

The above table shows the Denver and Rio Grande Railway locomotive grade ratings based on actual practice, with the corresponding results as computed by formula. It will be seen that the agreement between the formula and actual practice is, as a whole, remarkably close for all engines and for all grades except level. The Denver and Rio Grande rating for level track is no doubt put at a low figure to provide for curves and small irregularities in surface, while the formula assumes a perfectly straight and level track. In the same table is given the rating for the New Zealand engine, type B, and the 85-ton engine proposed for some of these lines, as given on page 6 of my report of February, 1902, calculated by formula.

Train-resistance on Straight and Level Track.

Mr. Chanute says Clark's formula gives results too large for freight-trains at moderate speeds, and too small for passenger-trains at high speeds. Experiments on the Erie Railway with dynamometer, engine and tender excluded, gave 5.25 lb. per short ton of train. Mr. Chanute used 6 lb. for safety.

Train-resistance on Grades.

Experiments by A. J. Cassatt and H. J. Lambert, vice-presidents of the Pennsylvania Railway, give results from which the grade-resistance is calculated at $R = 0.38 F$ for tons of 2,000 lb., and for tons of 2,240 lb. $R = 0.4255 F$; while I have used $R = 0.4240 F$, an agreement within four-tenths of 1 per cent. R = train-resistance per ton due to grade alone, and F = rate of grade in feet per mile.

A speed of ten miles an hour going uphill will permit any properly designed engine to develop an adhesion of nine-fortieths of the weight on drivers, and this has been used in the calculations.

From these ratings it will be seen that an engine of type B will haul a train of 278 tons behind the tender up to Otira; while to haul the same train from Otira to Bealey assistant engines will be required, as given in Table II.

TABLE II.

Line A ...	...	...	...	One assistant engine of type B.
Line B ...	...	...	...	One assistant engine of type B.
Line C ...	...	...	...	One assistant engine of 85 tons.
Line E ...	...	...	...	One assistant engine of type B and one assistant engine of 85 tons.
Line F ...	...	...	...	Two assistant engines of 85 tons.

Another arrangement of the motive power for line E would be to cut out the type B engine at Otira, and let it return to Greymouth with the west-bound train. Two 90-ton engines could then take the load which it had brought to Otira eastward across the summit to Bealey.

If we assume that an 85-ton road-engine should at some future time be adopted for use on the line between Greymouth and Otira, it will haul a train of about 408 tons behind the tender up the grade to Otira. To haul this train of 408 tons over the summit to Bealey assistant engines will be required, as follows: Line A, one assistant engine of type B; line B, one assistant engine of 85 tons; line C, one assistant engine of 85 tons and one assistant engine of type B.

Cost per Engine Mile.

The cost in detail per engine mile for type B, as given by the New Zealand Railways Statement for the year ended the 31st March, 1901, is shown in Table III., in comparison with the same costs for engines of the Denver and Rio Grande Railway working on grades up to 1 in 26, curves not compensated, and of the Southern Pacific system, Dunsmuir to Ashland, on grades up to 1 in 30; curves all compensated. It will be observed from the profiles and schedules attached that these locomotives of the Denver and Rio Grande Railway are doing their maximum work uphill all the time, additional engines being added as the rate of grade increases, and that they are all comparatively modern. Several of the locomotives on the Southern Pacific are old, and therefore not so economical in fuel as locomotives more recently designed and with relatively larger grate area.

The conditions of working the Soldier Summit grades on the Denver and Rio Grande closely approximate those at Arthur's Pass, and therefore the Denver and Rio Grande costs of fuel and repairs per unit of power are used, but the item of wages for the New Zealand type B, as given in the returns for 1901, is accepted as correct for this analysis.

The cost of fuel, repairs, and stores may be taken as proportional to the tractive power without any substantial error, the coal being reduced to a uniform price per ton of 13s. per long ton. The New Zealand railway returns for 1901 give the cost of coal at Greymouth at 11s. Estimating the cost of freight to Otira, fifty-one miles, and handling at 2s. per ton, makes the cost at Otira 13s., or \$3.12. The fuel used by the Southern Pacific costs, as shown, a little more than in New Zealand, while that used by the Denver and Rio Grande costs about 7s. per long ton. The second division of Table III. shows the actual cost per 10,000 lb. tractive power.

The Southern Pacific fuel consists of 1,078 cords of wood = 718 tons of coal of 2,000 lb., and 2,671 tons of coal of 2,000 lb.; total coal equivalent, 3,389 tons of coal of 2,000 lb., which costs \$13,997 = \$4.12 per ton of 2,000 lb., or \$4.62 per long ton.

The Denver and Rio Grande fuel is coal, costing \$1.68 per ton of 2,240 lb.

Then, if the cost of fuel per 10,000 lb. tractive power, of division 2 of Table III., for the Denver and Rio Grande is multiplied by $\frac{8.12}{1.68}$ and for the Southern Pacific by $\frac{8.12}{4.62}$, the comparison is reduced to equal cost per ton of coal at 13s., shown in division 3 of the same table.

The fourth division of the table shows the largest values of these latter multiplied by the tractive power of the several engines required for the proposed lines. Wages and general expenses are assumed as constant, the New Zealand items being used. The fuel, consumption, and repairs for the Denver and Rio Grande, being for a piece of road which most nearly approximates to the conditions at Arthur's Pass, are also used.