

should be calculated for increments of increase in velocity of one mile an hour.

The following table has been compiled in this manner for lines with ruling gradients from 0.5% to 1.5%, giving in each case the actual grade to be adopted at the stop, the length of such grade, and the time required to acquire the minimum allowable speed of 7 or 10 miles an hour. For lines with other ruling gradients than those given in the table, the same information may be obtained with sufficient accuracy by interpolation.

Ruling Grade of Line Actual Allowable Grade at Stop	0.50%		0.75%		1.00%		1.25%		1.50%	
	Dist. Feet	Time Secs.	Dist. Feet	Time Secs.	Dist. Feet	Time Secs.	Dist. Feet	Time Secs.	Dist. Feet	Time Secs.
Amount of Reduction...	0.02%	35.3	0.31%	37.5	0.60%	39.2	0.88%	407	1.15%	417
	0.48%	100	0.44%	108	0.40%	999	0.37%	991	0.35%	1064
Minimum Allowable										
Speed...										
7 m. per hour	35.3	67	37.5	71	39.2	75	407	77	417	79
10 m. per hour	75.3	100	83.4	108	999	116	991	124	1064	130

The length of the grade given in the table is the clear distance which the train must have after starting in order to acquire the

necessary speed. At important stations at which the train must stop after leaving the siding to permit of closing the switch, the grade must be lengthened accordingly.

The intelligent and consistent use of momentum grades may prove a great source of economy, either during construction or in improving the grades of old lines. Few railways have been built, even in recent years, in which the quantities might not have been greatly reduced by the adoption of a virtual profile in localities where its use would not have impaired the efficiency of the line. The strict adherence to the maximum gradient, particularly on lines with short undulating grades, which could be surmounted by the assistance of momentum on a grade much greater than the ruling grade, has added greatly to the cost of such lines without a corresponding reduction in the cost of operation.

On lines with long ruling gradients, the saving thus effected may be inappreciable, but it is seldom that such great reductions in the grades of a line are contemplated that from 30 to 50% cannot be operated as momentum grades, whereas, if the ruling grade were strictly adhered to, much heavier work would be necessitated as well as the reduction of many grades from which no advantage is obtained in operation.

In adopting a momentum grade, great care should be taken that it be located only at a point where every assurance is to be had that the train will have acquired the speed necessary to surmount the grade. The method generally followed, of using a grade such that the total rise is equal to that of the same length of ruling gradient, plus the difference between the velocity heads of the train at its initial and final speeds, is greatly in error, assuming, as it does, that the locomotive power over and above that required to overcome the frictional and grade resistances is constant for all speeds. A grade located upon this assumption might be such as to materially limit the engine rating of a whole section, and thus defeat the purpose it was intended to serve.

A momentum grade which could be barely surmounted by one engine with a full load

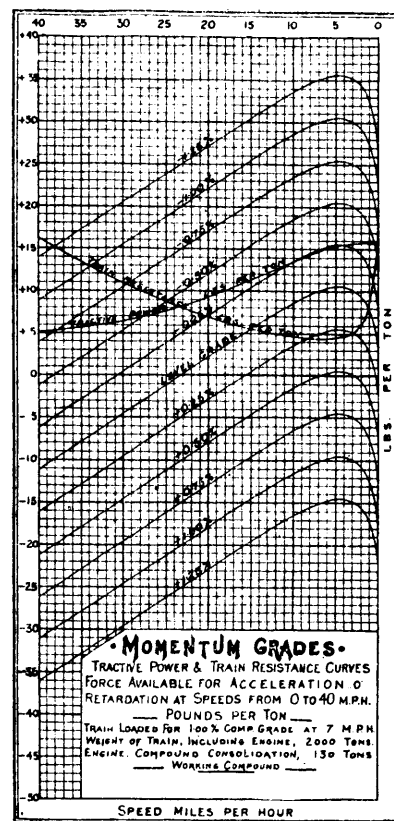


PLATE 4.

between certain initial and final velocities might, within minor limits, be too long for an engine of another class with a different tractive power curve. For this reason, that grade should be adopted which can be surmounted by the most unfavorable class of engine likely to be run on the section. Generally speaking, an engine in which the ratio of the tractive power at low speeds to that at

high speeds, is greatest is the most unfavorable in this respect, and should therefore form the basis of calculation.

$$\text{or } \frac{d}{F} = \frac{(V_1 - V_2) 2000}{F} \dots\dots\dots (1)$$

in which d = distance in feet through which train moves between the limits of velocity.

F = average force available for acceleration or retardation in lbs. per ton.

V_1 = Velocity head at initial speed.

V_2 = Velocity head at final speed.

The cylinder power is exerted to overcome frictional and other resistances and the grade resistance. The force F is therefore the algebraic difference between the tractive power per ton and the total resistance per ton.

$$\begin{aligned} F &= (t-r) - 20 R \\ &= f - 20 R \dots\dots\dots (2) \end{aligned}$$

in which t = tractive power per ton at any given velocity.

r = resistance other than grade, per ton, at any given velocity.

R = rate per cent. of grade

$$f = (t - r)$$

From this equation, plate 4 was plotted, which gives the net force available for acceleration or retardation on grades from + 1.25% to - 1.25%, at speeds from 0 to 40 miles an hour. The maxi-

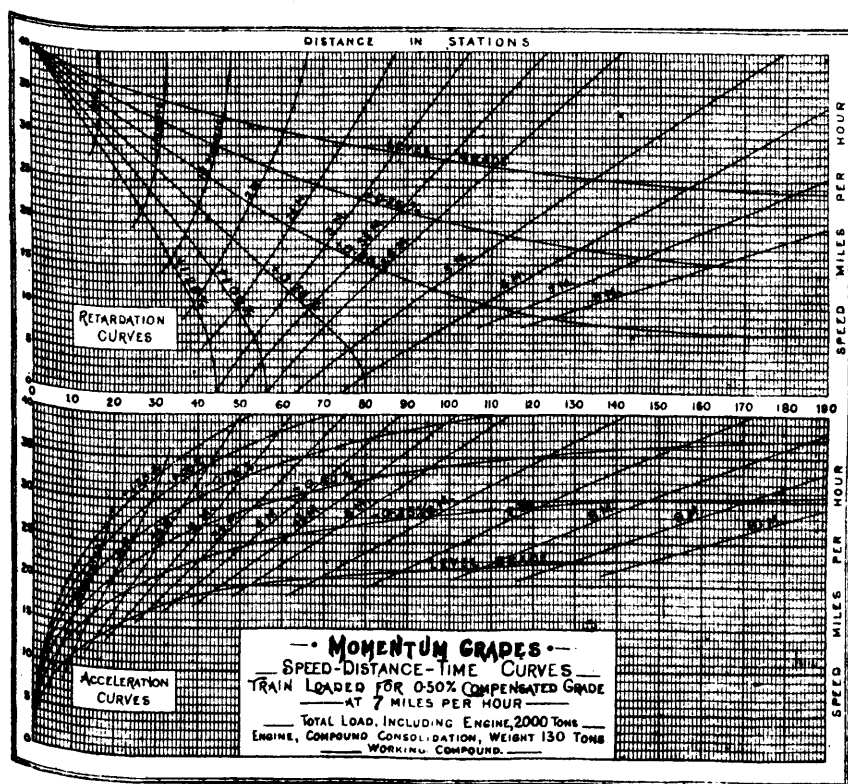


PLATE 5.—ECONOMICS OF RAILWAY IMPROVEMENTS.