope for mechanical equipment which could lay prefabricated track with the occupation of one line only. About 15 to 20 years ago, extensive use had been made of the Morris track-layer on the former L.N.E.R. That machine was a self-contained unit, capable of picking up 1,000 yards of old track and laying 1,000 yards of new track, pre-assembled, at an average rate of twelve 60-foot lengths per hour. It operated on the track which was being renewed and was therefore able to deal with renewal on single lines. Furthermore, by arranging single-line working, it was possible to carry out renewals on certain double lines on a weekday. The Morris track-layer suffered from certain limitations, mostly on account of clearances, but it might be that those could be overcome if a new design were ever to be made. After several years' use, the machine had come to need very extensive repairs, the cost of which had been considered prohibitive, and it had therefore been put out of use.

As an alternative to the Morris track-layer for renewal on single lines, there was the Diplory equipment, which was used extensively in France. It was portable, and the cost was relatively low. Frames of track were assembled at suitable sidings in the vicinity and transported to the sites on small portable trolleys, loaded one or two tiers high. At the site the track was lowered into position by hand-worked winches, mounted on gantries which ran on a light service track laid astride the running line. The old track was loaded by the same means on trolleys and hauled back to the sidings for dismantling. At a recent trial of that method on the Eastern Region, 340 yards of track had been renewed at an average rate of eight 60-foot lengths per hour. Some improvements would probably have to be made as a result of that trial. Although the Diplory method was unlikely to compare favourably in cost with crane or track-layer methods, it would serve a very useful purpose for renewals on single lines, and particularly in providing mechanical means of carrying out renewals in difficult places, such as single-line tunnels.

The three main headings of expenditure on permanent way were wages for maintenance work, cost of materials, and wages for re-laying. Mr Maycock could appreciate that it might be difficult to discuss the question of economies in maintenance at the present time, but he thought that the same objection would not apply to renewal. There was abundant

experience of mechanical methods of renewal, and he thought that some summary and evidence of the savings which had been made by various methods in terms of money would have been of advantage.

Mr G. D. S. Alley mentioned, as an alternative to the "Kango" hammer, the Jackson vibrator, which had been used extensively in Britain. A great deal depended on teaching the staff how to use the vibrator, because in many cases where it had been used it had not been successful, but in other cases, where the staff had been adequately trained, and on switch and crossing work, it had been very helpful.

Many attempts had been made in the past to utilize mobile gangs, but many of those attempts had broken down; solely due, he thought, to the fact that an attempt had been made to use the existing staff, scattered up and down a system of length of line, as a new gang—it being laid down that their home station would be at a certain fixed point. He did not know whether in the case of the proposals now under consideration, and to which reference was made in the Paper, it was the intention to try to get those men at some fixed point; if that were not so, he thought that there would be the same troubles that had been experienced before.

Reference was made in the Paper to the fact that the corrosion of rails in tunnels could often be extensive. What had been the practice of the Western Region in regard to water troughs? Had they provided additional sleepers or timbers in order to try to even out the bearing at those places where more trouble was experienced?

With regard to permissible side wear, how was a return made from the inspectors so that the District Engineers could be aware of the position? Without that, the gauge would not be as useful as it might otherwise be.

It was stated in the Paper that tests on flat-bottom track had been interrupted by the outbreak of war. The tests on the former L.M.S.R. had been continued throughout the war, although they had not been extended because fresh 131-lb. rails could not be obtained.

Mr Alley failed to see why the holding power of the coach screw should become impaired any more than the through bolt; why single out the coach screw?

With reference to re-laying, it was suggested in the Paper that for piecemeal manual re-laying approximately one man per chain of plain track would be employed, and the figures given in Table 1 were somewhat on the same lines. Unless it was stated what those men were doing, figures could be rather misleading. The men would have to lift the track and they would have to unload ballast and box in. Was the ballast coming in a hopper wagon, and were the men for those duties included in the figures quoted?

The Author stated that the twin-jib cranes could work on track with 4 inches superelevation. The type used by the London Midland Region showed a definite advantage there, since it could work on track with up to 6 inches superelevation without any difficulty.

In connexion with the costs for different types of plant given in the Paper, for item (12), the twin-jib track re-laying crane, an estimated machine-hour rate of 10*s*. was given. That was based on a user of 1,110 hours per annum. He did not know whether that twin-jib crane could be used on the Western Region except on running lines, or in other words whether their prefabricating depots were laid out so that that crane could be used there, or in what other way the use was so extended as to reach 22 hours per week.

Mr Sidney Stevens said that he would like to amplify what had been said about two items which were mentioned in the Paper, the " Kango " hammer and the rail barrow. One or two questions had been put to the Author with regard to the " Kango " hammer, which had been developed on the London Division of the Western Region, where the rail barrow had also originated. He said " Division " because it had then been a Division and not a District.

Fig. 1 showed the " Kango " hammer in use, but, as Mr Rock had said, they had to be used in pairs to get the full compacting effect of the hammer. The tool shown in *Fig. 1* had a cranked end just at the rear of the wedge-shaped tamping head, but there was a straight shaft which was useful in certain circumstances. The weight was approximately 25 lb. complete, and it should be noted that all portable plant which was devised for permanent-way men had to be truly portable. Good ideas often failed to be adopted in practice owing to excessive weight. The internal-combustion compactors and tamping machines seemed excellent in theory, but they did not find actual application in practice to the extent which they would otherwise have done, because they were too heavy to use ; the " Kango " tamper, however, could be used without any effort at all. The criterion was the opinion of the operator.

The " Kango " had been tried in No. 1 gang, Paddington, with the D-type hammer, and the suggestion had been made that the manufacturers should develop a machine which was heavier in its impact, though not appreciably in weight. The E-type hammer was the result. It had not been designed purposely for permanent way, but when it was designed it was with the idea that it might be used on the track. The vibrating blow was compensated inside the hammer, and the effect on the operator was small ; there was no active vibration on the handles, and the blow went into the head. It would lift plain line, and when a ganger used it on plain line he had to watch it to make certain that he was not disturbing the top.

With regard to the rail barrows, it was advisable occasionally to think about how the ideas had originated. In the case in question, the 300-foot welded 113-lb. flat-bottomed rails, thermit welded and laid on the London Division of the Western Region, had been laid in with the help of the L.T.B. " iron man," the portal frame with the travelling carriage. It had taken six men to lift each " iron man " and carry it to the new position ; something lighter was therefore necessary, and a light-alloy portal frame to ease

the position and achieve the object of lightness was designed. The idea of the rail barrow had come to the designer when wheeling manure in his garden. He thought that if he could lift the load which he did, he could surely lift 10 feet of 113-lb. flat-bottom rail, or more easily 10 feet of 95-lb. rail. The idea of using a wheelbarrow type of frame had been thought of before, but it usually failed on the question of the lifting appliance. On that occasion, however, the idea had been evolved of the cam-operated clip, which was perfectly safe and easy to operate; the re-layer who used the rail barrow said that he would rather use it all day than do other re-laying work. Mr Stevens regarded the rail barrow as one of the greatest advances in permanent-way handling which had been seen for many years. It made the criterion of manual re-laying the speed at which the sleepers could be laid instead of the speed at which the rail could be lifted into position.

Mr A. H. Cantrell thought that there was little doubt that by using welded rails there was a saving in maintenance, but on a broader basis it was necessary to consider the actual renewal of the track. In some places possessions for renewing were so short that they had to be cut down to the minimum and, with the mechanized renewals which were adopted nowadays, it would be difficult to carry out the pre-assembly method when laying welded rails unless it was first done in 60-foot lengths and then re-railed. That would be more expensive in the end, and as in many places track possessions were difficult to obtain, the whole of the work had to be done at one time.

Had the type of scarifier mentioned in the Paper been used in a tunnel where a really hard bottom had been formed? Fairly recently, on the Southern Region, a tunnel had been dealt with in that way. The heavier type of scarifier with big rubber-tired wheels had been used, and in seeing that operating it had occurred to him that nothing lighter would do at all; weight was necessary. At the same time, he thought that the big rubber tire was of use in getting the scarifier out of the way and on to the adjacent track, if it was necessary to do so, as it had been in that case.

In connexion with the problem of through bolts, the Southern Region had, in the past, generally used screw fastenings. It was difficult to understand the statement in the Paper that " As the life of the sleeper progresses, the holding power of the coach screw becomes impaired and it is necessary either to plug the hole by use of plastic wood or to enlarge the thread of the coach screw by the addition of a former." That was done in such a small percentage of cases that it could almost be ignored. In most of the track it was never necessary to have the coach screws out and compound put in or a former used, and so far as spread of gauge was concerned, that occurred more frequently with through-bolt fastenings than where there were coach-screw fastenings. The Author might say that that was because sorbitic rails and through-bolt fastenings had been used together and the patent oil to lubricate the bolts ignored; but that was not so—

Mr Cantrell was thinking of cases where there were not sorbitic rails and where the through bolts had had excellent maintenance.

He agreed with Mr Maycock that point and crossing work should not always be designed purposely to suit the conditions at the site, but he was not certain what the Author intended by the passage in the Paper to which Mr Maycock had referred. Would different angle crossings be used in every case, or would the usual standards be adhered to as far as possible? It was desirable to reduce to the minimum the number of types of crossing in use, so that in an emergency it would be easy to get a replacement. There were, however, many cases where there was a difficult lay-out, and there Mr Cantrell agreed with the Author on the need for purpose-made material.

Mr E. J. M. Matheson observed that there was little in the Paper about setting out, presumably because the Author considered it so essential that it was obvious that it had to be properly done. Mr Matheson thought that many economies could be made in re-laying crossing work if careful attention were given to the setting out, and he was sure that it paid to put one of the best men in the office on setting out permanent way. The normal crossing job might have sixty or seventy men on it, and if the crossing which was being handled by crane did not go down in quite the right position, sixty men wasted their time. Whenever it was necessary to adjust something with a slewing bar, again, sixty men wasted their time. It was most important that the junior engineer in the office should go out with the re-laying inspector to every complicated job and discuss where the pegs were wanted, and then put them where they were required. That made the re-laying inspector think about his job, and, once he had confidence in the engineer, they would work together as a good team, and in that way there would be a considerable saving on every job. A saving of even an hour on a job meant a saving of at least £30, and if there were ten jobs where the setting out was perfect, as opposed to being not quite perfect, and an hour had been saved on each, £300 was saved.

Reference was made in the Paper to those savings which were difficult to measure in terms of hard cash, the imponderables, as they were sometimes called. It was most important that engineers should make some attempt, in conjunction with the other departments, to assess those imponderables in terms of hard cash, because the railway accountant looked only at the percentage savings in maintenance which were shown; if those things which the Author mentioned as being difficult to assess could be added to them, and something could be put in respect of them which could be supported, any proposals which were made were much more likely to find acceptance.

Mr C. J. Chaplin said that the design of the rail barrow seemed to be excellent for flat-bottom track, but where it was necessary to lift the

rail for the additional height necessary to slip it into the chair, as in the case of bull-head track, that might make a difference. The suggestion had been made that there should be a larger diameter wheel, so that when dealing with bull-head rail the conditions should be equivalent to those with flat-bottom track. He had watched a number of operations with those barrows, and apart from one or two of the type to which he referred, he thought that the rail barrow was an excellent innovation. The rubber tire was apt to become very worn if, when carrying the rail in, it was not possible to get it exactly in position and the men attempted to slew with the barrow.

With regard to the half life in tunnels, he though that re-railing was an economic proposition. In one instance before the L.M.S. had introduced the system of half life in tunnels, there had been twelve rail fractures in 12 months (the 12 months before the normal re-laying time), but the introduction of the half life system had stopped all such fractures.

About 2 years ago the question of re-laying 3 miles in a single-line tunnel had been raised, and some inquiries had been made about the Morris track-layer, but it seemed to be gone beyond recall. The Robel cranes of the Southern Region were excellent for loading and unloading rails on single line, and there were the long low 63-foot sleeper wagons of the Eastern Region. By employing Robel cranes for loading and unloading rails and by utilizing the Eastern Region wagons for the sleepers it had been possible to carry out the job without any of that heavy handling which was so undesirable in tunnel work.

Mr R. L. McIlmoyle said that a through-bolt fastening, provided that it was kept tight during the first year after it had been installed, kept the track in gauge under all conditions. If, however, for any reason the maintenance follow-up was not good, and slackening occurred, the hole would be enlarged and it would be almost impossible to keep the track tight to gauge. The great advantage of the coach screw under conditions of that kind was its taper neck. That had a slightly greater area of contact, and a certain amount of slackness could be allowed before it started to enlarge the hole and allow any serious movement to take place ; when it was tightened up again, the taper on the neck helped to establish close contact with the timber. Experience of both types of fastening over some time had shown that it depended entirely on the maintenance. If that was good in the first year or 18 months, it was possible to get an exceedingly satisfactory track with through bolts, but if attention was not given to that tightening immediately and steps were not taken to make sure that the through bolts were kept tight, there would be trouble.

Mr Arthur Dean would have liked to have seen ballast treated as a matter of serious concern in relation to economy and some reference made to the economy which arose from the adoption of the right sort of service vehicles, so that the engineer could do his job. Economy of track maintenance ultimately depended, to a considerable extent, on

the ballast: its depth under the track, its quality, and the way in which it was kept clean.

With that was associated the means whereby that ballast was quarried, distributed, and put underneath the track. It was known from actual records that, according to the type of vehicle in which that operation was done, the cost might range from 1*s.* 6*d.* to 6*s.* 6*d.* per cubic yard. The provision, therefore, of the right type of ballast-distributing vehicle and the economic running of those vehicles backwards and forwards to and from the sources of supply could make a tremendous difference to the engineer's expenditure in that field alone.

With regard to the question of relative manning for re-laying, the figures in Table 1 in the Paper were scarcely adequate because they told only half the story. No reference was made to the men who put the rails in the sleepers at the point of pre-assembly and took them out when they came back to the depots, nor to the men who did preparatory work at the site. A comparison of the actual numbers of men on the site was not a complete comparison, and it would have been more valuable if the Author had set out the whole story and shown what the comparison in fact was in man-hours, or in any other comparable unit, throughout the whole range of examples which had been given for the whole re-laying operation.

Mr Dean wished that the Author had made a summary in the Paper and said what it was that was aimed at, and what, if anything, was the policy behind that aim. It was known that the annual cost of maintenance of track per mile might range from £300 to about £850. Where the maintenance cost was heavy, the traffic was generally so heavy that it would pay for that maintenance. Somewhere down that scale the cost of maintenance, low though it looked, would be uneconomic in that it could not be afforded by the traffic using the line. It seemed, therefore, that there were two ways in which the matter could be tackled. There were not available in Britain the facilities which existed in other countries for big on-track machines, but where there was light traffic it was necessary to look to very different processes for economy from those of normal length-gang maintenance. Elsewhere, where the traffic was intensive, other means of reducing the cost had to be employed. In Britain it was not economically possible, in general, to go any further in putting in heavier materials in order to economize on maintenance. It was necessary, as the Author had shown, to try to nibble at the manning which was necessary by various means of mechanization; over the more intensively worked lines of the railways of Britain it was necessary to rely upon that method and to look for every item where, by mechanization, with small tools or other means, it was possible to nibble away at the manning which had hitherto been required.

Mr Keith Brinsmead also emphasized the question of maintenance, because that was where most of the money went, in dealing with the

ordinary day-to-day maintenance problems. Engineers seemed at times to be blinded at times by such words as " mechanization," which was much used at a high level at the moment and regarded as having magic qualities, so that engineers were being badgered a good deal on the subject. He felt that there was still much to be done in actually organizing the work. For many years the traditional idea of a small gang, miles from anywhere, had been accepted and almost everything had been left to the ganger. It had been obvious, in going round, that the poor ganger pecked away at one place and then at another and was never on top of his work, whilst the good ganger did his own systematic maintenance.

London Transport had commenced an experiment of amalgamating three length-gangs ; they were short lengths with heavy manning. The main object had been to turn three gangs into two, a larger gang which would concentrate entirely on the main job of fettling, and which was now working through—not pecking at the track but doing really solid fettling from one end to the other—and a small gang to do all the less important things. It was not yet known how that method would work out, but it was thought most important that the men should work through and do a job properly before they left it, and not dash from one place to another to try to prop things up.

Mr Smith had frightened him by giving a figure of 23 per cent. saving due to the laying of long rails. Mr Brinsmead was glad that his Chief Engineer was unable to be present, and expressed the hope that that figure would not be published, otherwise he might be asked to save 23 per cent., and that would not be possible. His own experience had shown, on a test which had run for 10 years, something nearer 7–8 per cent. He had found the difference between short rails and long rails very glaring when the formation was poor. Many of the tracks of London Transport were out in the open, with a fairly light service compared with that in the centre. The rails there lasted a long time, and there were still quite a lot of the old 45-foot rails. In the Middlesex clay, after the recent heavy rains, every 45 feet a grey splodge and a little flick out on the ballast shoulder could be seen, and it was not necessary to look at the rails to see where the joints were.

With the heavy traffic and the small size of the London Transport system, elaborate machines like the " Matisa " tamper could not be used, and a fettling gang had recently been completely equipped with " Kango " hammers for a follow-up job after re-ballasting. He was also interested in the possibility of their use for pure maintenance work.

In the inner area of London Transport the traffic was very intense, and they had changed to measured shovel packing more than 10 years ago. A study of the job had shown that for much of the time the men were jacking up the rails and dropping them down again, and not doing much useful work. A peculiar phenomenon had arisen, namely a tremendous increase in the breakage of positive insulators compared with the negative

ones. Subject to tests which were being carried out at the moment, it appeared that the lifting up and dropping, where there was heavy traffic, put a good deal of stress on various pieces of equipment. In that connexion, something not mentioned in the Paper, but with possibility, was the use of hydraulic jacks, which did not trip and let things down with a bump, as did the mechanical jack.

The Chairman observed that he had always felt—and the Author's illustration of the " Kango " hammer reminded him of it—that electricity was greatly to be preferred to pneumatic power for the type of work in question, because pneumatic means were an inefficient method of transmitting power compared with electricity. Had progress been made in that direction or not?

*** **Mr Walter Leigh** agreed with the Author that rail-joint design was of considerable importance, since probably 30 per cent. of a gang's time on track maintenance was spent in dealing with joints.

With regard to the Author's remarks about high pressures on the fishing surfaces with consequent lubrication difficulties, those difficulties could be overcome by the use of a girder-type fishplate, making positive bearings on the adjoining chairs and " supporting " the rail on the underside of the rail head.

With the girder-fishplated joint the tension in the fishing bolts was taken up by an upper bearing on the web of the rail and the lower bearing on the outside of the lower head of the rail, instead of on the conventional fishing surfaces which were also subject to live load.

The maximum pressure on the fishing surface was reduced to less than 8·8 per cent. of the pressure with the normal fishplate. Also the direct bending-moment stresses in the girder plate did not exceed 29 per cent. of those in the standard-type plates and the stresses were independent of the track-ballasting conditions. In the opinion of some the design might have theoretical shortcomings, but on test no practical detrimental defects appeared to have developed over a period of 6 years, although only one girder fishplate and one standard fishplate had been used at each joint. Mr Leigh thought, however, that two girder fishplates were desirable.

That low-stressed joint should be particularly suitable for flat-bottom rails, which had a higher moment of inertia than the bull-head rail.

The Author had made no reference to the girder-type fishplated joint, but its use would make for economy by :

eliminating rail-end breakages through joint " stiffness " and/or defective ballasting ;
equalizing the lives of the fishplate and the rail ;
reducing bolt breakages and replacement costs ; and
reducing rail-end batter.

*** This contribution was submitted in writing.—SEC. I.C.E.

The Author, in reply, said that Mr Smith's remarks on the subject of the welding of rails probably referred—in mentioning 23 per cent.—to a percentage of on-track maintenance only and not the full-gang operations. There was a tendency to give percentages without a long enough experience, and when an effort was made to get figures of that description in practice it was found that the range was very wide.

With regard to the question of broken fishplates, and the fact that if welding were done it would reduce the number of broken plates, that number could also be reduced by providing a stronger fishplate. A man had once calculated the number of expansion gaps between London and Bristol and had startled the directors of the old G.W.R. by telling them how much rail they had not got; that gave rise to the reflection that if rails were welded a good deal of additional rail and capital would be involved.

The Author agreed with Mr Rock that the position of the "Kango" hammer shown in *Fig. 1* was not a desirable one; the photograph had been taken to show the plant as such. As had been mentioned later, those hammers had been used in pairs in opposition.

Rails of 180—300 feet were not easily transportable and it was not possible to pre-assemble them, although experiments had been carried out by one Region to see whether long lengths of pre-assembly could be carried and whether the track would be sufficiently flexible to take curves on its way out to the job. The results, however, had been far from satisfactory.

Mr Rock had mentioned abrasion of the underside of concrete sleepers and had referred to some which had been in the track for more than 20 years and which had shown no such feature. Some sleepers of the ordinary reinforced type, laid in 1929, had been taken out and, whilst the mould markings on the underside of the sleeper could still be seen, there were definite patches where abrasion had taken place.

The Author's experience of the chair screw was not great, but he had had opportunities of walking a fair amount of track with chair screws, and he had been amazed at the number which were leaning. If they were leaning, they were not doing their job; they had not got a good hold on the sleeper. Regions, other than the Western, had tried through bolts. After several years in the track those through bolts were not satisfactory; the position of the nut on the bolt showed that they had never had a spanner on them since the day they were put in. Unless the bolts were as well maintained as were coach screws, it was wrong to say that the bolt was no good. One opinion was that the coach screw did not need the attention which a through bolt required. It was necessary to take it out to re-furrule it, and then the opportunity would be taken to use "Fillplug" or enlarge the screw thread.

On the question of the renewal of rails in tunnels, tunnels on all Regions differed largely in their characteristics. On the Western Region there was one where the life of the rail in some places was only 1½ year, whilst

in other places in the same tunnel it was 6 years. In cases like that it was not economical to work on a fixed half-life renewal. Where there was heavy chair gall and the question of corrosion of the rail arose, both in tunnels and on water troughs, the Western Region used a heavier-weight rail to start with—the old "00" (97½ lb.) of the Great Western—and a thicker-based chair as well, which assisted in dealing with chair gall.

With regard to the two methods of renewal, one advantage of lifting out by crane and laying in manually was that, if it were impossible to get long enough possession of both roads from the operating department, advantage could be taken of an occupation in the night, even though it might be an hour at a time, and a small crew could be sent out to load up all the old track. The manual gang would come on in the morning with a clear run in front of them, which would give the impression that they had only half the work to do. That had a moral effect, and when accurate figures were obtained it might well prove that that was one of the cheaper methods of doing the work. With the other method—taking out track by hand and laying in by crane—occupation during the night for the stripping out of one road only might be obtained, and during the day limited occupation of the other road, also on which to use the crane, would be possible.

Mr Rock had asked what was the maximum length of restriction which could be enforced at one place on the Western Region. Generally, that had been a mile in the past, but on a recent Sunday 107 chains had been laid in one day by pre-assembly. There had been thirty-five men on the crane party for laying that track and taking out the old, and they had been followed by another gang of thirty-five on the first lift and pack, following up behind the crane gang. On the Western Region normal practice had been to shorten the restriction on long lengths during the week by lifting the restriction on the running-off end of the job. The Author did not know whether that really helped the traffic department, but it was a gesture on the part of the permanent-way people.

Mr Berridge had referred to the fastening of the rail and base-plate to the sleeper with one fastening, as mentioned in the Paper. There were many other types of fastening which were the subject of experiment, and had there been space in the Paper the Author could have mentioned the Polish, Swedish, and many other types of base-plates. With regard to rail anchors, he thought that with bull-head track the first remedy for creep was to use a steel key. If a steel key did not do the full job, then some anchors could be added. So far as flat-bottom rail was concerned, it would appear from the reports received from their District Engineers that the amount of creep experienced was small. That tended to show that, in spite of what Mr Berridge had said, the spring fastening appeared to be doing its job fairly well, in the early stage of its life at any rate.

Mr Maycock did not like the reference in the Paper to point and crossing work being purpose-made. When the Author had made that

statement, he had not intended it to apply in every case, but the Western Region believed that the legs of the crossings should be curved to suit the turn-out and not manufactured straight and odged in on the ground, and that the switches should be set in the works and not crowed in on the ground.

With regard to Table 1, giving the number of men employed, he had hoped that it was made clear in the Paper that that was the number of men employed on the Sunday, and as such it had a certain value because it gave a comparison between the numbers paid at an enhanced rate. He knew that time had not been mentioned, but the Table was on the basis of a 60-chain length, and to go into the question of time involved many more features.

He was always interested to look at photographs in the *Railway Gazette* of railways which had a narrow gauge and employed the Morris track-layer type of machine—it was a very nice job. If the standard-gauge sleepers were less than 8 feet 6 inches—say 7 feet 6 inches—it might be possible to design a similar machine within the loading gauge; but if the length of the sleepers were reduced, other troubles would arise.

Mr Maycock had suggested that comparative figure for wages, cost of material, and wages for re-laying would be of interest, and the Author agreed. The figures were very difficult to obtain under some accounting procedures, and if a comparison of that kind were to be made it was necessary to compare lengths of equal merit: that was to say, a 20-chain length of one sort against a 20-chain length of another sort, and that had to be done through the whole range of 20-, 30-, 40-, 50-, and 60-chain lengths to be re-laid.

Mr Alley had referred to the question of mobile gangs in the schemes under consideration. That was an experiment, and might last a year or for ever. For the time being, therefore, it was necessary to keep the men at their present home stations and collect them. If the scheme were successful, there would be a gradual change to a central home station.

Mr Alley had asked how a return of side wear was made by the inspector to the District Engineer. The Author had mentioned that the gauge which he had shown was used in conjunction with a step gauge, which could be passed between the head of the rail and the underside of the gauge. The inspector gave the minimum reading of his side cut on the step gauge to the District Engineer and, according to the practice which was laid down, so the District Engineer knew at what stage he should begin to make arrangements, or tell the inspector to make them, to change the rails.

Mr Alley had also remarked that the experiments on flat-bottom rails had continued during the war. That was so, and the statement in the Paper should have been that the extension of the experiments had been interrupted.

Mr Matheson had suggested that the setting out of point and crossing work was an important feature. That was certainly the case. In view

of the fact that an accurate survey was made in the first place for the ordering of point and crossing work, the Author took it as a natural consequence that it would be set out equally carefully. Although the railways were nationalized, they still, he was afraid, did not all talk the same language in each Region. Mr Matheson had referred to a "re-laying inspector," but the Author did not quite know what such a person was. Mr Matheson had also suggested trying to get some figures for the "imponderables." There was a valuable field of research there for anyone who cared to make the attempt.

Mr Chaplin had pointed out that in *Fig. 12* the rail barrow was being used on a bull-head rail, and thought that it was difficult to lift sufficiently high to keep it in the clear. On the Western Region rail barrows had been used on both bull-head and flat-bottom rail, and had worked equally well on both. They had also been used on concrete sleepers where the depth was even greater. Mr Chaplin had suggested that Robel cranes should be used to load and unload the rails; why not use the end-off method, pulling off with the locomotive? For a tunnel job it was practicable to unload the rails in that way. It would be possible to use a skid, as shown in the Paper, for end off-loading the sleepers.

It appeared that Mr McIlmoyle thought that chair fastenings should be maintained for 1 year only, but supported the Western Region's principle where "fang bolts," as they were called, were used on point and crossing work. The Author considered regular maintenance of fastenings essential.

Mr Brinsmead had referred to the emphasis which was laid on renewals rather than on maintenance. If renewals were done well, that was the first stage in helping in subsequent maintenance. Hydraulic jacks were a subject on which the Author did not feel empowered to talk at the moment; there were good and bad hydraulic jacks.

The question had been raised whether the track re-laying cranes were used in the depot during the week, or whether they were used only on Sunday. The track re-laying crane could be used in the depot, but it had a limited height for stacking the track sections, and therefore an ordinary steam crane was preferred. A track re-laying crane, had been used on a Sunday, had done a job on the Wednesday, and then another on the following Sunday, so that a fair amount of use had been made of it. As for the ability to work with 6 inches of cant, as compared with the 4 inches mention in the Paper, the Western Region always preferred to have something in reserve; the locomotive people had told them that they could use their machine on 6 inches but they preferred to err on the side of safety.

Mr Cantrell had raised the question of scarifiers. Both the caterpillar and the rubber-tired types had been tried, the latter in the Severn tunnel. It had not been very successful there, because the ballast conditions had been rather exceptional.

The Chairman had referred to electrical tools as opposed to pneumatic. If it were possible to have permanent electric points established near the crossing work, it paid to have that done and to use electric tools. If, on the other hand, those tools would be used only occasionally at the site, a portable compressor of the " pram " type and a pneumatic tool could be employed, if that was preferred.

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