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THE
Railway and Marine World

With which are incorporated The Western World and The Railway and Shipping World, Established 1890

Devoted to Steam and Electric Railway, Marine, Grain Elevator, Express, Telegraph, Telephone and Contractors' interests

Old Series, No. 215.
New Series, No. 133.

TORONTO, CANADA, MARCH, 1909.

For Subscription Rates, See page 197.

Entered as second-class matter, March 5, 1908, at the Post Office at Buffalo, N.Y., under the act of Congress of March 3, 1879.

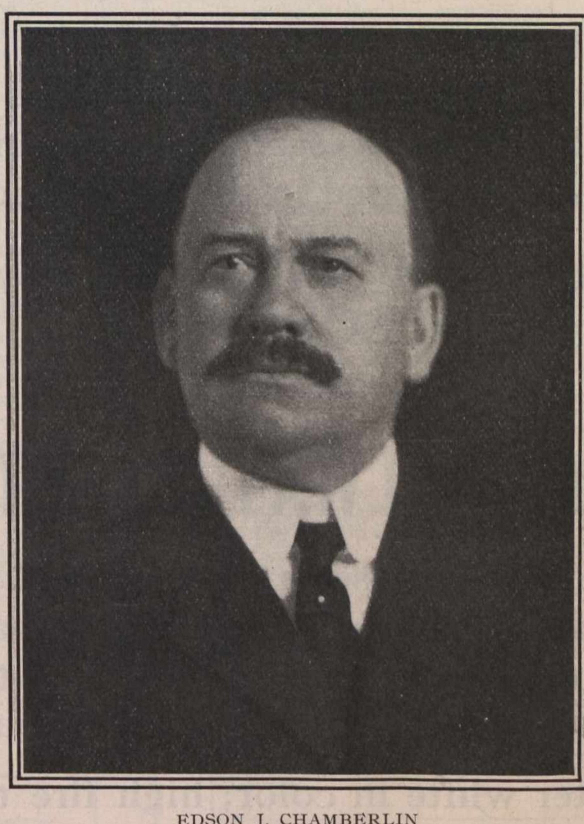
The Hammer Blow from Incorrect Counterbalance.

By *H. H. Vaughan, Assistant to the Vice-President, C.P.R.*

The generally accepted solution of a consideration of the action on the rail of a wheel containing counterbalance is that of a variable pressure between the rail and the wheel equalling the static weight on the wheel, added to or reduced by the vertical force due to the action of the unbalanced weight. Thus in fig. 1 (pg. 159), if OA represents the time of one revolution, BC the pressure between the rail and the wheel due to the weight on the wheel, OB and ODAE the vertical force due to the action of the overbalance, the result and pressure between the rail and the wheel is shown by the line BFG and equals the ordinate of the shaded area at any time.

Should the overbalance be excessive and the speed so high that the vertical force caused by the overbalance exceeds the weight on the wheel, there may be a negative pressure between the wheel and the rail, or in other words, a force tending to lift the wheel, which condition is shown in fig. 2, where the cross hatched portion below OA represents an upward force which tends to lift the wheel and attains a maximum value TP at the instant when the counterbalance is vertically upwards. For a numerical example suppose the weight on the wheel is 20,000 lbs. and the maximum vertical effect of the overbalance is 25,000 lbs. The pressure on the rail will become 45,000 lbs. at the point S, while at T there will be a force of 5,000 lbs. tending to lift the wheel, and that the wheel does lift under the action of this force is well shown from the experiments on the Purdue and St. Louis testing plants. The greatest pressure on the rail occurs when the counterbalance is vertically downwards, and as this in many cases of improperly balanced engines reaches such figures as 50,000 to 60,000 lbs., the damage that has occasionally been caused to the rail, when such engines have run at specially high speeds, has been ascribed to this great downward force. A consideration of the diagrams shows that however great this force may be at this point, its application is entirely gradual, and it cannot possibly partake of the nature of a blow given by a falling weight, however high the speed, as the pressure between the rail and the wheel gradually increases from nothing or a comparatively small amount until it reaches its maximum, and then decreases, and it has therefore become usual to regard the hammer blow, so often mentioned in connection with counterbalance, as a misnomer, and to ascribe the damage that may occur, to the high pressures which exist, rather than to the effect of an actual fall of the wheel on the rail.

In the early part of 1908 a serious case of damaged rails occurred on the C.P.R., the rails being sharply bent for about a mile, on both sides at intervals about equal to the circumference of a driving wheel. The damaged spots were carefully measured over a considerable distance, averaged, and the diameter of the wheel so found corresponded with that of an engine which had



EDSON J. CHAMBERLIN
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made a very fast run over the damaged track the day previous. The wheels of this engine were taken out and the main drivers found to contain an excessive amount of overbalance, actually amounting to about 1,000 lbs. As the weight on these wheels was 22,000 lbs., the force on the rail at the speed estimated varied from 57,000 lbs. to an upward force of 13,000 lbs. A portion of the rail was experimented with in a testing machine, and it was found impossible to bend it in the same manner as had occurred on the track, with different centres of supports and with loads as high as 200,000 lbs. While the cause of the damage was thus located, the method by which it was effected was still not apparent, and a general disbelief in the calculations of the forces caused by the unbalanced weights on the wheels was the natural result. It then occurred to the writer to investigate the action of the wheel when lifted from the rail by the upward force caused by the overbalance, with results that are interesting and to a large extent explain the action which takes place.

The wheel is taken as a mass of 3,200 lbs. weight, pressed down by the spring with a force equal to the static weight on the rail, less its own weight, running on a rigid track and acted upon by the forces caused by the overbalance. As an example, the speed was assumed to be 300 revolutions per minute, the weight on the rail 20,000 lbs. and the force due to the overbalance 25,000 lbs., so that the force tending to lift the wheel attained a maximum of 5,000 lbs. The mathematical discussion which applies to any set of conditions is given below, and the results are shown in fig. 3 for this particular example.

The horizontal dimensions in this diagram indicate the movement of the wheel in degrees, 0° being the position of the wheel when the counterbalance is vertically upwards, while the vertical dimensions indicate to three different scales, the forces acting on the wheel, the velocity of the wheel upwards and its upward movement. Thus, at about — 37½°, or when the centre line of the counterbalance makes that angle with the vertical, the upward force due to the overbalance equals the weight on the wheel, and beyond that exerts an upward force on the wheel, tending to lift it, which becomes a maximum of 5,000 lbs. at 0° and zero again when the counterbalance has moved 37½° past the centre. The wheel then commences to be acted upon by a downward force due to its weight and the force of the spring which becomes greater than the effect of the counterbalance. Since the latter continues to decrease, and at 90° becomes zero, and later in its turn acts downward, this force increases rapidly. Further consideration indicates that the upward velocity of the wheel, zero at — 37°, gradually increases until the wheel has turned to 37°, when its upward velocity is a maximum, since, while the forces acting on it upward have been decreasing from 0°, they have still been acting to increase its upward velocity. As the downward forces become reversed, they first destroy this upward velocity, which becomes zero at about 75°, after which they impress on it an increasing downward velocity until the wheel reaches the rail. To find the point at which this takes place, it is necessary to plot the space line or that showing the movement of the wheel vertically upwards from the rail. This commences with zero