A NEW GENERAL FORMULA FOR TRAIN RESISTANCE.*

The alchemists of old sought diligently for the philosopher's stone, the inventors of a later age for perpetual motion, and engineers of the nineteenth century have been almost as eager to obtain a general formula which shall reconcile all existing data and experiments upon train resistance. The first two objects of effort are now known to be unattainable, and the third has until now baffled the best minds in the railroad profession. Only a month ago Locomotive Engineering, which for years past has devoted special attention to this subject, said editorially: "We do not believe that it is possible to devise a formula that will show an approximation of the resistance due to different kinds of trains at different speeds when train tons are the basis of calculation."

A general formula which appears to be applicable to passenger trains of all weights, running at all speeds up to the highest limits so far reached, has been lately worked out, however, by John Lundie as a result of a long series of tests of trains in actual service, and is here given to the engineering public for the first time. His methods of obtaining data are decidedly different from, and much more satisfactory than those commonly employed hitherto, where indicator cards of engines drawing trains at constant (?) speed on level (?) track have been made the basis (with an arbitrary allowance for engine friction) of estimates of resistance per ton moved. In order to be of any value such tests must be made in long distance runs, and it is almost impossible to find a hundred miles or more of absolutely level track for the purpose, while it is also difficult to obtain perfectly uniform speed even on a dead level. Mr. Lundie's method of determining train resistance is based on an examination of the speed curves of a train when coasting from any speed to a dead stop. The possibilities of such a method will be instantly evident to an engineer, and it may be said, at once, that the results warrant a decided predisposition in its favor. It is not only possible to obtain the gross resistance due to track and journal friction and air resistance combined, but to differentiate between the air and the friction elements. The frictional resistance of a train being reasonably constant within somewhat wide limits of speed, the speed curve should be a nearly straight descending line from full speed to a point somewhere near a full stop. Now the actual speed curve dips below this straight line, as seen in Fig. 2, clearly showing a decreasing retarding force (due to air resistance), with decreasing speed.

In Fig. 1 are shown in graphic form the results calculated from more than 150 runs made by Mr. Lundie with trains of different weights on the South Side Elevated Railroad of Chicago. It will be seen that these results expressed by the location of points on the diagram, cluster around "straight line curves," and that these lines intercept each other, with surprising accuracy, at a single point located at a definite distance above the origin. This indicates, of course, that the first step in obtaining the final formula has been reached, in the establishment of a constant, representing the minimum possible train resistance for all speeds and weights, and it is interesting to note, by the way, that in none of the recorded experiments so far made on passenger or freight trains of all weights has the resistance per ton been less than the figure indicated by this constant—4 pounds.

Mr. Lundie's formula is as follows:

$$R = 4 + S\left(0.2 + \frac{14}{35 + T}\right)$$

where

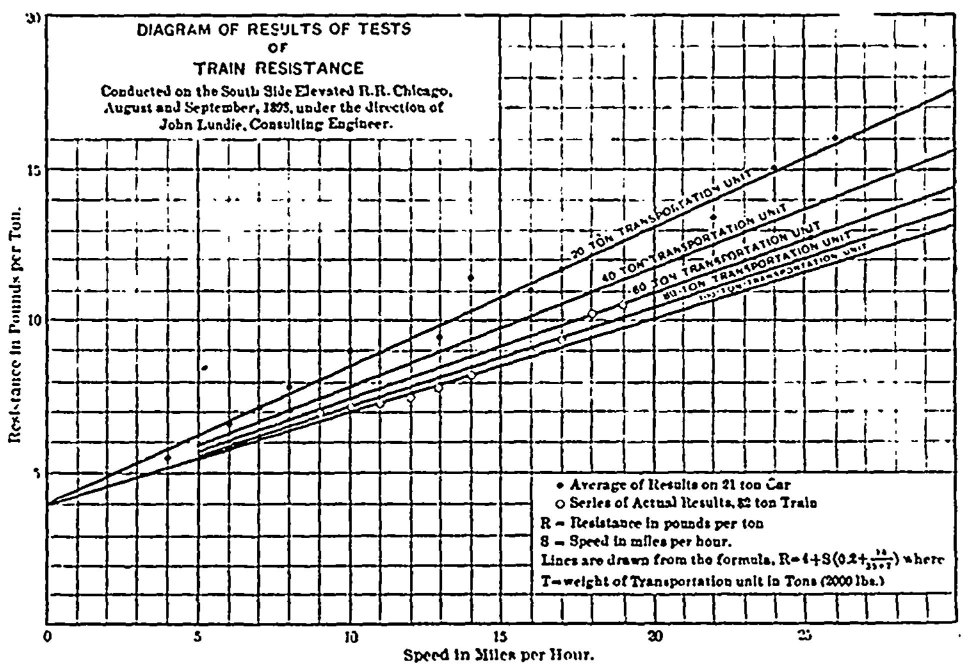
T=the weight of the transportation unit in tons (2,000 lbs.)

R=resistance in pounds per ton.

S=speed in miles per hour.

It will be seen at once that unlike most previous formulae, there are here two variables after the constant, namely speed and train weight. Many other investigators have endeavored to accomplish this, but unsuccessfully, and in the formula which has been in most general use in engineering hand-books, that of D. K. Clark, speed only appears as a variable. From a careful study of his results, Mr. Lundie developed the formula on the following mathematical basis: The expression by which "S" is multipled is proportional to the tangents of the angles made by the lines developed for different weights, as shown in Fig. 1, and is the characteristic of a rectangular hyperbola which (throughout the range of tests made) co-ordinates quite accurately the relations between train weights and the inclinations of the lines mentioned for corresponding weights. The term 0.2 is an intercept on the axis of y; 14 is the constant product of x and y, with the intersection of the asymptotes as origin; and 35 is an intercept on the axis of x.

The test of any formula lies in its application. Gauged by this test, Mr. Lundie's formula unifies in a remarkably close manner nearly all recently published experiments, together with other formulae of more limited application, as will be seen by an inspection of the accompanying table. The Stroudley, Sinclair and Dudley tests of train resistance scheduled in this table were brought together by A. M. Wellington in The Engineering News in 1892, and referred to as intrinsically worthy of confidence on account of the careful manner in which they were made. To these we have added further experiments made on the Philadelphia & Reading Railroad in 1889, and on the Central Railroad of New Jersey in 1892, so that a fairly complete range of train weights from 200 to 400 tons, and of train speeds from 40 to 70 miles per hour is given in the table. The Lundie formula checks up all these tests very closely, though in all but one case the results obtained by its use are slightly



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