JOINT MEETING WITH THE INSTITUTION
OF MECHANICAL ENGINEERS.

16 December 1941.

PROFESSOR C. E. INGLIS, O.B.E., M.A., LL.D., F.R.S.,

President Inst. C.E., in the Chair, supported by

Mr. WILLIAM ARTHUR STANIER, President Inst. Mech. E.

Discussion on

“Hammer Blow in Locomotives”¹

and on the

“Balancing of Locomotive Reciprocating Parts.”²

Sir Harold Colam, in reply, observed that he wished to express his appreciation of the remarks of the President and of the theoretical support he had given to the Authors' deductions from experimental results. It was just 40 years since Sir Harold had attended a series of lectures given by the President on the balancing of engines, and though most of it was speedily forgotten the notes were carefully preserved and twenty years later had come in useful. Therefore it was to the President that he had naturally turned in 1928 when looking for some sympathetic ear to listen to his heretical views on overbalance in locomotives, and he had found, to his relief, that the President had come more or less to the same opinions as the result of the facts disclosed by the investigations of the British Bridge Stress Committee.

Mr. Stanier had expressed doubt whether the railways in India knew what balance weight they actually put in. If he was referring to the engines as delivered from the manufacturers his doubts were well founded, as had been made clear by the facts recorded in the Paper, at all events as regards the older engines turned out before real attention began to be paid to balancing. If, however, it was his intention to suggest that the experiments on the Madras and Southern Mahratta Railway were of little value

¹ Sir Harold N. Colam and Major J. D. Watson, R.E. “Hammer Blow in Locomotives: can it not be abolished altogether?” *Journal Inst. C.E.*, vol. xvii (1941-42), p. 197 (Jan. 1942).

² E. S. Cox, “Balancing of Locomotive Reciprocating Parts.” *Journal Inst. C.E.*, vol. xvii (1941-42), p. 221 (Jan. 1942).

because the Indian engineers could not be sure that they had exactly removed all overbalance, Sir Harold had to join issue with him at once. The static balancing was carried out very carefully, and in those cases where there was no attempt at cross-balancing and the counterweights were supposed to be at 90 degrees out of phase, the method followed would have given fairly accurate results. In any case, what errors there were could not have been large and would naturally be in both directions, so that whereas in some cases the overbalance would not be wholly removed, in other cases it would be more than removed and actually turned into an underbalance. Assuming such errors to have been made, it was pertinent to point out that the subsequent experience with those underbalanced engines should be accepted as even stronger support of the general thesis of the Paper, namely that overbalance was unnecessary within the limits of weight and speed concerned. It had also to be remembered that even before the experiments started there was ample evidence that many engines with underbalance had been giving satisfactory service for years, both in India and in England.

In face of the evidence collected by the British Bridge Stress Committee Sir Harold confessed that he did not understand Mr. Stanier's statement that British railways at least knew what overbalance they put in. A few years ago they certainly did not. It might be pointed out also that for about the past 10 years the wheels of new engines delivered to India had had stamped on them the radius passing through the centre of gravity of the counterweight, and its moment in inch-pounds, both determined before the wheels were pressed onto the axles. There was little room for error in those cases, and the practice might be recommended as part of the regular inspection at the works.

It was advisable to emphasize that although the evil effects of hammer-blow had been shown up in India and England by bridge engineers, they were of even greater importance in permanent way, as had been shown clearly by the long series of investigations into stresses in railway track made in America. It was a great pity that those investigations were not better known, but unfortunately they had been recorded in many voluminous and rather formidable reports spread over many years and not easily available. A few references to them had been made in the discussion. Mr. Train's remark that mechanical engineers would be astonished at the high stresses that could be caused in rails was very true: they were so high that most people would not believe them unless they had seen the original evidence. Stresses very near to the safety-line were found often, and stresses beyond that were not uncommon. Mr. Robertson had expressed the opinion that hammer-blow did not increase rail stresses unduly, and that the calculations of those stresses were mainly speculative and had not led to any major improvements. Sir Harold begged leave to differ on all three points. Stresses in rails caused by hammer-blow were not small and their elimination was of the greater importance when the

total stresses were already dangerously high. If Mr. Robertson would refer to Technical Paper No. 245 published by the Indian Railway Board in 1925, he would, Sir Harold thought, agree that, given the track and engine data, the calculated stresses were remarkably near the observed stresses. Certainly the latter had been astonished when he made the calculations. Further, amongst improvements directly arising out of those investigations was the trailing bogie in place of the trailing axle in nearly all modern heavy engines in the United States, it having been shown by calculation and verified by observation that the trailing axle was responsible for more trouble than any other owing to its relatively great distance from adjacent axles.

The President's mathematical analysis of the probable effects of totally unbalanced reciprocating masses in reasonably heavy engines had led him to conclude that neither the resulting swerving couple nor the variation in drawbar pull, including resonance, would be of any importance. Mr. Cox, using a different method, agreed as to the swerving couple, but concluded that variation in drawbar pull would be too great for comfort and that consequently part of the reciprocating masses should be balanced. His conclusions as regards drawbar pull were shown in *Fig. 11* (page 239, *ante*) for a particular case. That showed a *calculated* maximum variation of ± 0.5 ton due to lack of overbalance at about 10 miles per hour. Sir Harold would suggest that that was of no importance whatever, seeing that a variation five times as great occurred, and was bound to occur, at a still lower speed owing to steam-thrust, and that all that mattered was the variation at the higher speeds, at which the engine spent by far the greater part of its working life, at all events in those cases where comfort was of any real importance. In the particular case the maximum was calculated to be about ± 0.35 ton for the unbalanced engine, which Mr. Cox considered to be too great because it exceeded the arbitrarily selected desirable maximum of ± 0.2 ton. Sir Harold considered that a good deal remained to be done before the figures given there could be accepted as justification of the statement that an overbalance of 50 per cent. was necessary in that case. It remained to be decided which of the two mathematical methods yielded the more correct results (which should not be difficult); more work was required before the desirable maximum could be fixed, in view of the cost of fixing it too high; and it was by no means certain that the same maximum was suitable for all cases.

It was interesting to note that the facts given by Mr. Cox on pages 244 and 245, *ante*, supported the conclusions arrived at from much more extensive experience in India, namely that leaving the reciprocating masses unbalanced did not lead to greater wear in the axle-boxes and moving parts. The theoretical demonstration on pages 204-206 indicated that there was no reason to expect it, and it was to be hoped that that ancient objection to removing overbalance would now die a well-deserved death.

Several references had been made to rough riding in light locomotives with no overbalance. Neither Sir Harold nor Major Watson had ever suggested that such engines should be totally unbalanced. Their Paper was expressly concerned with "modern" engines: it might have been better to make it quite clear that that meant "heavy" engines.

General answers to the question of how much extra load civil engineers would allow in return for a reduction of hammer-blow would be found in the British and Indian Bridge reports and in those on stresses in railway-track in America and India. No general answer, however, was of any practical use and the specific answer would depend upon local circumstances—the engines, bridges, and track concerned. As an example of what had been possible, on the Madras and Southern Mahratta Railway 17-ton axles were increased to 18-ton on the broad gauge; and on the metre-gauge 8.3-ton axles were increased to 8.7-ton in some places and 54-ton engines were allowed where 44 tons had been the maximum before. Those increases were not at all spectacular and were merely what had been asked for by the Operating Department, the available engines being what they were. In Sir Harold's opinion, they were much lower than could be allowed if required. There could be little doubt that with less of the rather extreme caution that had been allowed to clog the wheels of progress, material increases in static axle loads could be allowed. In that connexion he wished to draw attention to the diagram on page 219, *ante*, giving the total static and dynamic axle loads at normal maximum speed. That was the only form of diagram worth having, and it was to be hoped that the older form showing static loads only would soon be dead and forgotten. When he first began to collect data and record them in that way he came across a startling example of the uselessness of the older form in the first two cases. They were from different railways but by current notions were almost identical, with static wheel loads just under $8\frac{1}{2}$ tons. But at normal maximum speed (the same for both) one had a total wheel-load—including hammer-blow—of about $9\frac{1}{2}$ tons, whilst the other had no less than $14\frac{1}{2}$ tons. Yet the existing rules took them to be practically identical when deciding where they could and could not run. It was difficult to imagine anything more absurd.

It was important to realize that what could be given in return for reduction of hammer-blow was by no means the only consideration. It was within Sir Harold's personal experience—and it was very unlikely that it was unique—that enormous sums of money had been spent on renewing bridges that would not withstand the punishment from the hammer-blow of the heavier engines which it was desired to introduce. There could be no question that most of that could have been avoided by the simple expedient of cutting the hammer-blow down or eliminating it altogether. That kind of waste would go on until it was realized—as it surely would be—that it was sinful.

Summing up the case of the heavy two-cylinder engine :—

1. The President calculated that leaving the reciprocating masses unbalanced would have no untoward effects.

2. Mr. Cox agreed as to swerving couple, but calculated that the variation in drawbar pull would exceed the maximum admissible, which he placed at ± 0.2 ton. It had still to be decided which method of calculation was the more accurate, and it was by no means certain that the selected maximum was as high as it might be, or that it should be the same in all cases.

3. Actual experience on the Madras and Southern Mahratta Railway, extensive both in numbers and in time, had satisfied the engineers that overbalance could be cut out altogether within the limits of weight and speed concerned.

4. Mr. Cox, so far as he had any direct evidence, agreed that increased wear did not result.

5. Recent experience had revealed that hammer-blow could—and in some cases did—lift the wheel clean off the rail, from which it followed that wheels might often be, quite unexpectedly, in a dangerous state of near-levitation.

6. Elimination of hammer-blow meant elimination of damaging stresses, much wear and tear, and considerable expenditure; and could also result in increased operating efficiency.

It was hardly to be expected that all Locomotive Engineers would accept the heretical thesis propounded in the Paper. The Authors would be satisfied if some did and if that led to further experiments on the lines followed on the Madras and Southern Mahratta Railway, and they would await the results with confidence.

Major J. D. Watson, in reply, observed that he wished to associate himself with Sir Harold Colam's remarks, which, owing to the present circumstances and to Sir Harold's absence in India, had been made without close collaboration between the Authors. He considered that the discussion had substantiated the Authors' contention that a *prima facie* case for abolishing overbalance had been established. Mr. Train had asked for details of the deflectometer that had been used for the trials made on the Madras and Southern Mahratta. Those had been called for from India and would be forwarded to Mr. Train when they arrived.