



DATA SHEET

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Sheet #:	D4d.1
Title:	LOCOMOTIVE SPEED AND GEARING
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SPEED OF PROTOTYPE LOCOMOTIVES

There is no hard and fast rule for selecting the maximum speed of a prototype locomotive. There are, however, several "rules of thumb" that may be of some aid to the model builder. Locomotives built before the year 1910 normally had a top speed in miles per hour equal to the diameter of the driver in inches. A locomotive with 72-inch drivers was expected to have a top speed of about 72 miles per hour. With the development of better balancing techniques and the use of light-weight high-alloy steel rods, the allowable speed was raised to about one and one quarter miles per hour per inch of diameter. A modern steam locomotive with 72-inch drivers has a top speed of about 90 miles per hour.

The speed of diesel-electric and electric locomotives is a function of the balance speed of the traction motor, the wheel diameter and the gear ratio. The same car body and trucks when equipped with different gear set, can have different maximum speeds, just as in a model. Switchers are generally equipped for maximum speeds of about 60 miles per hour; road switchers, dual purpose locomotives and freight locomotives are generally equipped for speeds up to 75 miles per hour; passenger locomotives can be equipped for speeds over 100 miles per hour. A Baldwin-Westinghouse 49 ton 600 HP box cab motor built for xxxx had a top speed of 30 miles per hour pulling seven cars. The following table gives some other specifics:

MODEL	TYPE	TOP SPEEDS	GEARS	COMMENT
TR-9, -12 GP-9, SD-9 FP-9	Yard switcher Road switcher Dual Purpose	65 55, 65, 71, 77 83, 89 65-102	62:15	MR Blue Book 27 MR Blue Book 43 MR 11/63 p46
E-7, 8, 9 Alco C628 SDP-40	Passenger Freight Dual purpose	85, 92, 98, 117 70, 80 up to 90	74:18, 65:18	MR Blue Book 69 MR 11/65 p40 TRAINS 7/65 p8
DD-40X SD50, 60, 60M GE C40, 41-8(w)	Freight Freight Freight	80 70 70	66:20 70:17 83:20	UP as 1994 UP as 1994 UP as 1994

CALCULATING REQUIRED GEAR RATIO

In gear ratio calculations, scale doesn't matter as long as you are consistent in using prototype dimensions. The wheel diameter D is the prototype diameter in inches, and the constant Pi is 3.14 for figuring the circumference of the wheel, which is the distance traveled in one revolution. Your motor RPM in the calculation should be from the motor manufacturer's data. The RPM used in the calculation is based on the no load RPM listed at the given voltage (usually 12V). If you want to run at a different voltage, then the RPM used is directly proportional to the desired voltage. The MPH should be a realistic top speed. Also, we have to plug in a conversion factor of 1056 to convert MPH to inches per minute. Finally, you need an efficiency factor of about 70% to account for losses in friction. This friction is the composite of friction in the worm gearing and in the rest of



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CALCULATING GEAR RATIO - continued

the mechanism. A typical commercial quality fine-pitch worm gear set will only be 75 to 85% efficient, adding another 10% for losses in the mechanism, the overall efficiency of the locomotive is approximately 70%. The formula for the desired gear ratio is:

$$G = \frac{\text{Pi} \times D \times \text{RPM} \times .7}{\text{MPH} \times 1056}$$

SAMPLE PROBLEM

A model is to be made of a Pennsylvania K-4. The wheel diameter of the prototype is 80 inches and the model is to be designed for a maximum speed of 100 MPH. A Sagami 1630 motor with a no load RPM at 12 volts of 14,900 is to be used, but the maximum track voltage is 10V.

The RPM for the motor at the desired 10V is: $14,900 \times 10 / 12 = 12,420$.

$$\text{Then } G = \frac{3.14 \times 80 \times 12,420 \times .7}{100 \times 1056} = \frac{20}{7} \text{ or } 20:7$$

Now if you don't have a 20.7:1 gear set, but you do have a 28:1, then you can swap MPH for G in the formula and calculate the MPH given that gear ratio.

$$\text{MPH} = \frac{3.14 \times 80 \times 12,420 \times .7}{28 \times 1056} = 73.9 \text{ MPH}$$

SPEED OF MODEL LOCOMOTIVES

To calculate the equivalent prototype speed in miles per hour of a model locomotive, make a test run along a level track of known length in Feet and measure the time in Seconds. The formula for Scale Miles per Hour is:

$$\text{SMPH} = \frac{\text{Feet} \times \text{Scale}}{\text{Seconds} \times 1.467}$$

SAMPLE PROBLEM

The Pennsylvania K-4 is built in HO scale and then test run on a track exactly 10 feet long. The model K-4 ran the distance in 8.1 seconds. Then:

$$\text{SMPH} = \frac{10 \times 87}{8.1 \times 1.467} = 73.2 \text{ SMPH}$$



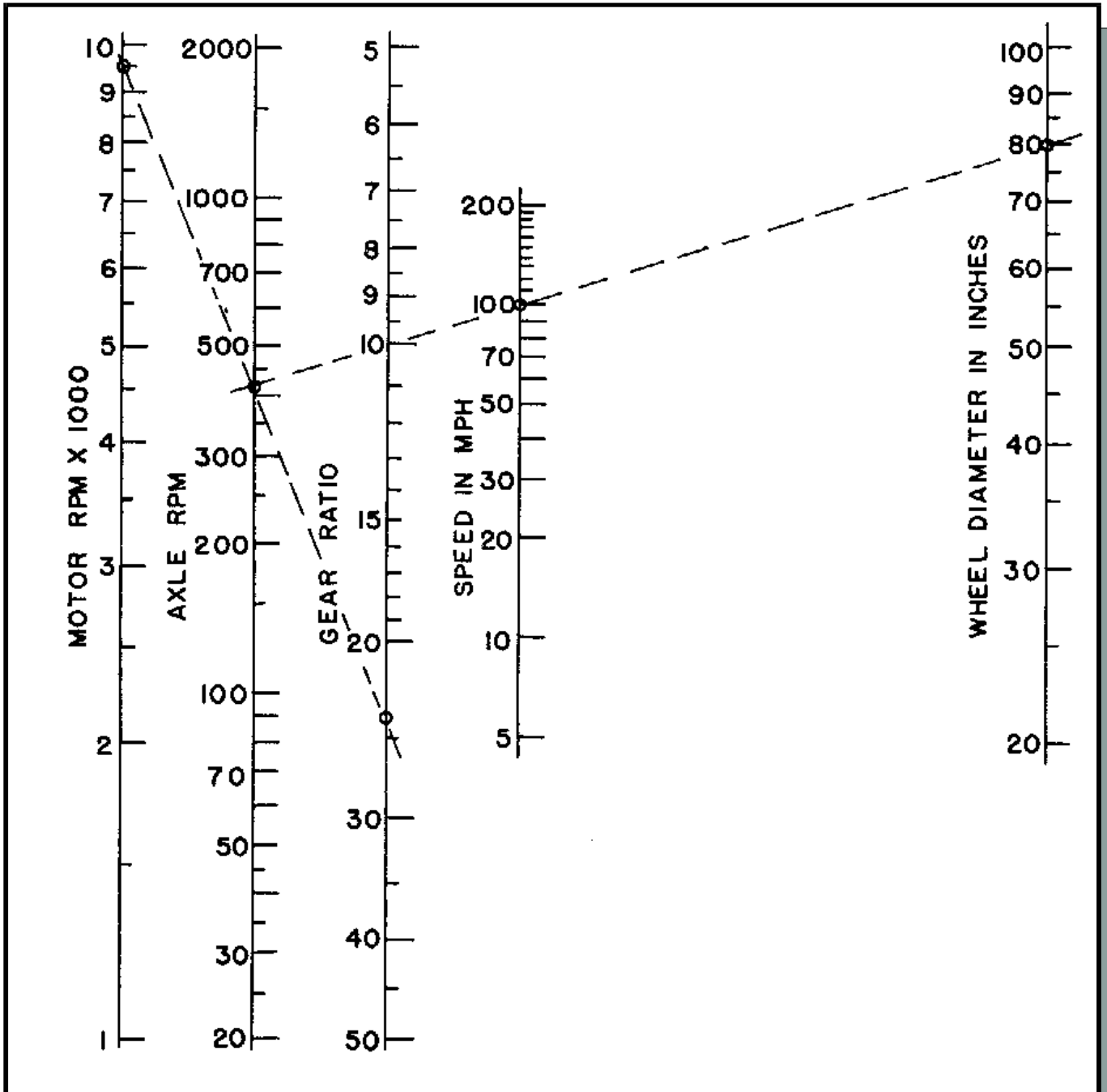
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NOMOGRAPH

Before the advent of the calculator, nomographs provided a quick way to make these kinds of calculations. The nomograph below will calculate gear ratio given wheel diameter, RPM, and MPH. You can also calculate MPH given wheel diameter, gear ratio and RPM. The nomograph does not account for inefficiencies, to do so, multiply the gear ratio by the efficiency factor.





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NOMOGRAPH - continued

To select a gear ratio for the K-4 using a 9500 RPM motor, place a straight edge between the point on the wheel diameter scale representing 80 inches and the point on the speed scale representing 100 MPH. Read the axle RPM required to obtain this speed (about 410 RPM). Now place the straight edge between this point and the point on the motor speed scale representing 9500 RPM. The straight edge now intersects the gear ratio scale at about 23. The required gear ratio is the reading on the gear ratio scale times the efficiency factor, which in this case would equal about 16 using an efficiency factor of .7.

COMPUTER AIDED CALCULATIONS

The personal computer with a spreadsheet program is a great way to calculate gear ratios and scale speed. For a good example of the use of a spreadsheet to solve gearing calculations, look at Jeff Scherb's spreadsheet in the December 1990 issue of Model Railroader magazine on pages 154 and 155. Jeff uses an efficiency factor of .6 to account for not only gear and mechanism friction, but also voltage losses for constant intensity lighting.

For those modelers that would like to give computer programming a try, see Bob Fink's program written in BASIC and listed in the March 1993 issue of Model Railroader magazine on page 122 and 123. This program "knows" what the realistic speed is for both diesel locomotives and steam engines. This program could be modified to incorporate efficiency factors and also a "look up" table to automatically select commercially available gearboxes.

