Discussion.

Mr. M. G. R. Smith, in introducing Part I of the Paper, said that it was an interesting and not uncommon feature of the visual examination of track after a derailment to have confident reports made that the track appeared quite satisfactory and could not even have contributed to the accident, whereas subsequent observations taken by instrument and plotted to a distorted scale showed that the track was not quite so good as it appeared to be to the eye. Visual examination might not disclose slacks of even 1 inch running out in a fairly short length ; nor would it disclose any local sharpening of the radius of a curve combined with a corresponding local decrease in cant at the same place, which very often occurred.

In order to obtain some idea of the extent to which variations in the level of a rail could be seen and their amount correctly estimated, he had recently carried out a simple experiment. A piece of single running line which was straight and level was chosen and was put into as nearly perfect condition as possible, with regard to top and alignment. A defect in the top, of a predetermined nature, was then introduced into one of the rails and was independently examined and noted by a party of five observers, none of whom knew the nature of the defect. That process was repeated for a series of twelve defects, all different, and the reports of the observers—a drawing office assistant, a permanent way inspector, a sub-inspector, a ganger, and the Author—were compared with the following correct list of the defects : (1) slacks of $\frac{1}{4}$ inch, $\frac{1}{2}$ inch, $\frac{3}{4}$ inch, and 1 inch at a rail joint ; (2) Similar slacks at the centre of a rail—half-way between two rail joints ; and (3) Similar slacks at the centre of a rail followed by a high spot of the same amount, that was, a slack of, say, $\frac{3}{4}$ inch followed by a high spot of $\frac{3}{4}$ inch, above true rail-level.

In all cases the rate of run out was made very sharp, namely, 1 inch in 15 feet ; thus correct rail-level was regained in 15 feet on either side of a 1-inch slack, and a correspondingly shorter distance was required for the smaller slacks.

Each observer was expected to record, for each defect in turn, what he believed the defect to be, whether or not he regarded it as severe, and whether he considered that the speed of trains should be checked and, if so, to what extent. In each case he had to state his idea of the defect, first while he was standing upright in the position of a ganger walking a length, and then after bending down and sighting along the rail.

As might be expected, the observations made when standing upright were far less accurate than when bending and sighting along the rail, the average correct percentage in the former case being 28 per cent. and in the latter 70 per cent. Secondly, a slack at a joint was observed much more correctly than one in the centre of a rail, which was much less noticeable and was nearly always underestimated : the ratio of correct observations was 3 to 1 in favour of the former. Generally speaking, it was only *for slacks of $\frac{3}{4}$ inch or 1 inch at a joint,* or when the slack was followed by a high spot of similar value, that the observers considered it necessary to check trains, the usual estimate for the safe speed in such cases being 15 miles per hour. A 1-inch slack in the centre of a rail did not appear sufficiently serious to lead any of the observers to call for a reduction of train-speed.

Each observer was awarded three marks for a correct observation and one for a near miss (an " inner," as it might be called). All the markings were fairly close ; but whilst the ganger was awarded the lowest marks for observations when standing upright, he obtained the highest marks when bending down and sighting along the rail.

It might be considered that the collection and plotting of information such as was given in *Figs. 4* was a lengthy and laborious process and tended to make the track appear worse than it really was ; but unless something on those lines was done it did not seem possible to obtain a reliable picture of the actual track conditions or to give an authoritative and confident opinion about it ; moreover, the collection of a number of such diagrams gave useful information about track conditions which could not be observed by eye alone.

To the recommendations made in the Paper as to the most useful steps to be taken to eliminate track conditions conducive to derailments the Author should have added that, wherever practicable, cant pegs at the lineside or cant nails on the sleepers should be provided for curves, as they served as a constant reminder as well as a useful guide to inspectors and gangers. The pegs were preferable to the cant nails because they were more noticeable and also the cant nails were liable to become covered with grease and dirt. Monuments to give alignment and cant were even better, but much time and man power would have to be expended before they could become really general.

With regard to the vehicle for measuring and recording too rapid changes of cant and alignment, much could be done, as a start, by the introduction of a light trolley fitted with a large dial, on which the cant would be shown by a pointer, correct to the nearest $\frac{1}{4}$ inch ; such a trolley, which could be pushed along by hand at walking pace, should not be very expensive.

Mr. A. W. Woodbridge said that his object in writing Part II of the Paper had not been to provide a catalogue of accidents for which the signal engineer was often called upon to account, but rather to indicate the factors which tended to cause accidents. It was not easy to separate accidents arising from lack of maintenance from those due to some cause against which the signal engineer had not provided. The difficulties of arrears of maintenance were all too painfully apparent, and no useful purpose would be served by enlarging upon them. The Great Western Railway had experienced considerable trouble owing to lack of maintenance—notably a comparatively high-speed derailment at a facing junction due to the facing-point lock not acting efficiently. That particular accident had not been due to lack of maintenance by one department, but rather to the cumulative lack of maintenance on the part of all the engineering departments.

A considerable portion of Part II of the Paper had been devoted to the problems of detection and the track circuit, because those two items were the fundamentals of the safety devices which the signal engineer used today. He had tried to concentrate attention on the problem of providing permanent way fittings with much closer tolerances than had been used in the past. Signals had to be put in to detect facing movements with an opening of $\frac{1}{8}$ inch for a pair of points, and if the opening were $\frac{5}{32}$ inch the problem was to render the signals inoperative—which was even more difficult from the point of view of the permanent way engineer than from that of the signal engineer.

The efficiency of a track circuit depended almost entirely on the contact between the tires of the wheels and the surface of the rail. Apparently the surface of the rail was the part which was seen, but in actual practice it was not; it was necessary to penetrate a very high-resistance skin, which might be $\frac{1}{1000}$ inch or less in thickness and for the breaking down of which a fairly high voltage was required. It was not possible to apply a pressure higher than about 2 volts to a track circuit without introducing other difficulties in regard to train shunting and Mr. Woodbridge considered that attention should be given to the production of a steel rail which would not have a high-insulation skin.

The Great Western Railway had formed a joint Committee to discuss the subject of permanent way and signal fittings which were attached to the permanent way, with a view to improving designs, and that Committee had served a very useful purpose.

Fig. 7 showed the effect produced by the bad fitting of a stretcher-rod; but it could equally well be the opposite way, if the packing-pieces introduced between the brackets and the stretcher rod were thicker than the curvature warranted. The bend was exaggerated in the diagram, because the effect of flattening it when a train passed through was felt very distinctly on the signal department fittings at the nose of the switches.

With the introduction of flat-bottom rail many common problems would doubtless arise, and in that connexion the Joint Design Committee should serve an extremely useful purpose. The signal engineer was now suddenly confronted with a section of rail which he had never seen before, and would have to fit his facing-point lock-bars, etc., to it. That might or might not be a mechanical proposition. The joint Committee should serve a very useful purpose in dealing with any such points that might arise.

The incidents recorded in the Paper to show that faults in the layout and the wear and tear of fittings might give rise to accidents which could not be foreseen would illustrate the necessity for eternal vigilance.

Psychology and physiology entered into accidents to a very large degree.

Some real cause would usually exist for a lapse on the part of a first-class signalman, an intelligent and alert man, with thirty or forty years' experience. The question should be studied very carefully in the hope of obtaining some information which would enable accidents caused by such lapses to be avoided.

Possibly the visibility curve shown in *Fig. 14* required a little further explanation. That curve had been accepted internationally as demonstrating the average sensibility of the eye to colours of different wavelengths, on the assumption that the same quantity of energy was converted into light. The curve definitely showed that red light had much lower visibility than green and yellow ; yet red had been adopted as the standard "stop" colour. In railway signals a fixed source of white light was used, and the colour was changed by the interposition of coloured filters in the light beam. Red, yellow, and green filters had different transmission characteristics and the red glass transmitted a smaller quantity of light than the others. If that were combined with the relative visibility shown in the curve, it would be seen that a driver's eye would receive a much smaller stimulus with the red light than with the green or yellow light.

Mr. E. C. Cookson observed that in siding derailments many factors other than actual defects came into the picture. For instance, sand or ashes were dropped from locomotives in busy places, where it was difficult for the maximum amount of attention to be given to the track, with the result that they became lodged between the switch-blade and the stock rail and switches were split.

Recently his attention had been drawn to the amount of wear which occurred on the eyebolt where a hand lever rod was connected to the switch stretcher. The ganger often seemed to think that it would be sufficient to put in a few pieces of packing here and there, in order to take up, as he thought, the wear at that point. Mr. Cookson considered that the ganger should be provided with an additional tool, such as a reamer, so that he could enlarge the hole in the eyebolt and provide an over-sized bolt, thus increasing the life of the particular component.

Another feature in siding derailments was that, owing to the necessity for smooth pathways for shunters, the paths were trampled down very vigorously and the drainage suffered, whilst through lack of opportunity of getting at fitting work, because of the heavy use of the track, the ganger was at a disadvantage, with the result that the track deteriorated more rapidly there than elsewhere.

With regard to the opening of switch tongues by pressure on the heel in the case of old type switches. If the maintenance of the heel fishplates were reasonable, it would be very difficult to obtain a sufficient pressure to open the switch tongue enough to allow the point to be split. In some tests carried out about 10 years ago, when hydraulic jacks were used to exert pressure on the heels of switches, it had been found very difficult to open the switch tongue sufficiently to allow the point to be split, provided that the heel fishplate bolts were not too loose. The staffs in shunting yards liked to have the heel joints loose, because they believed that the switches worked more easily then, and perhaps the only way to overcome the difficulty was for the ganger surreptitiously to give a half-turn or a quarter-turn on the nuts and tighten them up gradually to the desired degree without the traffic department noticing it.

The present-day oak keys in crossing guard rails, were not so good as the pre-war keys ; steel keys would probably obviate some of the maintenance defects. Laying the track slightly wide gauge at the crossing nose would assist in reducing the tendency to strike the nose of the crossing as the back of the guard became worn.

Mr. Cookson could not agree with the statement that it was easy to correct run out in sidings, because frequently it was a question of running out adverse cant and not much room was available in which to effect the run out.

The tests carried out on four-wheeled vehicles presented an excellent example of co-operation between departments. Nothing had been hidden, but all the information had been put on the table.

To complete the reference made in the Paper to the running of a test horse-box it should be stated that that horse-box had been used to try out axles recovered from derailed vehicles.

Excessive speed through fitting work on main lines was often a cause of trouble to the permanent way engineer and to the maintenance staff, because the fittings on the turn-out road were knocked about and it was difficult to maintain the main line alignment. A gradual increase in the number of speedometers on engines would be useful to the permanent way staff.

Mr. Cookson agreed that local bias in favour of the track might exist when the details of any derailment were being examined, and he considered that it might be advantageous to have a central examining body to deal with derailments, not on sidings but on running lines in particular. Further, in any recommendations for betterment in the future, mention should be made of the pressure grouting of track.

In dealing with the interference caused on track circuits by the development of film on the rail surface, the question of ice on the rail had not been mentioned, and information on that problem would be of interest.

What was Mr. Woodbridge's opinion of wire-worked points ? In one particular mishap which had taken place twelve months earlier, the only apparent cause had been "Gremlins."

Sir Alan Mount observed that The Institution was fortunate in having such an important subject presented with the authority of experts and he owed the Authors some personal explanation. He had been asked to present a Paper but had had to decline, not only from sheer inability to write so adequately but also from lack of time and opportunity in the present circumstances. Obviously the proper people to write Papers of the kind in question were those who bore the brunt and had the experience of the difficult day-to-day problems of operating and maintaining the great railway systems of Great Britain. Moreover it was not perhaps generally appreciated that, although an inspecting officer never appealed in vain to the railway companies' officers for assistance and, in fact, their co-operation was of the very closest—as it should be— the inspecting officer had no personal technical staff upon whom to rely, in contrast to the vast resources and experience of the railway companies, however inadequately they themselves invariably felt they were staffed. In fact, an inspecting officer had to carry out his work as an individual and express his opinions as such.

He regretted that no reference had been made to accidents into which official inquiries had been held, but he was glad to see that the term "mishap" had been used only twice in the Paper. That word seemed sometimes to lessen the gravity of an accident, even though it was used, as he had known it to be used, when many people had been killed.

He agreed that engine derailments usually commenced at the leading driving-wheels and were due to excessive flange pressures, induced by track defects or insufficient engine side control, or both—usually both. That had been dealt with very fully in the Report made to the Government of India by the Pacific Locomotive Committee in 1938, and he hoped that research in regard to flange-pressures would now be continued. He had heard it suggested in India and Great Britain that derailments actually commenced in the coaches of a train instead of in the engine so that derailment proceeded in a running train from back to front, the engine itself being finally pulled off the road ; but he regarded that as a very unlikely event, and he could not recall any case in which its occurrence had been proved.

Recent examples of derailments of engines with insufficient side control and to which defective track conditions had materially contributed, were the accidents at Hatfield in July 1946 and at Marshmoor in November 1946. Indeed, he believed that it might be said that the cause of any derailment on plain line, if no clear explanation, such as obstruction or failure of material, were apparent, was excessive flange pressure in relation to the weight on the wheel at the critical moment. That kind of statement of the obvious might sometimes help to clear one's mind. Mr. Smith had stated that nearly as many derailments occurred on the inside as on the outside of a curve ; the derailments at Hatfield and Marshmoor were examples of the former type. Where marked relief of weight occurred, the side thrust necessary to cause derailment was proportionately lessened, and it was known that some degree of side to side action always appeared when an engine or vehicle travelled round an easy curve at high speed. The cause of weight relief was sometimes obscure when no serious defect in cross level was evident, and Mr. Smith was doubtless right in his reference to the cumulative effect, under load, of a regular succession of minor slacks, and it was only the condition of the track under load that mattered.

The systematic investigation of derailments by the Great Western Railway Company gave confidence that few, if any, would remain unexplained. He presumed that such investigations were sometimes carried out jointly with the chief mechanical engineer, as track and vehicle were, of course, parts of the same machine.

Mr. Smith's description of the method of comparing the regularity of alignment and superelevation on curves was very interesting and valuable.

Another interesting statement was that, of twenty-one derailments of four-wheeled vehicles with short wheelbase, on fast passenger and freight trains, throughout the country as a whole, during the 10 years from 1935 to 1945, three had occurred on the Great Western Railway in the autumn of 1942, when the Company had appointed a Committee to investigate the subject. In Sir Alan's own report on the derailment in March 1937, of a four-wheeled fish van at the rear of an express passenger and parcels train, travelling at 65–70 miles per hour, at Barford, on the London and North Eastern Railway, he had mentioned a number of similar derailments which began to occur in August 1935; possibly they were included among the twenty-one derailments mentioned in the Paper. He always had mixed feelings when he read his old reports, and had gained the apparently erroneous impression that that report had started the idea of the extensive trials carried out by the Great Western Railway. He considered that the Ministry of Transport had not heard enough about those trials, and the Author's Paper had whetted his appetite.

He suggested that more should be published about research of the kind in question, and in particular the details of how it had been carried out. Very little had been stated in the Paper about the Committee's Report; but that subject was really worthy of a Paper in itself, for the information of railway men generally, both at home and abroad—particularly in view of the present deterioration in track maintenance, for which war-time conditions and present shortages were responsible, at all events in Great Britain.

In Sir Alan's report upon the trials which had been carried out at his request after the Barford derailment by Sir Nigel Gresley, he had described them as "Hallade tests for oscillation." He had been riding in a similar 9-foot wheelbase fish van at the rear of the test train, and had thankfully admitted that he had had enough! He had duly reported his anxiety in appropriate language, saying that "between Huntingdon and Peterborough speed was increased to 65 miles per hour, when there was a noticeable increase in vertical, lateral and rolling movements, which were severe enough at 68 miles per hour to cause instructions to be given for reduction of speed." He had lost no time in agreeing to those instructions! Following the break-away of the fish van and the automatic application of the brake, the train came to a standstill; but before it did so an express on the other line had collided with the fish van at 70 miles per hour. Fortunately the van was only just foul of the express, but that illustrated the risks, which could not be lightly accepted, of operating short-wheelbased stock at the tail of fast passenger trains.

Apart from the design and wheelbase of the vehicles themselves, the question was largely one of the adequacy of their maintenance and the upkeep of the track. Therefore, while they continued to be operated in such services, a strict limitation of speed should be enforced—which was unfortunate when it was remembered that a railway, as an instrument of transport, should be capable of passenger train operation at 85–95 miles per hour.

The General Recommendations made on p. 13 were unexceptionable, particularly the recommendation that more extensive use should be made of flat-bottom rails, which he had always advocated since his experience in India. He would, however, like to learn more about the special track-testing vehicle, in comparison with the use and cost of a portable Hallade instrument.

Mr. Woodbridge had wisely placed the integrity of track circuiting first. Apart from the problem of concrete sleepers in substitution for timber, the problem of preventing the formation of an insulating film between the wheel and the rail was evidently a matter for further research. Indeed, track circuiting might be looked upon as the most important contribution to the safety and density of movement on rail.

Mr. Woodbridge had quoted a good illustration from America to prove the necessity for re-siting signals to deal with higher-speed running, and his account of the effect of a red light on vision gave food for reflexion.

He entirely agreed with Mr. Woodbridge's remarks on automatic train control; but they would have been strengthened if he had emphasized the fact that that aid to the driver could fail in its object if the driver disregarded its warning as a result of misreading his fixed signal. That had occurred at Norton Fitzwarren in the winter of 1940, when the audible warning with its brake application had not had the desired effect because the driver had cancelled it, thinking that he was travelling on a parallel road for which the signals were clear. That was a psychological case, and presumably one of very few in thirty or more years of successful experience with the equipment in question, for which drivers had nothing but praise. It was impossible to tell how many unrecorded cases occurred in which an accident was prevented by the warning given, and Sir Alan certainly preferred that the "forestalling" or "cancelling" device should continue to operate as it did to-day. He hoped that a real move would soon be made widely to extend equipment of the kind in question, to assist drivers, particularly in bad weather.

Mr. M. F. Barbey observed that Sir Alan Mount's remarks about the four-wheeled vehicle at the end of the train had recalled to him his early days, watching the Camden-Carlisle freight train passing through Bletchley at 70 miles per hour. He thought that it would be interesting if the guard of that train were present to express an opinion on the subject.

He was aware of the need for checking track conditions by instruments as distinct from sighting: that was very well worth while.

Mr. Smith had taken readings at every sleeper; but quite noticeable results could be obtained by taking readings at every rail joint and half-way down the rail namely, at about every 30 feet.

The use of a void-meter was very interesting. The measured shovel packing method used in maintenance was the best practical way of getting defects shown up, and the extended use of cross-levelling would be very helpful in that respect.

Mr. Barbey had had some experience of derailments with short switches, and he had no doubt that those were due to looseness at the heel, combined with imperfectly fitted levers; fitting the modern type of R.B.S. stretcher-bar was of considerable assistance in preventing it.

Wood keys were a cause of trouble in crossing check rails, since they were apt to squeeze. The position of the check with relation to the nose—the cover to the crossing—was also important.

With regard to the uneven loading to which Mr. Smith had referred, Mr. Barbey cited a case of a hopper wagon which was unloaded on one side, and brought round a fairly sharp curve, with the loaded portion of the wagon on the inside of the rail, with the result that there was practically no load on the outside of the rail, and derailment occurred.

Could a few extra details be supplied about the run out of cant? It would be interesting to know how the 1 inch in 20 feet was determined. That applied chiefly to sidings, where, presumably, the question of speed of vehicles was practically ruled out. It seemed to boil down to the maximum gradient at which any bad effect would be taken on the frames of vehicles; and he understood that about 1 in 200 was taken to be the limit from that point of view. In his experience, 1 inch in 20 feet would be rather steep. What other factors were taken into consideration? A limit of 1 inch in 20 feet having been laid down, what would be the effect of a $\frac{1}{2}$-inch low joint, giving a considerably increased gradient at that point?

Mr. F. H. D. Page observed that the relation between the permanent way and signalling was an aspect of engineering in which he had been particularly interested. There were many types of permanent way inspectors, some of whom were very keen on a tight heel switch. On the Great Western Railway they were perhaps not so keen, but in one division there was a mechanized hump yard, where the points were worked by pneumatic machines and the inspector favoured a tight heel joint. After numerous derailments some experiments were carried out on slackening those particular heel joints. Derailments then ceased, but a considerable pressure had to be applied by Mr. Page before permission to make just one or two turns on the bolts could be obtained.

He believed that it was not always realized that a track circuit had to operate with a very small margin of distance. For instance, in the cases to which Mr. Woodbridge had referred, there was a margin of only about 5 feet 4 inches in front of the switch for the track circuit to operate to prevent a derailment. That was very small indeed and it necessitated a high standard of drainage and a very good standard generally.

With regard to derailments at facing joints, he had had one or two experiences of slackness at the bent-up end of the tie-plate and the chair bolts. On one occasion he had been present at the derailment of a passenger train running into a bay line. Everything appeared to be perfectly correct; the points were bolted and the switches were tight to the rail, but the train was derailed when running in slowly, owing to the spread at the facing point. The spread was only $\frac{3}{8}$ inch, but the flange of the tire had been worn to the shoulder and formed practically a knife-edge. In many cases it was very difficult to arrive at a satisfactory conclusion as to the cause of derailment after the damage had occurred. He remembered one case in which a report was drawn up by all three departments—permanent way, signal, and locomotive. The permanent way was perfectly satisfactory, whilst there was nothing wrong with the signalling apparatus or the flanges of the engine. After receiving the report, Headquarters wrote a letter stating that the report was excellent and proved that everything was quite satisfactory from every department's point of view, but they would still like to know the cause of the derailment!

Mr. W. A. Willox observed that the opinion which he had held for a long time, and had often expressed, that railways should be regarded essentially as an engineering proposition, had been reinforced by the Paper. Since a railway, as an organization, was a piece of engineering, he considered that every chief administrative post on a railway should be filled by an engineer. Two results would immediately follow and they could, in fact, be observed in other countries, where railways were generally regarded as an engineering proposition. One would be much closer co-ordination between the various engineering departments on the railways, the other a more liberal allowance for expenditure on engineering works, maintenance, design, and research. For example, after the war of 1914–18, the French railways began a programme of consolidating the foundations of their tracks on all the main lines and on many of the branch lines, and they were not cramped by niggardly expenditure. The old foundation was dug up where necessary and re-formed with adequate drainage and ample ballast to a depth of at least 1 foot beneath the sleepers. The work had been practically completed before the outbreak of war in 1939, so that all the French main lines had really stable foundations, and it was therefore possible to reduce the expenditure of energy and materials on maintenance. One reason why the French were able to do that was that they had engineers in charge of their railways as general managers. For instance, M. Dautry, permanent way engineer of the old *Nord* line after the war of 1914–18, had later been appointed general manager of the State railways, where he had applied his theories with remarkable benefit to that system. The present general manager of the whole French railway system, which was now nationalized, was M. Lemaire, a former district engineer on the *Nord* line.

As Sir Alan had said, the track and the vehicle were part of one machine, and it was surely reasonable to propose that an engineer-in-chief should be held responsible for every side of the engineering work—mechanical, electrical, and permanent way. Obviously he would have assistants specially skilled and expert in each of those branches; but he would co-ordinate their work, and there would not then be, as so often happened in Great Britain, war between the permanent way and locomotive engineers on the question of who was to blame when something went wrong. Mr. Willox considered that the permanent way was liable to be blamed for a considerably greater proportion of accidents than should be attributed to it. In the old days, before much attention was paid to the permanent way, travelling on Continental track made one wish to take out a life assurance policy before going on a train; yet the trains stayed on the lines, because the engines were very carefully sprung, with compensated springing and were presumably fairly well balanced. Speed and weight were now considered much more important than formerly, and locomotives were running on fast trains which as vehicles really ought not to be trusted on bad parts of the permanent way. It was true that there should not be any bad parts of the permanent way, but permanent way engineers in Great Britain had been very cramped in their expenditure. Side thrust due to locomotive flange pressure occurred which nobody measured or knew anything about and to which no special attention was given when the locomotive was designed. Balancing of locomotives was also haphazard, and nobody really knew what the hammer-blow or the side thrust might be at speed under certain conditions.

Statistics had often been shown to prove that the safest place for a human being was a railway train. More people were killed in their beds by falling ceilings than in railway accidents in the course of an average year. When derailments of express trains occurred on plain line, which ought to be the safest part of a railway, it was surely time that very serious notice should be taken of the matter and that some perhaps revolutionary change should be introduced into the general administration of what should be regarded as an engineering proposition.

Mr. P. S. A. Berridge observed that in India, as a junior officer, he had had to spend many sleepless nights in four-wheeled vehicles at the back of fast trains, and he had often marvelled that those vehicles had stayed on the line. Could the Authors hold out any hope of a four-wheeled vehicle ever being made sufficiently stable to travel well at the back of a train?

Mr. Berridge exhibited a film showing an accident in India caused by the spring hanger bolt of a locomotive catching between the tongue and the stock rail at a trailing point.

Mr. C. E. Dunton observed that he regarded the standard of visual examination as the key to the problem, because the survey methods which were applied to ascertain the reason for a derailment could not generally be applied sufficiently frequently beforehand to prevent the derailment. The deterioration which might occur in soft formation, particularly after heavy rainfall, was often too rapid to enable the careful methods described in the Paper to be applied. Clearly it was not so important to find out why an accident had happened as to prevent it; and for the latter purpose it was still necessary to rely upon visual examination of the track. He doubted whether even the Hallade machine could be operated with sufficient frequency to detect bad conditions, such as those at Marshmoor, which developed rapidly. It had been found impossible to get round his system fast enough with the Hallade machine, although the system was a very small one. Therefore he considered that the crux of the matter was to establish a satisfactory visual system of examination.

The engineer carried a standard in his mind, but it was not always the same as the standard of the people who maintained the track. A good ganger's standards were perhaps the same as a good engineer's standards, but a bad ganger's standards were not, and it was unfortunately true that many conscientious men who worked very well on the permanent way had not been trained to recognize defects in the top and in the line of the road. The problem was a difficult one and needed investigation. The use of measured packing sighting boards helped a man who did not naturally possess a good eye, whilst a mirror was also useful. When he used to walk over miles of track in single-tube tunnels he had found it very difficult to see the top of the rails. It was not possible to step to one side and obtain a side view but one had to stay in the 4-foot way, and he had found that the wear and tear on himself and his assistants and gangers was very heavy, because they had to be continually getting down on the ground and rising again. Therefore they had tried using a mirror, and had found that it gave a far better view, at a cursory glance, than could be obtained without it. If anything doubtful was seen in the mirror, they then got down on the ground and examined the track.

What was really needed was a school to teach the visual inspection of tracks and the correct standard to be adopted, and the pupils should be passed out as having the right standard and the right eye to see whether the tracks were suitable or unsuitable for high-speed running. The places where derailments occurred were not always those with a very bad and irregular cant or very bad curvature. There were many other places where derailments might occur; and how was it possible to correct such places except by improving the standard of visual examination so that they could be detected? The Authors had tested the powers of observation of inspectors, engineers, and gangers and had found them to be defective, because they could not agree on what they had seen. Could not an improvement be made in that respect, so that they could see what the condition of the track really was?

Mr. E. G. Brentnall observed that he was pleased that Mr. Woodbridge had mentioned the very close limits to which signal engineers had to work with facing points. On some railways the clearance of $\frac{1}{8}$ inch was divided on each side of the plunger; the plunger fitted into the notch in the lock stretcher with $\frac{1}{16}$ inch clearance on either side, and a movement of $\frac{1}{16}$ inch caused the signal not to clear, so that very close attention had to be devoted to the permanent way.

Mr. Woodbridge had indicated the trouble that might be caused by a badly fitting stretcher-rod, but even if stretcher-rods fitted correctly they were very stiff, and when the points were moved over a tendency for the stretchers to be flexed in an S-form made the points very difficult to work and also affected the maintenance. Some experiments had been carried out with a pin joint in the stretcher, so that it tended to be more free to move, and further research was desirable.

Had Mr. Woodbridge experienced the difficulty which sometimes occurred from wear on the stock rail and on the wheels? In such cases a tendency developed for the flange of the wheel to ride on a facing-point bar, and it was essential that the stock rail should be changed when the wear approached that condition. That was a difficult matter for the permanent way department, because they were short of staff and it would probably involve changing the whole lay-out of the switches.

Mr. Brentnall had known failures of track circuits where there had been one axle only standing on the very end of the track circuit. Apparently the rails had been quite clean; at all events no rust was visible, and there had been no question of a broken bond. Probably those failures had been due to a film on the rail, and Mr. Brentnall agreed that research into the type of steel used and into the question of oil and grease being carried along would be of assistance.

Mr. Arthur Dean considered that the question raised by Mr. Willox would form an excellent subject for a Paper.

Regarding the formation of non-conducting films on the running surfaces of rails, only one troublesome case had been experienced on the Southern Railway, but Mr. Dean suggested that the solution of that and other difficulties in maintaining the perfect track circuit was not to undertake a great deal of research to obtain a track which was partly a perfect conductor and partly a perfect insulator. Rather should the research be directed to perfecting reliable means other than track circuits for showing the location of trains. The track could then revert to its primary function of adequately carrying traffic.

The avoidance of derailments due to irregularities in the track became ultimately the problem of defining a practicable standard and maintaining the track to that standard. Mr. Dean suggested that each Railway defined a standard, but he questioned whether there existed adequate and reliable knowledge as to the real extent to which the track was, in fact, being maintained to that standard. He thought that appreciable departures therefrom must exist at many places.

It was Mr. Dean's view that until there was a change in the design of locomotives, there would always exist the remote but nevertheless finite probability that once in every so many million locomotive miles there would occur at an irregularity in the track a combination of unstable characteristics of a locomotive, such that derailment could take place. Such might not necessarily occur at the place where the greatest departure from permanent way standard existed.

Many irregularities in the track did not arise suddenly, but developed over appreciable periods. Permanent way engineers knew from experience the form of track irregularities which would re-act most seriously on the stability of a locomotive, and which should be avoided until, at any rate, locomotive engineers designed locomotives less prone to derailment.

How then could it be ensured that such irregularities would not develop and that the defined standard of track would be maintained ? Mr. Dean did not put complete faith in the ganger's eye, and doubted if all gangers could be trained to have an absolutely reliable appreciation of track condition from visual examination only. There was much in favour of Mr. Smith's suggestion to use special recording trolleys.

Much faith had been placed in the use of the Hallade instrument, but whilst Mr. Dean thought that instrument most useful for its original purpose, to show where track alignment at changes of curvature was particularly bad, he did not consider it was by any means so useful for maintenance checking. It recorded the behaviour of the coach on the track, and a record could often be impossible to interpret as a true guide to the existence and nature of track irregularities.

Something better was needed to show the actual condition of the track and recording instruments should be developed for that purpose and records taken at regular intervals so that true knowledge of normal condition could be obtained, practicable standards defined, and maintenance to those standards kept under continuous review.

*** **Mr. R. T. Carr** observed that accidents occurred as a result of circumstances to which the conditions, both of track and of vehicles, were contributory ; in those cases the conditions of track and vehicles were to some extent complementary, since a small deterioration in one might be neutralized by an improvement in the other, and vice versa. That being so, it was necessary to determine responsibility, as between the two departments concerned, in relation to standards laid down for each department in advance of the accident; ideally those standards would be interrelated, selection being determined by economic considerations from among possible combinations of standards which could ensure safety: the concessions to safety would be greater from the department which could provide them more economically.

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

The introduction of formal standards placed a heavy responsibility upon the authorities formulating them ; in the absence of such standards, however, those carrying out the work of maintenance had to make their own assumptions, on a basis of inadequate knowledge, and, moreover, responsibility for an accident tended to be assigned in accordance with indefinite standards tacitly assumed by someone after the accident—when it was easy to be wise. The foregoing, of course, exemplified a more general principle.

The Authors, in reply, observed that tests had shown that with a rate of run out of cant of 1 inch in 7 feet 6 inches there was a definite liability to derailment. The sharpest run out of cant in sidings permitted on the Great Western Railway was 1 inch in 20 feet, and that was not considered at all desirable. The desirable rate of run out in sidings was 1 inch in 66 feet ; 1 inch in 40 feet was the minimum which was approved, whilst anything like 1 inch in 20 feet was allowed only in exceptional circumstances.

In the investigations which were carried out on the Great Western Railway the information available was shared by the chief engineer and the chief mechanical engineer. and an effort was made to find the real cause of the derailment, no matter which department might be found in the end to be responsible.

The publication of four-wheeled-vehicle reports was a managerial matter.

In reply to Mr. Barbey, the Authors regarded it as essential for instrumental readings of the levels to be taken at every sleeper, if diagrams such as those shown in the Paper were to be plotted. It was not considered sufficient to take readings at every rail joint or at every chain or half-chain.

Mr. Berridge's remarks on four-wheeled vehicles sounded as though they came from the heart of a divisional engineer. Four-wheeled inspection coaches were a very sore point with at least some divisional engineers who had them ! It was possible to design a four-wheeled vehicle permitting travel with a certain degree of comfort ; but it depended largely upon the wheel-base, and a short-wheelbase vehicle could never be very comfortable to travel in at high speeds. The report of the four-wheeled vehicle tests carried out on the Great Western Railway had referred very feelingly indeed to the experiences of the Hallade operators and the other people travelling in one of the vehicles at about 65 miles per hour.

With regard to the training of track examination men, a simple form of trolley with a cant-indication would probably be the best thing to show up the defects which were difficult to see, with the exception of deflexion under load.

The Authors agreed that films on rails were a nuisance, but they did not know how to eliminate them. Ice films might be removed from points by some kind of heating appliance, but obviously that would not be possible on the straight permanent way.

The derailment to which Mr. Cookson had referred had occurred on the Great Western Railway. Half of the train, which fortunately was not a passenger train, was derailed at a facing junction. At the joint inquiry it was found that the points and the signalling gear were in perfect order and the points were properly bolted in the correct direction. The conclusion reached was that it was possible to stretch the wire working the points or bolt and get them in a fully reverse position against obstruction. If a vehicle were standing, say, on the locked bar it formed an obstruction and, although the lever might be pulled fully over, there would be the tension in the wire, and, if it happened to be released for some reason—possibly by lifting of the vehicle—over would go the bar and the bolt would be shot. Mr. Cookson could now rest assured that such a risk would be eliminated in due course.

Mr. Page had rightly stressed the fact that signal engineers expected to be presented with a perfect permanent way, but had shown that the permanent way was far from perfect !

The Great Western Railway's Joint Committee on Permanent Way had discussed various problems, including the stiffness in stretcher-rods, the bad fitting of stretcher-rods, and defects in the bending or internal stresses of the switches which contributed to difficulties in working and undoubtedly imposed an extra strain on the signal department's fittings.

It was rather disappointing that the locomotive engineers had not been present to express their views ; further the value of the discussion would have been enhanced if the medical officer of a railway company could have described his experience in the testing of staff : that was a matter which required a considerable amount of research.

The Chairman announced that the constitution of the Divisional Board for Session 1947–48 would be as follows :—

Appointed by the Council in accordance with Rule 1 of the " Objects, Constitution, and Rules " :—

Mr. V. A. M. Robertson, *Chairman.*

Sir William Halcrow ; Sir Alan Mount ; Mr. F. H. D. Page ; Mr. A. S. Quartermaine ; Mr. J. C. L. Train.

Elected by the members present at the Meeting, in accordance with Rules 10 to 14 :—

Mr. James Briggs ; Mr. Arthur Dean ; Mr. John Ratter ; Mr. Harold Savage ; Mr. Sidney Stevens.

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