

## Vehicle Drive Calculations

The force to drive a vehicle is composed of the sum of (1) road resistance, (2) force necessary to climb a grade, (3) force needed to accelerate to final velocity in the allowable time, (4) force to overcome air resistance, on fast moving vehicles. Each of these forces can be calculated or estimated from the formulas on this page, then added together. In selecting an engine, allow enough extra power to make up for losses in the mechanical transmission system including gear boxes, clutches, differentials, chain or belt drives.

**Travel Speed** in M.P.H. (miles per hour) is found by multiplying wheel RPM  $\times$  wheel circumference.

$$\text{M.P.H.} = \text{RPM} \times d \div 336, \text{ or}$$

$$\text{RPM} = 336 \times \text{M.P.H.} \div d$$

$d$  is wheel diameter in inches.

**Axle Torque** for driving the vehicle is found by multiplying drawbar pull (or push) times wheel radius.

$$T = F \times r \text{ or, } F = T \div r$$

$T$  is axle torque in inch pounds.

$F$  is drawbar pull in pounds.

$r$  is wheel radius in inches.

**Drawbar Pull** to keep the vehicle in steady motion on level ground depends on the road surface. The following figures are pounds of drawbar pull per 1000 lbs. of vehicle weight.

Concrete . . . . .	10 to 20 lbs.
Asphalt . . . . .	12 to 22 lbs.
Macadam . . . . .	15 to 37 lbs.
Cobbles . . . . .	55 to 85 lbs.
Snow . . . . .	25 to 37 lbs.
Dirt . . . . .	25 to 37 lbs.
Mud . . . . .	37 to 150 lbs.
Sand . . . . .	60 to 300 lbs.

**Horsepower** required on vehicle wheels is torque times RPM:

$$\text{HP} = T \times \text{RPM} \div 63024$$

$T$  is wheel torque in inch pounds.

**NOTE:** Additional HP is required at the engine to overcome transmission system losses.

**Conversion Formula** between torque, HP, and speed.

$$T = \text{HP} \times 63024 \div \text{RPM}$$

Torque values are in inch pounds.

**Momentum** of a vehicle is equivalent to that constant force which would bring it to rest in one second by resisting its movement.

$$\text{Momentum} = \text{Weight} \times V \div g$$

**Weight** is in pounds.

$V$  is velocity in feet per second.

$g$  is gravity acceleration = 32.16

**Acceleration** of a vehicle is expressed in this formula involving weight, accelerating force, and time.

$$F = (V \times W) \div (g \times T)$$

$F$  is accelerating force in pounds.

$V$  is final velocity in feet per second.

$W$  is vehicle weight in pounds.

$g$  is gravity acceleration = 32.16

$T$  is time in seconds that force acts.

**Note:** The gravity acceleration symbol,  $g$ , converts weight into mass.

**Grade**, in mobile work, is usually expressed in percentage rather than in degrees. For example, a 10% grade has a rise of 10 feet in a distance of 100 feet, etc.

**Grade Resistance** is the drawbar pull needed to keep the vehicle in constant motion up a grade. This is in addition to the drawbar pull to overcome road resistance as expressed by another formula.

$$F = GR \times W$$

$F$  is drawbar pull in pounds.

$GR$  is grade resistance in percent (20% is written as 0.20, etc.)

$W$  is gross vehicle weight in pounds.

**Air Resistance** will be important only on fast moving vehicles (over 20 to 30 M.P.H.).

$$F = FA \times 0.0025 \times \text{M.P.H.}^2$$

$F$  is additional drawbar pull needed to overcome air resistance.

$FA$  is frontal area of vehicle in square feet.

$\text{M.P.H.}$  is vehicle speed, miles per hour.

**Axles** and drive shafts must have a diameter large enough to transmit the torque without excessive deflection. The angle of deflection for a solid round axle may be calculated from this formula:

$$A = 583.6 \times T \times L \div (D^4 \times E)$$

$A$  is angle of deflection in degrees.

$T$  is applied torque in inch pounds.

$L$  is shaft length in inches.

$E$  is modulus of elasticity of material. (12,000,000 for steel)

$D$  is shaft diameter in inches.

Some authorities say that a steel shaft should be limited to an angular deflection of 0.08 degrees per foot of length to avoid failure.

