Stiffness of S. T. sleeper $=6{\cdot}05\times 13{,}500=81{,}675$ in ton

Moment of inertia of wood sleeper $=\dfrac{10\times 5^3}{12}=104{\cdot}16$ in$^4$

E sal $=883$ tons, E chir $=622$ tons.

Stiffness of a sal sleeper $=883\times 104{\cdot}16=92{,}000$ in/ton

,, ,, Chir sleeper $=622=104{\cdot}16=64{,}800$ ,,

Minimum moment of resistance of a S. T. sleeper $=$

$$=Z_t\times 9$$
$$=21{\cdot}6 \text{ in/ton}$$

Min$^{m}$ moment of resistance of a sal sleeper $\dfrac{bd^2}{6}\times$ fc.

$$=41{\cdot}67\times\frac{1{,}560}{2{,}240}$$
$$=29{\cdot}0 \text{ in/ton}$$

Min$^{m}$ moment of resistance of a chir sleeper $=\dfrac{bd^2}{6}\times$ fc.

$$=41{\cdot}67\times\frac{810}{2{,}240}$$
$$=15{\cdot}0 \text{ in/ton}$$

Thus it will be seen that the standard B. G. steel trough sleeper is neither as stiff nor as strong as a B. G. sal sleeper though in both respects it is superior to a chir sleeper.

## DISCUSSION

The Author, while introducing his Paper, said that the object of this paper was to bring to the notice of the Engineering profession in general and the Railway Engineers in particular the fundamental considerations that affected the design and usage of the various types of sleepers in India. The Railway Engineer's work covered such a wide field of engineering that he was unfortunately left with a very little time to study the theory underlying the design of the component parts of the track which was, really speaking, the fundamental requisite for any Railway. A Railway Engineer was, therefore, inclined to take a sleeper as a matter of course and may overlook some primary features of its design that affected its utility and durability in the track. In this Paper, an effort had been made to put before him the different aspects from which a particular design of a sleeper should be studied, before he exercised his personal preference in its favour or against it. On reading this Paper his prejudices for or against a particular type of sleeper may receive a rude shock. The main object of this Paper was to remove certain well-known prejudices.

Unfortunately in the past prejudice exercised fully its baneful influence in affecting the destinies of the various types of sleepers as only those designs were accepted which fully satisfied the whims of the Engineer in authority. Happily, this state of affairs was a thing of the past. With the creation of the Central Standards Office as a Central Design Section of the Railway Board, the designing and standardisation of suitable designs had ceased to be personal affairs. The Standards Office was assisted and advised in its work by various Standards Committees, one of which namely the Track Standards Committee, had been frequently referred to in this Paper. All members of those committees were experienced engineers representing the leading Railway Administrations in India. Their recommendations referring to the Civil Engineering subjects were further discussed by the Engineering Section of the Indian Railway Conference Association. The members of that section were Chief Engineers of the important Indian Railways. After a theoretical design had been approved on the basis of existing practical knowledge, it was checked up for manufacturing feasibility. It was then ready for undergoing a service test on several Railways. It was standardised only when it was found to give satisfactory service.

It might be stated that as a matter of principle the Central Standards Office refused to adopt as their standard a proprietory or a patented article. It would thus be seen that the designs produced by the Central Standards Office had the benefit of the experience of all the Railways in India and that in the development of their designs, prejudice had little scope.

The Paper before them contained several controversial questions The chief among them were the following :—

(*i*) Is it possible, with our existing knowledge, to design rationally any track for a given load and for a particular locality? If not, what research is necessary?

(*ii*) Are the metal sleepers any superior to the wood sleepers? If so, under what conditions?

(*iii*) Is it possible to supply adequate number of wood sleepers from the Indian forests to meet the full requirements of the Railways in India. If so, what steps have to be taken to achieve this object and is the pursuit of this object economically justified?

(*iv*) Have the various elements such as the shape, the size, the weight, the bearing area, and the types of fastening, etc., received their due consideration in the present day designs of sleepers?

In several cases the view on the above points, expressed in this Paper, were different from those officially accepted by the N. W. Railway Administration, to which the author belongs, but they were stated so as to invite the personal views of the members of the Congress on the basis of their experience, as it was hoped that such exchange of views might help at least to clarify the main issues that affected the solution of the above mentioned controversial points.

For non-Railway engineers it might be mentioned that N occurring in the Paper represented the number of yards in a rail length; thus if a rail is 36 ft. long, N would be equal to 12.

**Khan Bahadur Nizam-ud-Din**, while commenting on the Paper, said that engineers, and especially the railway engineers were much indebted to Mr. Kumar for his Paper, which contained a great deal of information on the theoretical aspect of railways sleepers.

Much too large a variety of sleepers was at present in use in this country. Going over a railway section, one would see a length of wood, followed say by steel, then cast iron, then steel or wood again and so on. In cast iron alone, there were some 9 or 10 types belonging to the various stages of evolution in the sleepers made from this material. One only wished there was none of this variety and that instead of the kinds and types of sleepers changing at short distances in the line, there were long continuous lengths of one kind at a time. It would make matters so much simpler both for maintenance and renewal purposes. Local conditions, after all, did not change every two or three miles as did the sleepers.

While reading the Paper it was noticed that Mr. Kumar did not commit himself by recording a definite opinion as to which sleeper or sleepers he considered the most suited for use, say on the N. W. Railway. But at the same time, from the remarks appearing in the last but one para of the 'conclusions,' and from remarks elsewhere in the Paper, the author appeared to favour the treated *chir* sleeper used with the N. W.

Railway anchor plates. He further appeared to assign the second place to CST/9, and seemed to give rather a cold shoulder to the steel trough.

Not so much to try to refute any of the author's arguments for this grading, but merely to express his personal opinion in the matter, and thus to invite the opinions of other engineers, he considered that for most of lengths of Indian Railways, both economically as well as from considerations of what Mr. Kumar called 'technical suitability,' there was nothing to beat the steel trough sleepers.

In the earliest types of steel sleepers the jaws were formed by cutting the metal on three sides near the rail seat and pressing it up. This resulted in weakening the rail seat and providing only weak jaws even when buttressed by corrugations. The failure of such sleepers after doing about 40 years' service was traceable to this defect. The introduction of the detachable jaw, which was yet capable of further improvement, was a great step forward in the elimination of this source of weakness.

Mr. Kumar's calculations for the annual cost of sleepers given at page 31 of the Paper, were based on the life figure arrived at by the N. W. Railway in 1937. According to these, the steel sleeper with a life of only 37 years, came out the most expensive. Really, figures of 1943 based on six years' further experience should have been adopted. These latter were less favourable for wood, and much more favourable for the steel sleeper. The author of the Paper, however, agreed that with the 1943 life figure of 45 years, the steel sleeper would prove to be the cheapest.

The speaker here mentioned that steel sleepers laid in the Bolan Pass in 1895 were being renewed after they had done a life of 48 years. Some of them would be in the track for another one or two years.

As all engineers knew, no steel structure could last long without a certain amount of nursing in the shape of timely, though minor, repairs and periodical repainting. This remark applied to steel sleepers also. Yet they received no such attention. Having been laid 48 years ago in contact with ballast and a certain amount of mud, the Bolan sleepers were now being taken out when they had started showing signs of distress. So far as he knew they were never repaired and never painted. This treatment was hardly fair.

His opinion was, and it was not only his opinion, that steel sleepers should be taken out of the track every 10 or 12 years, minor repairs, such as rivetting on of a plate at the rail seat or of a new jaw, where required, and the patching up of a torn end, etc. done. The sleepers should then be heated and tapped to remove rust scales, and, while hot, passed through a hot bath of tar, and, when dry, put back in the track.

It was evident that if this were made the rule, steel sleepers should have much longer life. He maintained that they should last for not less than 60 years. The additional cost, mostly on labour, would be fully justified.

In the calculations appearing in the Paper, the annual cost of maintenance of sleepers, *i.e.*, 0·1631 rupee per sleeper, was taken to be the same both for steel as well as for wood sleepers. He felt that the job analysis that had produced such results was more of academic interest than of practical value.

The best man to give reliable information on this point was one who supervised track maintenance work from day to day. Such a man was the P. W. I.

Any P. W. I. having both wood and steel sleepers in his section would tell that wood sleepers required more frequent attention to packing than steel troughs. This was not difficult to understand when it was realised that while a wooden sleeper lay flat on top of the packing, the steel sleeper held it inside the channel. Under traffic, the former sleeper tended to disperse the packing while the latter only consolidated it.

There was no doubt that steel sleepers when first laid, took some time to bed down. Depending on the amount of work the gangmen would put in, it might take one year or even longer to accomplish that. At this stage P. W. Is did not like the steel sleepers. Once, however, the troughs were well filled, and packing consolidated, they required much less attention than any other kind of sleepers now in use. Joint sleepers did need repacking at more frequent intervals. This was not because of the packing working out but due to more consolidation and perhaps sinking of the ballast into the formation.

Mr. Kumar after accepting the life of a treated *chir* sleeper as 19 years (it is only 16 according to the 1943 life figures) hoped that by using the anchor plate and round spikes the life might be still longer, *i.e.*, more than 19 years. While he was one with the author in wishing that it were, so, he was not quite as optimistic.

The main weakness of the wood sleeper holding the rail by means of dog spikes, was creep. Every wheel on a train had a wave formed by the track running in front of it, and tended to push the rail in the direction of traffic. The driving wheels of an engine on the other hand push the rail backwards. The balance was in favour of the forward movement. By the wave action, dog spikes got prized up, and left the rail more or less free to slip through. To arrest creep, anchors were employed. Every type of anchor in use was somebody or other's patent. Their price was disproportionately high. The P. W. I. never got enough of them. Then the villager happened to have a special liking for anchor steel to make his implements with. So, quite a few of them got pilfered. The anchor gripped the rail foot and butted against the side of the sleeper.

In the case of the N. W. Railway anchor plate, creep was arrested but the creep force was transferred to the round spikes, which in turn transferred it to the sleeper holes. With anchor plates and unlike the C. I. chairs, the spike holes were nearer the edges of the sleeper. It was feared that with anchor plates, spike killing might be comparatively intensive, which was likely to shorten the life of the wood sleeper. This might particularly be the case, where in the same rail length, anchor plates were used only on some of the sleepers, and ordinary bearing plates on others.

Anyway, the anchor plate having come in comparatively recently, its effect on the life of the sleeper had yet to be seen.

After the Bhita accident, and as Mr. Kumar had stated, certain research work was carried out in this country to ascertain track stresses and the strength of various types of track. Mr. Kumar stated that as regards lateral strength "track laid with CST/9 or steel trough sleepers was found to be the best." I would here add that there had been cases of accidents though very infrequent, resulting from the spreading of gauge on curves, laid with wood sleepers. Such accidents could never take place on steel sleepers and for the matter of that on any type of metal sleepers.

As stated in the Paper, the modulus of steel sleeper track was 1,500 lb and that of wood sleeper track only 1,000 lb. This meant that the amplitude of the wave travelling in front of a wheel was smaller for steel road than for wood. Consequently, the wear and tear of rail and sleeper fastenings should be proportionately and comparatively less in the case of steel track.

In Appendix 'B,' Mr. Kumar had arrived at the conclusion that the sal wood sleeper was stiffer and had a higher moment of resistance than the steel trough. *Chir* sleeper, he had concluded, was weaker even than steel. This comparison, he presumed, was merely of theoretical interest and that the author of the Paper did not by any means imply that steel or chir sleepers were unsuitable for the purpose for which they were intended.

**Mr. A. D. Dhall,** while commenting on the Paper, remarked that there was no doubt that Mr. Kumar had spent quite a lot of labour and time in collecting the data for his Paper and he must congratulate him for such an exhaustive and detailed study of his subject. But connected as Mr. Dhall had been for a number of years with the purchase, treatment and supply of wooden sleepers and other track material for the N. W. Railway and also with all experimental track work, he felt that the impression that this Paper was likely to create needed correction in certain respects and amplification regarding others.

On page 2 and also in his conclusions on page 32, Mr. Kumar stated that India possessed an inexhaustible supply of wood in its extensive forests. This was true in a sense but most of these forests were inaccessible. The only forests that were being worked at present were those on the banks of the rivers or those in the sub-montane regions where carriage by carts or pack animals was easy. In the former category were the conifers of Northern India ; in the latter the sal forests of the Tarai and Nepal or the teak forests of Southern India. The remaining forests were inaccessible at present and the present methods of transport would have to be improved very considerably such as by the erection of serial ropeways before they could be exploited. This could only happen if the present price of wood rose very considerably and made the expenditure involved in improving the means of transport an economic proposition. The competition from steel and cast iron sleepers was an effective check against this under present day conditions. The net result of this was that the quantity of wooden sleepers that was available to the Indian Railways was not only limited but was actually dwindling. It was for that reason and to utilize the resources available in the best possible manner that the Railways formed the Sleeper Pool. The purchases made by the Northern Group Sleeper Pool would show how the available supplies had been gradually becoming less and less. During the twenties this Group used to purchase over five lakhs of B. G. Deodar sleepers a year besides supplying large number of M. G. deodar sleepers to Bikaner and Jodhpur Railways. Just before the war the number of broad guage deodar sleepers that could be purchased had come down to less than two lakhs a year and the supply of M. G. deodar sleepers had almost completely ceased. The North Western Railway foresaw this as long ago as 1922 and erected a Creosoting Plant at Dhilwan for treating and using inferior timbers.

In Chapter 4, page 22, Mr. Kumar had compared the lives of wooden sleepers in different countries. It was said that figures could lie and Mr. Dhall said that he would show how they could be made to tell very plausible lies. The total number of wooden sleepers on the North Western Railway was 130 lakhs approx. For a number of years the annual requirements of new sleepers of all kinds for use in renewals had been in the neighbourhood of five lakhs. Many of these renewals were premature renewals due to the replacement of lighter rails with heavier rails and some for the renewals of C. I. or steel trough sleepers. But even if it be assumed that all the five lakhs of sleepers were used every year for the renewals of wooden sleepers, the average life of a wooden sleeper on the North Western Railway would work out to $\frac{130}{5}=26$ years. Quite possibly some of the figures of high life in other countries had been worked out in a similar manner. But it would be wrong to say that the North Western Railway was getting an average life of 26 years from wooden sleepers. The figures of 130 lakhs include all sidings, besides the running lines and in many of these sidings sleepers were allowed to remain in the track very much longer than what would be considered good practice for the main line. The figures of life given by the North Western Railway represented the serviceable life of the sleeper in the main line.

The next point about which a word of explanation was necessary was with regard to para (b) on page 23 about the alleged inadequate treatment of soft wood sleepers. When creosoting was first started at Dhilwan in 1922 the American practice of heavy impregnation was followed. Each B. G. sleeper was impregnated with 25 lb. to 28 lb. of a 50 : 50 creosote and oil mixture, that is, a little over 8 lb./c.ft. and the process of treatment used was the Lawry and Full-cell. In 1929, the Forest Research Institute, Dehra Dun, made the following three recommendations :—

(*i*) That the process of treatment should be changed from Full-cell to Rueping.

(*ii*) That the strength of the creosoting mixture should be reduced from 50 : 50 to 40 : 60 creosote and oil.

(*iii*) That impregnation with 9 lb. of the creosoting mixture per sleeper was quite ample to give adequate protection and that 15 lb. per sleeper should not be exceeded in any case.

These changes were immediately introduced. Between 1929 and 1932, large numbers of sleepers treated with only 9 to 12 lb. each of the 40 : 60 treating mixture left the Creosoting Plant and many of these have not done well in the track. After 1932 all fir and chir sleepers were treated with 15 lb. per sleeper by the Rueping Process. Treatment of deodar sleepers was only started in 1934. In 1939 as a result of certain trials and observations of treated sleepers made by him at Dhilwan it was found that in the case of fir and deodar treated by the Rueping Forces about 40 per cent of the creosoting mixture was thrown out by the sleepers within the first week in the form of bleeding. This amount was therefore being wasted and the net amount that was left in the sleeper at the time it was laid in the track was 9 lb. in the case of fir and 6 lb. in the case of deodar sleepers. It would be noticed that these amounts were extremely small. As a result and in order to eliminate this waste he had changed the process of treatment to Full-cell in the case of fir and deodar but did not make any change in the case of chir as very little bleeding was observed in the case of this species. The present practice at Dhilwan was to impregnate deodar sleepers with 10 lb. of the creosoting mixture as this species was naturally durable. All other species were being treated with 15 lb. per sleeper the process being Rueping in the case of chir and Full-cell in all other cases. With the present system of treatment whatever was put in the wood was being retained and nothing was being thrown out in the form of bleeding. The last changes made were much too recent and it was not yet possible to say if a further increase in the amount of impregnation could be economically justified. To compare the results of different impregnations and different mixtures of creosote and fuel oil, experimental lengths of differently treated sleepers had been laid contiguous to each other and careful records of their behaviour were being kept. When definite results were obtained necessary changes would be made in the process of treatments. In the meantime, it was not considered advisable to rush into making changes which might result in unnecessary waste.

Under recommendations for improving the economic order of wooden sleepers on page 25 Mr. Kumar had recommended relaxation of the existing sleeper specifications. He did not agree with him in this respect. Use of inferior wooden sleepers would reduce their average life in the track and increase their annual cost and thus make their use uneconomic. It was not correct to expect a corresponding reduction in their price. Just before the War, by the judicious management of the Sleeper Pool he had reduced the prices of deodar B. G. sleepers to Rs.4-8-0 each, chir to Rs.3-2-0 and fir to Rs.2-12-0. Several contracts were in fact made below these prices. These prices represented barely the working expenses of the timber contractors. What was rejected was being taken by the building trade at prices higher than what they were paying, and that really represented the contractor's margin or profit. It they had increased the pressure on available supplies by accepting inferior class sleepers also, the result would have been a very disproportionate rise in prices.

Under this head Mr. Kumar had made some detailed recommendations. Mr. Dhall said that he would discuss these one by one :—

(*i*) Mr. Kumar had recommended the acceptance of boxed heart—sleepers. He differed from him in this respect. It was an established fact that such sleepers split badly. On the North Western Railway all soft wood sleepers were treated before use. This treatment extended to only $\frac{3}{8}''$ to $\frac{1}{2}''$ below the surface. If a crack subsequently developed to below this depth, the value of the treatment was lost. White ants and fungus gained entrance and destroyed the sleeper. This was very likely to happen in boxed heart sleepers and he did not recommend their acceptance.

(*ii*) Mr. Kumar had recommended the acceptance of sapwood without any limit. The North Western Railway placed no limit to the amount of sapwood to be accepted in the case of all soft wood species excepting deodar. In the case of deodar, only 10 per cent of sapwood was accepted. The reason for this was that the treatment of deodar had been started only in 1934. The process then used was the Rueping and it was observed that by this process the sapwood was extremely difficult to treat. The limit of 10 per cent of sapwood was not therefore relaxed. In 1939, he had changed the process of treatment at Dhilwan and by the new method sapwood was being treated better but he had not yet recommended any change in the specification as he wished to see under actual working conditions in the track whether the treatment now being given was adequate to protect the sapwood against white an and fungus attack. As regards wane only 1" wane was being permitted as the width of the bearing plate being 9" did not permit a greater relaxation.

(*iii*) Further Mr. Kumar had recommended the use of other species of wood hitherto not used. As already stated, the North Western started the use of inferior species available in its area as long ago as 1922 after putting up its treating plant. The other Railways did not start it as they were getting adequate supply of sal sleepers or were situated close to sources of supply of iron and steel sleepers and found their use cheaper. It was probable that other creosoting plants would be put up after the War by other Railways, as supplies of sal were dwindling and it was becoming increasingly necessary for them to use inferior species which could not be used without treatment. In fact, one plant at Nahar Katya, which had been lying derelict for nearly 30 years, had already started working.

Mr. Dhall stated that his views about sleepers were that :—

(*i*) A wooden sleeper being an all-purpose sleeper was the most suitable sleeper to use but the choice of the engineer was very often limited by the availability of the material at his disposal.

(*ii*) That the following improvements could be made to increase the life of the wooden sleepers :—

(*a*) More universal use of anchor plates. These were stepped and as Mr. Kumar mentioned in his Paper would cause less rocking and therefore less degrade of the sleeper than ordinary bearing plates.

(*b*) The present design of the anchor plates was of the one-key type. Re-gauging was not therefore possible on these. Also, on account of inaccuracies of manufacture it was not possible to pre-bore treated wooden sleepers on both sides. Sleepers for use with anchor plates were at present being pre-bored on one side ~~only~~, the other side being bored at the site of work. Such holes were not usually treated at all by P. W. Is and even if a careful P. W. I. did observe the standard instructions and poured creosote in the spike-holes, the treatment was not as effective as in a creosoting cylinder. To remedy these drawbacks anchor plates should be of the two-key type. The extra cost would be re-paid by better maintenance of track.

(*c*) Where ordinary bearing plates were used, less insistence should be put on keeping the dog-spikes always driven home. The wave action in front of a moving wheel must raise the dog-spike above the foot of the rail by about 1/16″ to 1/8″. However often this was driven down, it must come up again. Too frequent driving would only result in spike-killing the sleeper rapidly. If, however, the spike was above the rail foot by an amount greater than one sixth of an inch it was an indication of bad maintenance. In this matter, he would go a bit further and say that even in the first instance with new sleepers the spike should be driven so that its head remained 1/16″ to 1/8″, above the rail foot.

(*d*) Even in the case of sal and other hard wood sleepers it would pay in his opinion, to treat them and to use bearing plates with them. Treatment would preserve the timber from rot, fungus and white ant attack and bearing plates would stop the rail from cutting into the sleeper as was happening at present. Not only would the increased life so obtained be a direct advantage but the indirect advantages would be very considerable. On account of the increase in the life, the annual demand for sleepers of the Indian Railways, as a whole, would be reduced and this would enable them to get their requirements at cheaper rates.

**Mr. R. P. Lall**, while expressing his views on the Paper, stated that, at pages 24 and 35, reversion to spot renewals which were abolished by this Railway for very sound reasons had been advocated by the author because he considered that thereby a uniform sleeper condition could be maintained and also the maintenance would be economical.

It would be a lengthy process to go into the merits and demerits of spot renewals. A study of the N. W. R. Headquarters Office file would convince anybody as to the harm done by the spot renewals. Very briefly the arguments against the spot renewals could be stated to be :—

(*a*) The marking of unserviceable sleepers which normally was expected to be done by the Assistant Engineer had to be actually left to the mate or the gangman quite often, as no subordinate could be present to mark the sleepers opened out in day-to-day overhauling. The result of this was that while in some cases good sleepers were marked as unserviceable, in the other cases, unserviceable sleepers were left in the track. The so called re-checking by the subordinate later suffers from the usual defects of a re-check. In some instance, it was noticed that only 50 per cent of the sleepers demanded for spot renewals were actually required and utilised.

(*b*) In renewing random sleepers, the bed of the sleeper so renewed was disturbed, the level of the track was thrown out and other sleepers either touched up or unevenness left in. In any case, the running became rough because the bed under the sleeper was not uniformally consolidated.

(*c*) The gauge in the existing sleepers was not always uniform and even if the new sleepers were linked in conformity with the gauge of the adjacent sleepers, the gauge here became variable due to the shrinkage of new sleepers and other causes.

(*d*) Sleepers being of variable strength, a greater strain was placed on the new sleeper which led to its more rapid deterioration and vitiated the economy claimed.

(*e*) It was not clear from the recommendations made by the author as to the stage at which he considered the renewal of unserviceable sleepers should be undertaken. If he followed the old practice that obtained on the N. W. R. that is of changing the sleepers when they were more than 20 per cent unserviceable it really meant that up to the time the percentage remained below 20, no sleeper would be changed. This by itself did not lead much to the uniformity claimed. Further, the laying of new sleepers among unserviceable ones or which might be on the verge of becoming unserviceable did not lead to the uniform condition of the track.

(*f*) With the type of labour and staff available on Indian Railways, to leave the job of marking sleepers to gangman which was inevitable in spot renewals, was to introduce not only an uneconomical but a dangerous system and so long as the conditions remained as they were, it would be a highly retrograde step to go back to the spot renewals.

At page 3 under item (*c*), the author had stated that the wooden sleeper track was quieter than steel trough sleeper road. This did not appear to be generally correct. On the other hand, the steel trough road was quieter than the wooden road. Even if the wooden sleeper road was quieter, to begin with in certain localities where the steel trough sleeper was not well packed or otherwise well-attended to, as the time passed the rattling of the bearing plates, etc., led to a much more noisy track than that with the steel trough sleepers. This was quite understandable as the steel trough sleeper held the rail in a much better grip than the wooden sleeper with dog spikes and bearing plates. He was sure the author would be convinced if he rode on the Up line track between Amritsar and Lahore and noticed the running from Amritsar to mile 324 and beyond. There was very marked difference in the noise, the wooden sleeper being much more noisy.

In item (*h*), page 3, it had been said that the wood sleeper required less than half as much attention immediately after laying as one with metal sleepers. His experience was that the figure should be somewhere near 75 per cent of the metal sleepers. The regauging of wooden sleepers and readjustment of creep immediately after laying which invariably occurred to some extent were also to be considered when judging of the cost.

He was afraid that the first feeling which the track laid on wooden sleepers created as compared with that laid on metal sleepers had produced a prejudice against the metal sleepers, which the author was so keen to fight.

As regards item (*i*), page 3, it was pointed out that the same metal sleeper could be used for different types of rails with different type of keys though the range could not be as large as that of wooden sleepers but while the wooden sleeper would suffer enormously by the change over from one rail to the other, the metal sleeper would remain unaffected.

On page 8 clear space for metal sleepers at the joint was given as 2″. It varied from 1″ in C. I. plate N. W. R. type sleepers whose width was 14″ to 4″ in the K. K. type sleepers—width 11″. So far as C. I. plates were concerned, no great difficulty had been noticed in packing them when spaced 15″ centre to centre.

The one point, however, which did not appear to have received the attention so far as N. W. R. type C. I. plate was concerned was the great importance of packing the keel below the sleepers. It had been found that so long as this keel was kept well packed, the plate would hold well and the running remained satisfactory.

The landing sleeper, as stated by the author, required greater attention and in places where Duplex joint sleepers had been used, the leading shoulder sleeper required much greater attention.

The C. S. T. 9 sleepers had been noticed to suffer from one defect. They gave kinkiness to the road, perhaps they were not laid correctly originally or the rails not jimmed before linking. To remove these kinks, the easiest method was found to be to lift the track but unfortunately the kinks appeared again though not in the same number and were not removed till the rails were jimmed. Therefore, the laying of these sleepers needed much greater attention than the other C. I. plate road.

At page 14, it had been stated that the disadvantages of boxing up to the top of tie bar far out-weighed the advantages. It was not clear from this as to which type of sleeper the author had in view because in all the existing C. I. plate sleepers considerations of stability and proper packing demanded boxing up to the top of the tie bar at least for a certain length of the tie bar even if a central hollow was left. If this boxing was not done up to the level of the top of the tie bar, the packing from under the sleepers would move out.

Even in the case of N. W. R. plate sleepers where the cost of maintenance for the same reasons as advocated by the author was claimed to be less, boxing was done up to the top of the tie bar.

The cost of through packing of steel trough, 3 S/TSC and KK plate sleepers was given as higher than the overhauling while in the case of wood and N. W. R. type C. I. plates it was the same. In the note on the same page the author admitted that in through packing the removal of ballast for screening was not included. Therefore, the higher or equal cost of through packing when compared with the overhauling was not understood. As a matter of fact, through packing should cost less than overhauling. Could this be explained ?

At page 16, great stress had been laid on the comparative bearing area of the wood and other sleepers and the reason why the wood sleeper was said to be preferable to the block sleeper was that a certain reserve area was available in wooden sleepers which could come into play when the train was passing. A more cogent reason in this case appeared to be that the block, which was held rigidly by the rail, hammered the ballast below with the joint weight of the rail but with wooden sleepers the free play of the wave motion of rails, because of the spikes getting prized up along with the interposition of the cushion provided by the sleeper, reduced the shock on the ballast which was not crushed to the same extent as it was by the blocks.

Among the disadvantages of the rail-free Duplex joint sleepers should be added the difficulty of maintaining proper gauge at the Duplex and shoulder sleepers. Minor gauge kinks developed at the shoulder and rail joints and the packing and gauge of the shoulder sleepers required much greater attention.

The provision of baffles in the steel trough sleepers recommended by the author on page 21 was a very good idea. These sleepers had to be filled in at present, otherwise the packing always became loose because it moved towards the centre. If baffle plates were not provided, it was feared that the steel trough sleepers would in time become centre bound. The introduction of baffle plates and thereby keeping the central portion hollow might, however, make the track a little more noisy.

Regarding the use of non-removable keys, a better practice was to use the non-removable key on the inside and outside at alternate sleepers as then the rail could not be removed unless the sleepers were shifted which again could not be done till their packing was broken.

**Mr. D. R. Kohli,** while congratulating the author on the thoroughness with which he had dealt with the subject in a short paper, desired to offer a few remarks on Chapter II *re*: the "Theory behind the design of a sleeper." He said that Mr. Kumar had stated "It was originally believed that the wheel runs in a strictly horizontal path." He did not think this was correct. Ever since the appearance of the Elastic Theory, it had been realised that due to the sleeper supports and alternations in the wheel load due to lurching, etc., the wheel had a slightly undulatory movement and the reactions were concentrated at the sleepers. However, it simplified the calculations for rail stresses, etc., if the rail were assumed to be equally flexible throughout, specially as the actual effect of these concentrations was negligible.

In the same paragraph Mr. Kumar wrote that before the track could be designed on a rational basis, it was necessary to determine the vertical acceleration of wheels both at the joints and at the middle points of a rail. The factors governing this acceleration were, however, so numerous and varied so widely with different types of rails, ballast and rolling stock that in his opinion the derivation of a general set of rules was practically impossible. The impact effects of the type mentioned were covered by what was called the "Speed effect" in usual calculations and this term included all the dynamic effects like lurching and rolling and all other vertical movements which would be impossible to express mathematically. Tests had shown that the present methods of calculations gave stresses which we e very near those actually observed in practice. Also the existing formula for speed effect being equal to $\frac{V}{3\sqrt{u}}$, where V was speed in m. p. h. and u the Track modulus was very simple, and the detailed determination of the vertical accelerations of wheels did not appear to be absolutely necessary.

Referring to para 2, Chapter II, Mr. Kohli said that he was afraid that he could not agree with the author's supposition that the distribution of load was more or less uniform over the lengths AB and CD of the sleeper. Mr. Kumar had already accepted the track as an elastic structure and he suggested that he should calculate the distribution of load, bending moments, etc., by the Elastic Theory rather than by assuming a uniform distribution.

Regarding para 5 Chapter II, Mr. Kohli said that from the Elastic Theory it could be proved that

$$M_o = P \times \sqrt[4]{\frac{E\,I}{64\,U}}$$

$$Y_o = \frac{P}{\sqrt[4]{64\,EIU^3}}$$

where $M_o$ = Max. B. M. under wheel load P

$Y_o$ = Max. depression under wheel load P

E = Modulus of Elasticity of steel.

I = Movement of Inertia of section of the rail.

U = Track Modulus.

If 'S' is the spacing of sleepers, it is known that 'U' varies inversely as 'S' or $U = a/S$ where 'a' is a constant.
Substituting

$$M_o = P \times \sqrt[4]{\frac{E}{64\,a}} \times \sqrt[4]{I\,S}$$

$$= K_1 P \times \sqrt[4]{I\,S} \qquad (i)$$

$$Y_o = P \times \sqrt[4]{\frac{S^3}{64EIa^3}} = K_2 P \times \sqrt[4]{\frac{S^3}{I}} \qquad (ii)$$

where $K_1 + K_2$ are constants.

From (*ii*) P can be assumed to be equal to $K \times \sqrt[4]{\frac{1}{S^3}}$ as mentioned by Mr. Kumar only if the track depression is taken as constant. This has never been our basis of the design of track; it is always the maximum stress induced in the rail that controls and that depends upon the bending moment as given in equation (*i*) above. The stresses in two rails with section moduli of Z and $Z_1$ are therefore

$$t = \frac{PK_1\sqrt[4]{IS}}{Z}$$

$$t_1 = \frac{P_1K_1\sqrt[4]{IS}}{Z_1}$$

where P and $P_1$ are the two wheel loads

and if these are to be equal, the ratio of wheel loads

$$\frac{P}{P_1} = \frac{Z}{Z_1} \times \sqrt[4]{\frac{I_1 S_1}{IS}}$$

Comparing on this basis, following were the results :—

| Rail section | 1 | Z | No. of sleeper per rail 36 ft. | S | Safe axle load tons. | Axle load vide schedule of dimensions tons. |
|---|---|---|---|---|---|---|
| 75 lbs/R | 25·36 | 9·72 | N+1=13 | 38″ | 17·00 | 17·00 |
| 90 lbs/R | 38·45 | 13·05 | N+3=15 | $31\frac{1}{2}$″ | 21·6 | 22·5 |
| 115 lbs/R | 62·41 | 18·50 | N+5=17 | 27″ | 28 | 28 |

It could be seen that the results were not as inconsistent as Mr. Kumar had imagined. Also, the safe axle loads in the schedule of dimensions were presumably locomotive axle loads as the figures of 17, 22·5 and 28 tons suggested, and the actual stress would depend upon axle spacings, dynamic effects, etc., and could not be criticized so easily.

With regard to the calculations in Appendix 'A', as already stated by him, the method of calculation adopted by Mr. Kumar was based on an arbitrary supposition of uniform distribution of load and was far from accurate. He should base his calculations on the Elastic Theory. Also he was not at all sure that the maximum bending moment would occur at the edge of the bearing plate as it might not be in uniform contact with the sleeper when it bent under running conditions. In any case the exact distribution of load under the bearing plate was more or less indeterminate. In Chapter II, para 2, Mr. Kumar had indicated the shape of the bending moment diagram of a loaded sleeper. This showed the maximum bending moment at the centre of the rail seat and should be preferably adopted for calculations as it would be on the safer side.

**Mr. Berridge**, while commenting said that he thought that Mr. Kumar was to be congratulated upon the excellence of his Paper.

He had noticed the difficulty of packing the ballast under two sleepers close together at a rail joint. The method of ramming in the ballast with a beater—a snub-nosed pick axe—had the disadvantage that the lower corners of wood sleepers were liable to injury from badly-aimed blows with the beater. It appeared that this trouble might be got over by adopting the method of packing called, "Measured Shovel Packing." This method had been universally adopted on the main lines in England and it was claimed that it was so simple that excellent packing could be relied upon from the most inexperienced gangmen.

Measured shovel packing was accomplished in three steps. Firstly, the sag or dip in the track was measured by the use of sighting boards placed on the head of the rail. Secondly, the depression of the sleepers under a train was recorded on a series of Voidmeters; and thirdly, the requisite amount of chippings, determined in the first two steps, was spread under the sleeper with a shovel. To measure the extent to which the track was out of level (or dips between two high points) under static conditions, that is when no traffic is on it, a set of three special sighting boards was used. These boards were fitted to short posts having clips at the bases so that they were rapidly fixed on the head of the rail. One board was provided with a slit at the level of the eye of a man sitting on the rail; the second or intermediate board was painted half yellow and half black with a vertical division between these colours running down the centre of the board. The post of this intermediate board was adjustable in height and was provided with a scale so that the amount of extension required to bring the top of this intermediate board level with the eye-slit in the first board was readily determined. The third board was painted with the face divided into four spaces to present a chequered appearance of four rectangles, the yellow and black colours being separated vertically down the centre and horizontally across the board at the same level as the eye-slit of the first board. All three sighting boards are fitted with spirit levels to ensure that they stood perfectly vertical when clipped on the rail.

The ganger sights along the rail in the usual way and locates two high spots preferably not more than 120 feet apart. The first or eye-slit board and the third or target board are set up on the high spots. The second or intermediate board is then placed over the "low" sleepers and adjusted until the top was level with a line joining the eye-slit and the horizontal line on the third board. The number of divisions revealed on the scale of the intermediate board (after it has been raised) was then read off and the figure chalked on the sleeper immediately below this board. The intermediate board was then moved over the other sleepers until the amount of "static" slack for all the sleepers between the high spots has been determined. This process was then repeated along the other running rail between the same high spots.

The gangmen were also supplied with a dozen Voidmeters for measuring the depression under the passage of a train. Steel stakes, some 18 inches in length, were driven into the formation about three inches from the side of each sleeper and one inch outward from the end of the chair. To each of these stakes a Voidmeter was clamped at such a height that the bottom of the turned-down end of a spring loaded pointer was in contact and pressing against the top of the sleeper. There was a second or idle pointer and this was set so as to rest against the spring-loaded one. As a train pass over the line, the line sleeper was depressed downwards and the spring-loaded pointer pressing on the sleeper followed suit, pushing the idle pointer along the scale. After the train had passed, the spring-loaded pointer returned to its original position while the idle one remained where it had been pushed. The number of divisions on the scale was chalked on the sleeper. The sum of the figures obtained for each sleeper by these "static" and "dynamic" measurements determined the number of canisters of chippings required to be spread under each sleeper (15 inches outside and 15 inches inside of each rail) to take out both the depression in the "top" and the void which allowed it to sink under the wheel load.

Particular care was taken in using the Voidmeters to see that the stakes driven into the formation were firm so that they would not be moved by the resistance of the spring-loaded pointer when the train was passing. The upper idle friction pointer was adjusted so as not to be too stiff in its movement that it would not follow the movement of the spring-loaded pointer nor on the other hand to be too loose that it would not remain after it had been pushed up the scale. Adjustment was afforded by means of a small thumb nut.

In measured shovel packing, no slack more than one inch (combined static and dynamic) was tackled at one time, and it was usual to keep to half that figure as a maximum and to go over the section again with Voidmeters and sighting boards a week or so later.

It was of course important that the proper size of chippings be used and the size of the canister used on the London Midland and Scottish Railway had been based on the use of $\frac{1}{4}$ inch minimum to $\frac{1}{2}$ inch maximum granite chippings evenly spread over 15 inches on each side of the rail and completely covering the width of the sleeper for that distance. The canister, $3\frac{1}{2}$ inches internal diameter and 4, 7/8 inches high was made of 20 S. W. G. lead-covered sheet iron spot-welded. To make this canister a measure for 10 inch as well as 12 inch wide sleeper short slits were cut 7/8 inch from the top and for the narrower sleepers it was filled only up to these slits, while for the wider sleeper it was filled with the chippings flush with the top. The divisions on the scales. of both the Voidmeters and the intermediate sighting boards are in units of canisters of chippings and they did not necessarily represent a slack measured in inches, although on the L. M. S. Railway, each division on the scale represented 1/16 inch of slack.

The actual packing was done by spreading, the track being lifted with a jack designed to fit snugly below the top of the rail and capable of instantaneous release on the approach of a train. The rail was raised just sufficiently high to permit the clear passage of the packing shovel with its charge under the sleeper. The actual spreading was done from one side of the sleeper so it was necessary to rake out the balast from between every other sleeper only instead of from between every pair of sleeper as was done in the case of ordinary packing by the beating method. The spreading was done with a special goose-neck shaped shovel which had a flat blade $6\frac{1}{2}$ inches wide and 8 inches long.

In conclusion Mr. Berridge drew attention to the conservatism of engineers. The President in his address had mentioned that engineers brought up in the riveted-girder school had been slow to adapt themselves to the modern methods of welding. Mr. Berridge feared that this reluctance to adopt modern methods might delay the introduction of measured shoval packing on the railways in India; but, nevertheless, he thought this scientific method of packing was worthy of consideration by engineers in this country.

**Mr. D. N. Chopra,** while expressing his views on the Paper, opined that Mr. Kumar had made a valuable contribution on a subject most vital to Railway Engineers, judging from the fact that on the North Western Railway alone 40 to 50 lakhs of rupees were spent every year on sleeper renewals. The Author had stated that in judging the relative merits of wooden, cast iron and steel trough sleepers, prejudice had almost invariably played a decisive part. He was afraid, the Author, too, had been the victim of the same malady and his prejudiced views in favour of wooden sleepers had, unwittingly, at number of places, unduly tilted the scales of the arguments in favour of this type of sleepers.

To start with, some of the so-called disadvantages of metal sleepers described at pages 2 and 3 could be proved to be wrong, while others were really applicable to cast iron sleepers only.

(*a*) It was not true that steel trough sleepers deteriorate due to corrosion more rapidly than cast iron sleepers. The North Western Railway was annually renewing some 35 miles of metal sleepers in areas unsuitable for such sleepers and hardly one or two miles of track laid with steel trough sleepers normally appeared in this category. Again, the latest statements of mileages unsuitable for various types of sleepers did include lengths suitable for steel trough but unsuitable for cast iron sleepers, but none in the opposite category. It was the small and relatively thin buried fittings of the cast iron sleepers which rusted and jammed up rapidly.

(*b*) Good running on wooden sleepers started from, say, two years after the sleepers had been laid and stopped four or five years in advance of the 15-16 years period after which these sleepers must be taken out of the main line.

(*c*) It was true that the metal sleepers required 1½″ ballast which was somewhat dearer than the 2″ ballast used with wooden sleepers. The quantity of ballast required was, however, less than that required with wooden sleepers. The officially given quantities were 59,400 cft. 64,680 cft. and 71,280 cft. per mile for cast iron, steel trough and wooden sleepers, respectively.

(*d*) Only cast iron sleepers broke in large numbers in derailments.

(*e*) In India severe frost was seldom experienced. Therefore, fractures of rails due to this cause seldom occurred.

(*f*) It was a recognised fact amongst the permanent way staff that the steel trough sleepers required the least maintenance. The gang strength had lately been fixed on the basis of detailed job analysis of labour required for maintaining different types of track. The gangmen per mile (for primary lines) had been

worked out in detail in collaboration with the Track Supply Officer and were as follows (lives of sleepers as given in 1943 and price of material as prevailing just before the war) :—

| | |
|---|---|
| Treated Deodar sleepers cost | ... Rs.2,260.5 per trail mile |
| Treated Chir sleepers cost | ... Rs.2,116.6 ,, ,, ,, |
| Steel trough sleepers cost | ... Rs.2,238.1 ,, ,, ,, |
| C. I. CST. 9 sleepers cost | ... Rs.2,128.1 ,, ,, ,, |

Treated Deodar sleepers worked out to be the dearest and the treated chir the cheapest, but the differences were fairly small, as they should be.

The fear of the Author that the wooden sleepers were likely to be ousted appeared to be unfounded. It was a fact that the Railways had been accepting, even before the war, all the good quality sleepers offered in India. For good performance of metal sleepers it was essential that they were not laid in unsuitable places. Also station yards were, more or less, taboo for these sleepers. Out of the 7,150 miles of B. G. main line on the Railway 4,554 miles (63·5 per cent) were still laid with wooden sleepers. In the last 10 years the percentage of main line laid with metal sleepers had increased from 34·1 to 36·5 with 1937 miles laid with C. I. sleepers and 650 miles with steel trough sleepers.

Amongst the metal sleepers, the steel trough sleeper was decidedly the better one and in good many respects equalled or beat the best available wooden sleepers. He believed the use of this sleeper would, extend in future, and, presumably, for some time the only limiting factor would be the number offered or available. There was enough field for wooden sleepers, however, and those interested in the timber trade should exert to the maximum to increase the output of good quality sleepers including sleepers of varieties not already exploited. Also, further investigation was necessary for devising cheaper and more effective methods of treating the sleepers, so as to get better performance and more life from them.

**Mr. A. M. Sims**, addressing those present, said that Mr. Kumar's Paper opened by referring to the essential requisites of an *ideal* sleeper. He thought, from practical considerations, that it would be preferable to put these requisites in another form and say that a *well designed sleeper* should have adequate bearing area, strength as a beam under cantilever loading ; the sleeper must bed into the ballast well below the surface of the boxing ; must be rigid to hold the gauge without any alteration ; and must have resistance to lateral movement by shape rather than strength, also, and this is most important, uniform consistency and expected long life of its material.

Taking each kind of sleeper separately his remarks were as follows :—

The wood sleeper was the best sleeper for train riding purposes but not from the point of view of track economics. He was glad to hear Sir William Roberts make a very important point when he referred to the preference for wooden sleepers on the Railways in England, which he mentioned as a main steel producing country. It was probable that the English Railways had experienced that the running on wood sleepers was better than on metal. Sir William Roberts also referred to Kiln drying plants but, of course, the installation of plants must depend, to a certain extent, on the supply of sleepers likely to be available. This point would certainly be examined by the North Western Railway. Engineers must not allow their own purely technical views to put aside the comfort of passengers. The continued strength, gauge holding properties, resistance to lateral movement, consistency and life of the material were not much in its favour. The ballast, being harder than the wood, compressed it and bit into it on the underside. This caused greater depression or a lower elastic track modulus figure. For the benefit of those not familiar with this term, the Elastic Track Modulus was the number of lb. per lineal inch of track required to depress the track one inch. This modulus figure was used in calculations for the stresses in the rails but never had he seen the effect of the spike holes taken into account when calculating, for other purposes, the strength of the sleeper ; the effect of two spike holes being in a line was to reduce the cross sectional area by $12\frac{1}{2}$ per cent and, in a $9'' \times 6''$ sleeper, which was referred to in the Paper, by nearly 14 per cent. Horizontal cracks were of more consequence as regards strength than vertical cracks and for this reason boxed hearts were not desirable. In this connection, Mr. Dhall had spoken with regard to the possible lowering of the specification standard and had also referred to the supply being limited by the accessibility of the forests. The wooden sleeper gave very fine track for half its life ; then old age began to set in and the maintenance men were fighting a losing battle the whole time. The strength figures got lower and lower as the timber got older and the section decreased ; its powers of resistance ebbed away and, in the end, the maintenance men were glad to see it go ; frequently, he had found them say that the sleepers were in a worse condition than they really were and this wide margin for assessing the proper condition of the wooden sleeper led to expenditure which might be very uneconomic. Reference had been made in the Paper to anchor plates but he would like to correct what he thought was an erroneous impression with regard to the use of these. The anchor plate was originally designed to take the place of one bearing plate and one rail anchor for the purpose of holding creep, but, by some mischance, he found that anchor plates were being used on every sleeper where wooden sleepers were being put into the track and so formed a track with cast iron chairs for flat footed rails. The increased expenditure was considerable and the policy had since been altered to allow for the number of anchor plates per rail to correspond only with the number of rail anchors required, the plates on the remaining sleepers being ordinary mild steel bearing plates.

The steel sleeper had all the attributes of what he had termed a "well designed" sleeper, except that it did not bed so low into the ballast as he should like ; consequently, at times blowing joints were to be seen with this sleeper—certainly more frequently than with wood but with far less frequency than with cast iron sleepers. A steel sleeper was, he considered, by far the best economic proposition ; it had very simple fittings and, though the Paper states that metal sleepers were usually suitable for one rail section only, steel sleepers could be used with several sections of flat footed rails by means of special keys and this method had been exploited fully on the North Western Railway. He was very glad to hear the views expressed by Khan Bahadur Nizam-ud-Din with regard to steel sleepers and to hear that his views coincided almost exactly with his own

A careful analysis of the attributes of cast iron sleepers, in relation to the requirements of a "well designed" sleeper, had shown that they satisfied him only as regards bearing area, strength in the plates as separate parts of the sleeper, but not as a single beam under the two rails ; they were also satisfactory with regard to resistance to lateral movement. They had some of the other requirements in part—though he thought these qualities were apt to be stressed by prejudice, to which the Paper rightly, he felt, referred. During the course of his experience, his opinion of the cast iron sleeper had gradually deteriorated and he now saw little in its favour as an engineering proposition. By its design it could not hold the gauge properly. When the bars and cotters were embedded in the ballast, as they, practically, had to be, there was almost certain to be corrosion ; in fact it was essential, for running purposes and to secure as quiet a running track as possible, to box up to just under the foot of the rail. Under derailments, the certainty of fracture, of both plates usually, meant requisitions for ten thousand sleepers or more as replacements and this had been experienced on several occasions on the North Western Railway. This important factor had usually been ignored in the Code and by persons in favour of this sleeper when giving opinions of its average life. His attention to it was first drawn by Lt.-Col. Macrae, R. E., whom, the speaker expected they would remember as a former Chief Engineer of the N. W. Railway. The sleeper going by the name of the N. W. Railway Cast Iron Sleeper was a pioneer in its time of the more modern designs of this class of sleeper. The great defect, which was so obvious now, but the effects of which did not show up so much in the days of lighter axle loads, was that it sat right on top of the ballast section ; he wished, he knew more of the history of its design, but his real regret was that it bore the name of the North Western Railway. As regards the C. S. T. 9 sleeper, he agreed that it was the best of its kind so far but, if it had not been for the war, he would have used it very sparingly on the North Western Railway.

Consideration of sleepers in a fast main line could not really be divorced from the matter of ballast. In its capacity as affording support to sleepers he had found misconceptions regarding ballast and its ways of functioning. Because of its being packed and the necessity of its forming a rigid, though slightly elastic, support, the ballast, below the sleepers should be as solid and dense as possible—the surrounding, or boxing ballast between the sleepers and on the shoulders should be loose, clean, hard and uniform to allow for drainage and aeration of the sleepers and fittings and to form the future packing material. It was undesirable for the whole ballast section to be uniform in density and he had never agreed with the suggestion, which he had seen put forward many times, for the dispersion of sleeper pressure through the ballast at 45° from the lower edge of the sleeper. The ballast could not be, and was not meant to be homogenous. One other point *viz.*, depth, of ballast below the sleeper had little meaning; a breached bank, when a cross section could be observed, would show what he meant; there was much unequal forcing of the ballast into the supposed formation level.

The North Western Railway was in a fortunate position, on account of the soil met with in the Punjab and other Provinces served by the line and of having higher figures for the track modulus than many other Railways. From experiments the figures were 1,313 for wooden sleepers and 1,657 for steel. The figures for cast iron might be taken as high as for steel. The higher the figure the lower in some degree the stresses in the rails. The important point was that the figures for metal sleepers remained high during the life of the sleepers, but here again wood was fighting a losing battle in the second half of its life.

There were some general points mentioned in the Paper to which he would like to refer briefly. Under modern conditions of maintenance there was little or no chance of *centre binding of sleepers. The rail free principle* had been found to be quite unsatisfactory on the North Western Railway and, when he was at Delhi a fortnight ago, he found that only one Railway in India now had a good word to say for this and that was the line on which it originated; he was glad Mr. Kumar was in agreement with the undesirability of this principle. *The spot renewal system* had been tried and abandoned on the North Western Railway as it was found to be quite unsuitable. Many of the reasons for the failure of the spot renewal system were referred to by Mr. Lall during the course of his remarks. Too much attention should not be paid to *annual costs* of sleepers because the scrap values used were, in effect, an estimate of the prices which would rule 18 to 45 years hence; he would indeed be a good prophet who hit the right figure; the figures were guides and nothing more and, in many cases, the average lives of the sleepers could only be estimated at present. Mr. Berridge had given his views with regard to measured shovel packing and had suggested that this method might be tried on the North Western Railway. Shovel packing had already been tried but not in the advanced form of measured shovel packing which required a certain quantity of chippings to be placed under a sleeper according to the measured depression of the sleeper. The quantity of ballast chippings was measured in a canister of a fixed volume. From the reports received with regard to shovel packing on the Railway, the results were not very satisfactory and he considered this method to be rather above the intelligence of the gangmen, who work very well on the overhauling system and had been accustomed to this for many years past.

Concluding his remarks Mr. Sims said that it will not be difficult to judge his views on the various sleepers. Best of all, for track running purposes, was the wooden sleeper in the first half of its life but, from an economic point of view, he saw nothing better than the steel sleeper in situation suitable for metal sleepers. It did not fracture under derailments and gave a first class running track in time; he would like it to bed further down in the ballast and he felt little trouble would then be experienced from blowing joints; it would outlast the service of any engineer. For the cast iron he had little to say in its favour but he would say this—from a business point of view that it had served a real need in controlling the prices of wooden and steel sleepers, but he did not like it as track material. Perhaps a little prejudice would be attributed to him, but his opinion had been formed on a somewhat extensive experience.

He congratulated Mr. Kumar on his Paper and appreciated his industry in writing it; there were, of course, several controversial points in it, which the Author had recognised and, he was sure, would discuss with other Engineers. Finally and here he would plead with Engineers that if they would follow Mr. Kumar's example and write Papers they would find themselves better equipped professionally.

**Sir Arthur Griffin,** the President of the Congress, while winding up the debate said that he would like to congratulate Mr. Kumar on his Paper, and thanked those who had taken part in the discussion that morning. He trusted that other Railway Engineers would have an opportunity of reading what had been written and said, and that they would benefit from the experience of others who had given thought to this rather important subject.

As General Manager, perhaps he looked at the matter in a slightly broader fashion. The Railways required a sleeper which would prove economically satisfactory, and one which would ensure the maximum of safety and comfort for travellers. He would not stress his own inclinations, but they coincided with the views of Mr. Sims. A steel trough sleeper properly designed, was his choice where the soil conditions were suitable. Many years ago, as a Divisional Engineer, he took out of the track such sleepers which had been in for something like 45 years, and they were removed as the lugs, improperly designed as they now knew it, were giving way. I xcept for this fault there would have been many years' life still in these sleepers.

But he would like to stress a very important point. Their economics, their arguments in favour of a particular type, and their hopes, could all be upset by one thing—that was, poor or improper maintenance. The highest standard of maintenance was the primary consideration, and the less satisfactory the initial design of the sleeper, the more urgent did that consideration become.

**The Author** while replying to the discussion stated that K. B. Nizam Din had advocated that steel trough sleepers should be taken out of the track after every 10 or 12 years. The Author's experience indicated that this was not necessary, as hardly any corrosion had been noticed in the steel trough sleepers laid in the dry climate generally prevailing on the North Western Railway. The lugs of the latest type of sleepers may get torn, if the keys are habitually overdriven. A slight looseness of lugs can be got over by the use of liners. The cracks if any, in the lugs can be repaired by welding in situ. If the steel trough sleepers had to be taken out of the track for repairs, every 10 or 12 years, as recommended by K. B. Nizam Din, they will lose much of their economic superiority. The process would, for all purposes, mean a sleeper renewal which would inevitably upset the packing. This would be very undesirable, as steel sleepers take a very long time to bed down in the track, as admitted by him.

The Author agreed that he had found that the steel trough track was cheaper to maintain than a wooden track. The creep trouble in the wooden track had now been overcome by the use of a certain number of C. I. anchor bearing plates. There was no danger of these being stolen away by villagers as was the case with the ordinary creep anchors.

The holes for the round spikes in the anchor plates were at a safe distance from the edge of sleeper and no spike killing of holes had yet been noticed on any track laid with anchor bearing plates. It was probably yet too early to say whether this defect would not manifest itself to any degree at about the end of the useful life of the sleepers.

If the higher track modulus of the steel trough track was advantageous in reducing the rail stresses, it had the disadvantage of increasing the sleeper loads and thereby throwing a greater pressure on the subgrade. It was, therefore, not an unmixed blessing. Although, as shown in Appendix "B", a steel trough sleeper was adequate for the load it had to carry under the average conditions of maintenance, yet it was clear from the calculations that it did not have an equal margin of strength or stiffness to meet the unusual conditions which do arise if the maintenance of track remains neglected for sometime.

Mr. Kohli had stated that ever since the introduction of the elastic theory, it had been believed that the wheel had a slightly undulatory movement. If Mr. Kohli were to refer to page 10 of the Railway Board Technical Paper 245, the first Indian Publication on the subject, he would find stated in para 2 that "that the wheel runs in a strictly horizontal path".

Mr. Kohli appeared to believe that a further research to determine the accleration of wheel loads was unnecessary and that the formula

$$\frac{V}{\sqrt[3]{u}}$$

was satisfactory for design purposes, as according to him, tests showed that the actual stresses were in close agreement with the calculated stress based on this speed effect formula. This had been shown to be far from the truth by the researches of Gelson and

Blackwood. If Mr. Kohli were to refer to page 111 of their Technical Research Report, he would find that as a result of their experiment, they suggested different formulae for speed effect for determining the sleeper reaction and for calculating the rail stresses. This research, of course, had indicated what lines further investigations should take.

Bending moments in a sleeper calculated on the assumption of a uniform distribution of the load erred on the side of safety. On the basis of the elastic theory, it could be shown that the ballast underneath the rail carried greater load than that away from it. There was, therefore, no harm in simplifying the calculations by assuming a uniform distribution of loads.

Mr. Kohli had criticised the Author's method of calculation of safe axle loads for different rail sections and had suggested an alternative method of calculation on the basis of equal stresses in different rails. This latter method of calculation would be preferable, if in an ordinary track, the rail was the weakest link in the track structure which consisted of the rail, the sleeper, the ballast and the sub-grade. It was a well known fact that the average life of a rail was more than 60 years; whereas the wooden sleeper had a life of about 15 years. Moreover, the section of the wooden sleeper was the same for a 75 lb. rail, 90 lb. rail or even for a heavier rail. The same remark applied to C. S. T. 9 sleepers for 90 lb. or a 75 lb. rail. It was, therefore, reasonable for determining the safe axle loads, to assume that sleepers under both sections of rails should carry the same load. The sleeper re-action is equal to u yo s. As u and s are inversely proportionate to each other, for equal sleeper re-action yo should be equal for all axle-loads. Further, as the permissible axle-loads for different rail sections determined by the Author's assumption were lower than those determined by Mr. Kohli's method, it would be safer to accept the Author's figures. The Author agreed with Mr. Kohli that the exact distribution of load under the bearing plate was indeterminate. Under such circumstances, to make the problem determinate, it was reasonable to assume that the bearing plate was in intimate contact with the sleeper along its entire bearing surface.

Mr. Lall's views about the demerits of the spot renewals, it would appear, were unfortunately derived from a study of the North Western Railway Headquarter's file and were not based on his personal experience. The difficulties about the marking of the unserviceable sleepers were not unsurmountable. The argument about the illiteracy of the Indian labour standing in the way of adopting the American practice of spot renewals or the English practice of "shoval packing" had been repeated much too often. The same argument was advanced at the advent of reinforced concrete construction in this country. Wise men shook their heads and said that it would be unsafe to trust the Indian labour with this new material of construction. Experience had happily been otherwise.

Even now the unserviceable sleepers on the main line were being replaced casually by second hand sleepers, but nobody had made a song out of the inconvenience brought about by the change as Mr. Lall had done with regards to spot renewals.

The entire wooden track was now being laid on the North Western Railway with a certain number of C. I. anchor bearing plates and such track was being laid with a 1/16″ slack gauge. This practice was based on the assumption that the shrinkage of wood would not exceed 1/16″. This shrinkage could further be reduced by proper seasoning of wood by the modern methods recommended by the Author.

It was an accepted fact that sleepers, even when new, varied considerably in strength. Through renewals, therefore, did not ensure uniformity in the strength of the track. Again, it would be quite safe if a new sleeper renewed at random had to carry a greater load than its older neighbours, as it was best fitted to do so. The Author recommended that spot renewals should be started at a stage when the number of unserviceable sleepers began to exceed 10% in any length of track.

Mr. Lall had stated that the steel track was quieter than a wooden road. The Author with certain other Officers had gone over different lengths of steel road as well as over those of wooden road on his Division and it was unanimously agreed that a wooden track was quieter of the two. The noise on a steel trough road accentuated by the resonance was appreciably greater than that produced on a wooden road. Although the steel trough sleeper did not generally initiate any noise under traffic; whereas the rattling of bearing plates on a wooden track contributed to it, yet it appeared that the wood seemed to deaden the noise to some extent and that the steel trough sleepers had had the opposite effect.

Mr. Lall had emphasised the importance of packing the keel below the North Western Railway C. I. Plate Sleepers; whereas the Track Sub-Committee (*vide* para 23 of their second report) had stated that if the packing became consolidated under the keel, the sleeper was apt to ride on it and rock under traffic. To prevent this rocking tendency, the Eastern Bengal Railway had used these sleepers after chamfering the keel to the 'V' shape, so that the packing underneath could never consolidate under it.

The kinks noticed on the C. S. T. 9 track were, as suspected by Mr. Lall, due to initial kinks in rails. In about 1,000 miles of track laid with this type of sleepers on the East Indian Railway, this defect had never been noticed.

The Author's remarks regarding the boxing up to the top of the tie-bars referred to the class of sleepers where the tie-bar was located above the plate. In such cases, the boxing up to the top of the tie-bar would bring it to just below the foot of the rail.

It appeared that Mr. Lall had misunderstood the exact significance of the comparative cost figures of the through packing and of overhauling of different types of sleepers. The relative cost figures of overhauling were not in any way related to the cost figures of through packing. They indicated relatively the cost of overhauling of different types of sleepers, assuming the cost of overhauling of C. I. Plates of North

Western Railway type being unity. Similarly, the figures for through packing of different types of sleepers were on the assumption of that of North Western Railway C. I. Plates being unity.

If the non-removable two-way key was used, as suggested by Mr. Lall, it would make the rail renewal or replacement very difficult and would considerably increase the cost. In such cases, the sleeper packing would have to be completely removed and such a course was not therefore considered advisable.

Mr. Dhall had admitted that India had inexhaustible forests but a large number of them were inaccessible. He had stated that the opening up of these forests for utilising their timber was at present unjustified economically. The Author's view was that it was fully justified as Mr. Dhall had admitted that the supply of wood sleepers was rapidly dwindling. The policy of haphazard cutting down of forest trees in the beginning without a corresponding organised effort at afforestation was the cause of this. Although afforestation had now been started on a scientific basis, it would have its full effect after 20 or 30 years, hence the only course left open at present for increasing the supply of timber was to improve the means of communication to inaccessible forests. Available timber supplies would increase considerably and the prices of timber would surely fall. What the Railway would save on the purchase of sleepers would go towards paying the cost of improving the means of communication. Further such improvements to the means of communications would develop the mineral resources of the country and many other indirect benefits would accure. It will, however, be desirable for the State to subsidise such schemes.

The Author had recommended the use of boxed heart in sleepers while at the same time he had recommended the adoption of improved means of seasoning the wood and proper impregnation of the boxed heart by preservatives. If these recommendations were put into practice, Mr. Dhall's objection to the use of boxed heart sleepers would disappear.

Mr. Dhall had given no reasons against increasing the percentage of sap wood in deodar and sal sleepers. He had contented himself by saying that he would wait to see the behaviour of treated deodar sleepers in track before recommending any change in the existing specifications. Against permitting an increased wane, Mr. Dhall had contended that the present 9″ bearing plate could not then be used with such sleepers. The obvious solution was that the bearing plates should be redesigned to have a width of 7″. The Author had shown on page 23 of his Paper that from considerations of the crushing strength of wood, a bearing area of 50 square inches was all that was necessary for a bearing plate. He however, recommended that the use of bearing plates about 7″ (dimension parallel to the rail) by 10″ with two keys securing the rail to it. The reduced bearing width of the rail seat would be an improvement on the existing design of the bearing plate as had been mentioned by the Author on page 11.

It was heartening to note that Mr. Dhall was in agreement with the Author's recommendation for raising the economic order of wood sleepers.

Regarding Mr. D. N. Chopra's comments, the Author was constrained to say that the former had apparently drawn his conclusions from his experience of the North Western Railway only. For example, more rapid corrosion of steel trough sleepers than that of C. I. Sleepers could be seen easily in areas where the climate was moist or where the sleepers were exposed to a marine atmosphere.

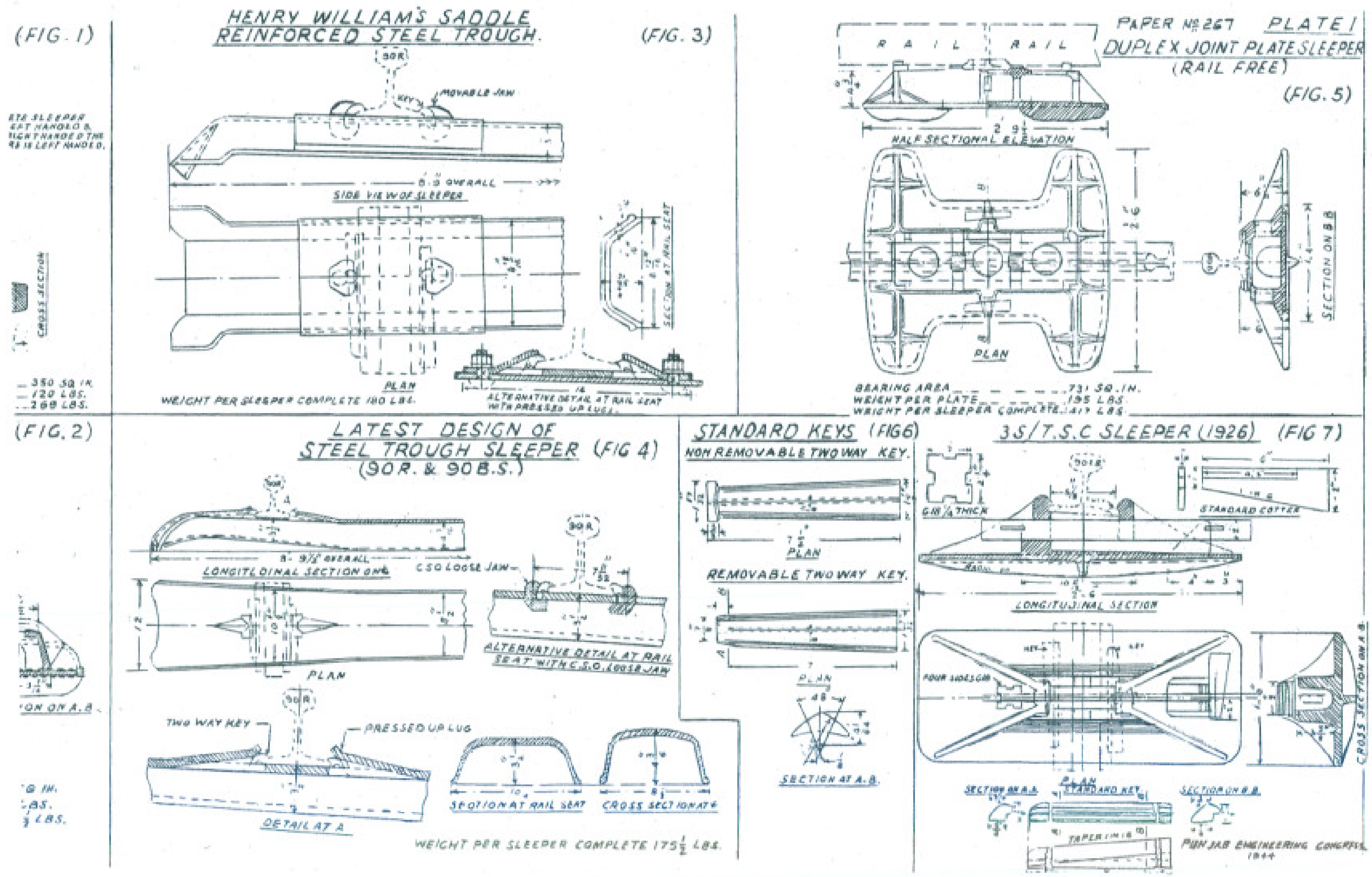
Good running on a newly renewed wooden track could generally be obtained within a couple of months after the renewals and not after two years, as stated by Mr. Chopra. On the other hand, the steel trough road would certainly take about two years after the renewals to consolidate. These are well-known facts which any P. W. I. would confirm.

Mr. Chopra was of the view that the varieties of timbers used for making sleepers in Germany, France, Canada or America were decidedly superior to those obtained in India. This impression was as unfortunate as it was incorrect. This was due to the fact that most of the Engineering literature which Indian Engineers read was written by European or American authors who mentioned all the qualities of the European timbers like oak, beech, etc., but did not say a word about the qualities of the Indian timber like teak, sal, deodar, irul and nangul. As a matter of fact, researches by the Dehra Dun Research Institute had recently shown that India could find out suitable substitutes for all varieties of imported timber.

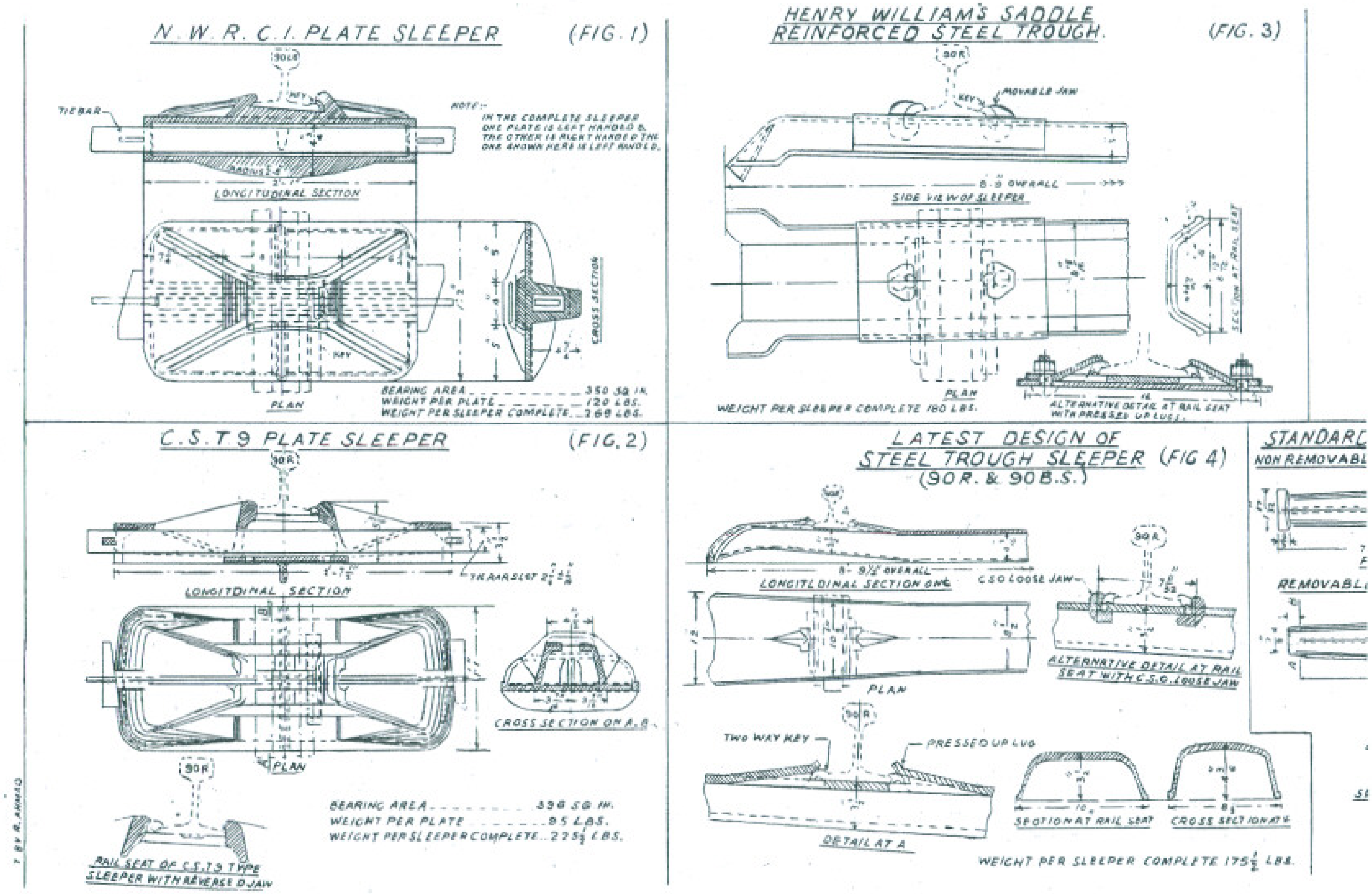
Mr. Chopra wondered why the Author had selected the 1937 life figure for comparison of the annual costs of Sleepers. This was purely for the purpose of illustration. The Author had further shown how his conclusions would be modified if the annual costs were based on 1943 life figures with the prevailing prices in 1937. For comparision of annual costs the price figures of 1943 should not be used due to the abnormal conditions prevailing in the market on account of the war.

Mr. Sims, it appeared, preferred a through type sleeper to a block sleeper. He did not seem to like the C. S. T. 9 sleepers though he agreed that this was the best of all the C. I. Sleepers designed so far. In this connection it would be interesting to mention that this type of sleeper had been very extensively used on the East Indian Railway and to some extent by other Indian Railways, and had given complete satisfaction.

Mr. Sims had stated that he could not possibly accept the dispersion of sleeper pressure through the ballast at an angle of 45° from the lower edge of the sleeper. The Author hoped that Mr. Sims at least agreed that dispersion of lead did take place through the ballast and that he did not deny its existence altogether. Whether the angle of dispersion was 45° or more could then be decided.



(FIG. 1)
HENRY WILLIAM'S SADDLE REINFORCED STEEL TROUGH.
(FIG. 3)
MOVABLE JAW
SIDE VIEW OF SLEEPER
PLAN
WEIGHT PER SLEEPER COMPLETE 180 LBS.
ALTERNATIVE DETAIL AT RAIL SEAT WITH PRESSED UP LUGS.
SECTION AT RAIL SEAT
CROSS SECTION
PAPER No 267 PLATE I
DUPLEX JOINT PLATE SLEEPER (RAIL FREE)
(FIG. 5)
RAIL
HALF SECTIONAL ELEVATION
PLAN
SECTION ON B.B
BEARING AREA 731 SQ. IN.
WEIGHT PER PLATE 195 LBS.
WEIGHT PER SLEEPER COMPLETE 417 LBS.
(FIG. 2)
LATEST DESIGN OF STEEL TROUGH SLEEPER (FIG 4) (90R. & 90B.S.)
LONGITUDINAL SECTION ON C
C.S.O. LOOSE JAW
ALTERNATIVE DETAIL AT RAIL SEAT WITH C.S.O. LOOSE JAW
PLAN
TWO WAY KEY
PRESSED UP LUG
DETAIL AT A
SECTION AT RAIL SEAT
CROSS SECTION AT C
WEIGHT PER SLEEPER COMPLETE 175½ LBS.
STANDARD KEYS (FIG 6)
NON REMOVABLE TWO WAY KEY.
PLAN
REMOVABLE TWO WAY KEY.
PLAN
SECTION AT A.B.
3S/T.S.C SLEEPER (1926) (FIG 7)
STANDARD COTTER
LONGITUDINAL SECTION
FOUR SIDES GIB
PLAN
CROSS SECTION ON A.B.
SECTION ON A.B.
STANDARD KEY
SECTION ON B.B.
PUNJAB ENGINEERING CONGRESS 1944



N. W. R. C. I. PLATE SLEEPER (FIG. 1)
TIE BAR
KEY
NOTE:- IN THE COMPLETE SLEEPER ONE PLATE IS LEFT HANDED & THE OTHER IS RIGHT HANDED THE ONE SHOWN HERE IS LEFT HANDED.
LONGITUDINAL SECTION
CROSS SECTION
PLAN
BEARING AREA .......... 350 SQ. IN.
WEIGHT PER PLATE .......... 120 LBS.
WEIGHT PER SLEEPER COMPLETE .... 269 LBS.
HENRY WILLIAM'S SADDLE REINFORCED STEEL TROUGH. (FIG. 3)
90R
MOVABLE JAW
KEY
8'-0" OVERALL
SIDE VIEW OF SLEEPER
SECTION AT RAIL SEAT
PLAN
ALTERNATIVE DETAIL AT RAIL SEAT WITH PRESSED UP LUGS.
WEIGHT PER SLEEPER COMPLETE 180 LBS.
C.S.T 9 PLATE SLEEPER (FIG. 2)
90R
LONGITUDINAL SECTION
CROSS SECTION ON A.B.
PLAN
RAIL SEAT OF C.S.T.9 TYPE SLEEPER WITH REVERSED JAW
BEARING AREA .......... 336 SQ. IN.
WEIGHT PER PLATE .......... 85 LBS.
WEIGHT PER SLEEPER COMPLETE .. 225½ LBS.
LATEST DESIGN OF STEEL TROUGH SLEEPER (FIG 4)
(90 R. & 90 B.S.)
8'-9½" OVERALL
LONGITUDINAL SECTION ONE
C.S.O. LOOSE JAW
PLAN
ALTERNATIVE DETAIL AT RAIL SEAT WITH C.S.O. LOOSE JAW
TWO WAY KEY
PRESSED UP LUG
DETAIL AT A
SECTION AT RAIL SEAT
CROSS SECTION AT ¢
WEIGHT PER SLEEPER COMPLETE 175½ LBS.
STANDARD
NON REMOVABL
REMOVABL