

Table 2 the average speed had to be assumed in the absence of full data. In cases where the data is complete, it is believed that the agreement would be substantially exact, as with engine No. 401. The average freight locomotive does not have cylinder and steaming capacity enough to maintain a tractive effort equal to its adhesion at greater speeds than nine or ten miles per hour. As the speed increases the mean effective pressure and amount of steam used per revolution is reduced, and the coal consumed per engine-mile is nearly proportional to the amount of steam used. If, then, we compute the cost of fuel per engine-mile at \$1 per ton for a speed of ten miles per hour, and a tractive effort equal to the adhesion, and also construct curves showing the mean effective pressure and the amount of steam or fuel used per mile for all speeds required in percentage of the maximum of fuel consumed at ten miles per hour, as above noted, we may then read off directly the percentage of fuel consumed for any given speed. It is assumed that the engines will be doing their maximum work all the time, as they ought to do, to obtain economic results, either in overcoming train or grade resistance, or in acceleration. Diagram 1 shows the percentage of fuel used per engine-mile for all speeds between ten and thirty-eight miles per hour, the maximum at ten miles per hour being 100 per cent. Diagram 2 gives the cost of fuel per engine-mile in cents at \$1 per ton for any size of engine up to 100 tons on the drivers, and for 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 per cent. duty. The speed being known, Diagram 1 gives the percentage of duty or fuel-consumption which, interpolated in Diagram 2 over the weight on drivers for the engine considered, gives the cost of fuel per engine-mile at \$1 per ton. This figure must be multiplied by the cost of fuel per ton for the case required.

The returns (Table 1) for costs of repairs and stores are somewhat erratic, but general considerations are sufficient to show that the repairs vary directly as the weight or size of the machine, and that it will be near enough to consider the repairs and stores as one item. Not having complete data, I have assumed, after some deliberation, that the cost of repairs for an engine standing with steam up, not running, will be about one-tenth of what it is when the engine is doing its maximum work. Also, that when the engine is running down hill, with steam shut off, the cost of repairs will be about 55 per cent. of the maximum. It is not contended that this is exact, but that it gives results that compare well with the average of the returns of Table 1, as will appear from an examination of Table 2, which is a comparison of the costs per engine-mile calculated by formula and the actual costs from Table 1. Diagram 3 gives the cost of repairs and stores per engine-mile for engines up to 100 tons on the drivers when doing their maximum work, when running down hill with steam shut off, and when standing, or not running, with steam up.

An inspection of Table 1 indicates that the cost of wages per engine-mile does not vary materially with the weight of the engine, but does vary with the speed. Assuming approximate average speeds for ten of the returns in Table 1, and plotting the results, the curve of Diagram 4 is obtained, which shows the cost of wages per engine-mile for speeds up to ninety miles per hour.

Diagram 5 gives the cost of general expenses per engine-mile for all speeds. The curve of this diagram was obtained in the same general way as that of Diagram 4.

Diagram 6 is a convenient combination of Diagrams 4 and 5, and gives the cost of wages and general expenses per engine-mile for any speed.

The following formulæ are the equations of the lines and curves of the graphical Diagrams 2 to 6 inclusive:—

C = Total cost of the engine-mile in cents.

F = Cost of fuel per engine-mile in cents.

G = " of general expenses per engine-mile in cents.

W = " of wages expenses per engine-mile in cents.

R = " of repairs and stores per engine-mile in cents.

t = Tons on the drivers.

s = Average speed in miles per hour.

d = Fuel used per engine-mile at the speed of s in percentage of the maximum at ten miles per hour from Diagram 1.

e = Percentage of maximum cost of repairs and stores.

e = 100 per cent. when the engine is developing its entire steaming-capacity.

e = 55 per cent. when running with steam shut off.

e = 10 per cent. when standing with steam up, but not running.

c = Cost of coal per ton of 2,000 lb., in dollars.

$$\text{Then, from diagram 2, } F = 0.3 t d c.$$

$$\text{" 3, } R = 0.0864 (t + e t).$$

$$\text{" 4, } W = \frac{35}{\sqrt{s}}.$$

$$\text{" 5, } G = 1 + \sqrt{\frac{8}{s}}.$$

$$\text{" 6, } W + G = 1 + \sqrt{\frac{43}{s}}.$$

Combining these in one equation we obtain the formula for the cost of the engine-mile.

$$C = F + W + G + R.$$

$$C = 1 + \sqrt{\frac{43}{s}} + 0.3 t d c + 0.0864 (t + e t).$$

We now have in Diagrams 1 to 6 inclusive the cost of all the items that go to make up the total cost of the engine-mile, and knowing the tractive power of the engine or the weight on its drivers, and the average speed while running under steam, and also with steam shut off for the round trip considered, both the cost per engine-mile running under steam and the cost per engine-