

mum speed which a train loaded for a 0.5% grade can acquire on any other grade is given in the intersection of the curve representing that grade with the zero line of tractive power.

Substituting the value of F in Equation 1, we obtain

$$d = \frac{(V_1 - V_2) 2000}{f - 20r}$$

from which plate 5 was plotted.

For short increments of 2.5 miles an hour increase or decrease in velocity, we may, without sensible error, take the average of F at the beginning and end of the increment.

Similar curves have been plotted for trains loaded for 1.0% and 1.5% grades. For other grades, sufficiently accurate results may be obtained by interpolation.

The following example will demonstrate the use of the diagrams: It is advisable, on account of a heavy increase in traffic, to reduce all the grades on a certain section of line to 0.5%. There are at present several 0.75% grades which limit the engine rating, and which must therefore be reduced. One of these is situated as shown in fig. 2, and we desire to

know what length of the 0.75% grade can be surmounted by momentum before the speed of the train is reduced to seven miles an hour.

From the acceleration curves, plate 5, we find that 9,000 ft. on the -0.25% curve corresponds to 28 miles an hour—the speed acquired at the foot of the grade. From the retardation curves, we find that 28 miles an hour on the +0.75% curve corresponds to 2,650 ft., and 7 miles an hour to 7,300 ft. $(7,300 - 2,650) = 4,650$ ft. is the distance which can be surmounted before the speed is reduced to 7 miles an hour, and beyond this point, therefore, the grade must be reduced.

To find the time required to traverse the distance from the acceleration curves we find that 9,000 ft. on the 0.25% curve corresponds to 5.7 minutes. From the retardation curves, 2,650 ft. on the +0.75% curves corresponds to 0.83 minutes and 7.30 to 4.40 minutes. The total time from the station to the point at which the grade must be reduced is therefore $5.7 + (4.40 - 0.83) = 9.27$ minutes.

When a grade is so long that it cannot be surmounted by momentum, but not of such a length that a new line must be built, it will generally be found more economical to reduce

the grade both at the foot and the summit, thus avoiding unduly heavy work at either point. The length to be reduced at the foot or the summit to give the most economical results depends entirely upon the topography of the ground, and can only be determined by a series of trials.

The time lost in operating a momentum grade is seldom so great as to be worthy of consideration in freight transportation, but the exact amount may be directly ascertained from the diagrams, and its yearly value estimated.

Improvements made in the physical features of a line, unless of a very extensive character, affect but little the expense of conducting passenger transportation. To within certain limits, the size of passenger trains is seldom governed by the grades, and time lost in ascending is regained in descending. The tonnage of freight trains, on the other hand, is wholly limited by the ruling grades, and any improvements which may be made in the way of eliminating curvatures and rise and fall, or grade reductions, will decrease at once the cost of handling freight traffic.

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