NOTES INTRODUCING SUBJECTS FOR DISCUSSION.

SECTION I.—RAILWAYS.

"The Design of Permanent-Way and Locomotives for High Speeds."[1]

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THE impact on permanent-way arises necessarily from two sources: the condition of the permanent-way itself; and the design of the locomotives. The increase in the train-mileage, at any rate on British Railways, is mostly on long-distance traffic. This generally means heavy trains hauled at a relatively high speed, and heavy axle-loads.

Permanent-Way.—The strength of the permanent-way and the condition of the road-bed are of the first importance; for when the permanent-way is of too light construction, or the road is improperly packed and badly drained, there can be no satisfactory running at high speed. Indeed the increase in high-speed traffic entails a more imperative necessity than heretofore to give greater attention to these matters, as well as to the alignment of the lines, and to the super-elevation of the outer rail in curves.

The next point is equally important: namely the maintenance of a standard of width gauge. Instances have occurred of new road laid in straight line, where the sleeper had not been adzed, and the chairing had been done by hand, and it was consequently found that the gauge varied to the extent of $\frac{1}{8}$ inch to $\frac{3}{16}$ inch. Although the permanent-way was of a heavy section, the joints good, and the packing and ballasting properly done, the running was so far from satisfactory that the whole length so laid was re-gauged. Then the traffic was again sent over it at high speed, with the result that the engines and carriages ran much more smoothly.

Reduction of impact at switches and crossings, and smooth running through junctions, are largely brought about by attention to the following five points: making curves of easy radii; using

[1] *The Engineer*, vol. xcv., p. 616. *Engineering*, vol. lxxv., pp. 821 and 830.

long enough switches; avoiding short rails; keeping accurately to a uniform gauge, especially along levels; restricting the speed on curves. As crossings and junctions are so frequent on railways in Great Britain, attention to these points goes a considerable way towards the attainment of smooth running. Swinging and swaying arise chiefly from a sudden change of curvature; and, as this depends on the laying-out of the line and on the land at the disposal of the railway, it cannot be altered much on existing railways. On new lines there is in general no reason why the disadvantage of sudden change of curvature could not be met in originally laying out the line. On railways with express trains running up to 60 miles per hour, no curves should be of less than 40 chains ($\frac{1}{2}$ mile) radius. Although on many routes with high-speed traffic the curves are sharper, the Author considers that a speed of 60 miles per hour should be avoided on curves of less than 40 chains radius. Wherever possible the length of straight line intervening between reverse curves should be equal to at least the length of a train, say 700 feet.

The foregoing short enumeration of the main elements in a road which make for reduction of impact, and consequently for smooth running, shows how fully it is recognized that the result aimed at is in no small degree influenced by the design and maintenance of the road. In Appendix 4 of the Report of the Committee appointed by the Board of Trade to inquire into the vibration produced by the working of the traffic on the Central London Railway, the following conclusion is stated in p. 10, as the result of a mathematical investigation of the wheels and rails with respect to the action of the road and to the irregularities of the surfaces in contact:—"If the unstrained rail has an uneven surface, or if there is want of uniformity in its supports, then the stiffer the rail, the smaller will be the amplitudes of the vibrations in the ground, and the greater their frequencies." In ordinary language, the heavier the rail, the smoother will be the running at high speeds over a road kept up to a defined standard of excellence—a principle which is resulting, at any rate in this country with the chair-road, in the adoption of rails weighing 90 lbs. to 100 lbs. per yard.

Locomotives.—From the condition of the permanent-way cannot be separated the design of the locomotives to run upon it. Certain classes of locomotives, when driven at high speed, oscillate laterally and vertically to a dangerous extent, even on a good road; and the only way to obviate their oscillation is to reduce the speed. Locomotives having four front wheels coupled and a trailing bogie under the footplate—4-4 American notation—are a specially undesirable class for running at high speed: as exemplified by the Doublebois accident on the Cornwall Railway on 13 May, 1895, when two such locomotives taking a fast passenger-train left a practically new road, laid with bull-headed rails, and having easy curves. Engines with single driving-wheels, and only one axle in front and one behind, are likewise unsatisfactory: they plunge considerably at high speeds, even on good roads. In this respect there can be no doubt that the introduction of the leading four-wheel bogie, giving a longer wheel-base, is the greatest improvement which has yet been carried out; and, with the increasing weight on the driving-wheels, it is considered necessary for securing steadier running and easy passing round curves. In such engines drivers have much greater confidence. Recently, owing to the increased loads and the consequent desire to obtain greater adhesion and tractive force either by additional coupling or by additional weighting of the coupled wheels, the "pony" radial axle has been introduced; but it yet remains to be found whether for fast running the pony axle has the advantages of the four-wheel bogie. The Author thinks it has not, and that the bogie-wheels are undoubtedly safer at diamond-crossings in curves. The equalization of weights over four points, as effected by the bogie, he considers is by far the best plan: it reduces impact, and is so important that it should not be given up, even to save a few feet in length of engine-framing.

The introduction of compensating-levers, for equalizing the weight on the pair of leading-wheels with that on the front driving-wheels, has much to recommend it, although it seems that it cannot so satisfactorily equate the varying weights as does the ordinary four-wheel bogie. The latitude thereby given to the driving-wheels is theoretically not desirable, because the object of all steadying arrangements is to ensure that the front end of the engine shall creep and not jump, and shall so prepare the way for the driving-wheels to exert their full effect. The steadier the driving-wheels are kept, the greater will be their efficiency; and consequently the less will be the wear and tear of the road. This principle ought to underly all locomotive building; and the Author therefore thinks the provision for steadying a locomotive should be separate entirely from that for driving. For the same reason, the more completely the pairs of driving-wheels are equalized between themselves, the greater will be their adhesion and tractive force. The extent to which equalization is carried in America is shown in Mr. Cowan's Paper[1] on "American Locomotive Practice," read at the Institution last Session. What is wanted for the sake

[1] Minutes of Procee ngs Inst. C.E., 1903, vol. cliv. p. 38.

of the permanent-way is that the locomotives shall run with a creeping motion, not with a hopping or plunging gait; they will then also cost less to maintain.

At high speed, one advantage of the four-wheels-coupled engine over the single-drivers is that the counterbalancing can be spread over four wheels in place of two. No doubt the principal reason why it is so difficult to build a single-driving locomotive which shall run smoothly, even with the advantage of a bogie in front, is that the whole of the counterbalancing has to be done on the single pair of wheels. Several railways in Great Britain have tried compound locomotives with three and four cylinders; and the Great Western Railway is awaiting delivery of a French compound engine, having four coupled wheels with four-wheel leading-bogie and trailing-axle, from the makers of those running on the Northern Railway of France. Great hopes are entertained that the construction of this engine, with its four cylinders, long wheel-base, and weight concentrated more towards the middle of its length, will result in a further equalization of the counterbalancing, and so conduce to smooth running. Trains drawn by compound engines in other countries are not free from oscillation; but from many inspections the Author is inclined to attribute their unsteadiness to shortcomings in the road, and not to the build of the engines.

Recent practice has tended in the direction of raising the centre of gravity of the locomotive; but, although theoretically locomotives with a high centre of gravity are first-class machines if running on a perfect road, it may be suggested that this practice has its limit, and that the limit is now reached under present conditions, for the reason that any imperfection in the alignment of the road has a correspondingly increased effect at high speed in developing in the engine a swaying motion sideways, which is more intense and more lasting than in locomotives with a lower centre of gravity. From the foregoing it may be gathered that a practical disadvantage is found to arise from such engines having to run round curves through yards and junctions, where the full cant necessary for the speed at which the train is running cannot be obtained.

The following speakers took part in the discussion of the subject:—Messrs. J. W. Jacomb-Hood, L. B. Wells, J. F. McIntosh, F. A. Lart, W. R. Galbraith, and S. W. Johnson; and Mr. G. H. Sheffield, who was unable to be present, communicated his views in writing. In the absence of the Author Mr. G. E. Louth replied to the discussion.