Rolling Resistance Measurement Procedure for Highway Truck and Bus Tires – SAE J1379 AUG83

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1. Introduction—The rolling resistance of pneumatic tires results in a significant loss of energy in the operation of motor vehicles. This recommended practice provides methods for determining rolling resistance data of highway truck and bus tires under controlled conditions. This procedure is intended to provide a way of gathering data on a uniform basis to be used in comparison with test results from road fuel economy tests.

A companion document, SAE Information Report J1380, "The Measurement of Highway Truck and Bus Tire Rolling Resistance," enlarges on this subject and gives background information. The format of both documents is the same, with corresponding topics presented under the same headings.

2. Scope—This recommended practice applies to the laboratory measurement of the rolling resistance of pneumatic tires designed primarily for use on trucks and buses in normal highway service, as defined by the Tire and Rim Association, Inc. (TRA); it does not include light truck tires (designated LT). The procedure applies only to straight, free-rolling tires under steady-state operation and includes the following three basic methods:

2.1 Force Method—Measures the reaction force at the tire spindle and converts it to rolling resistance.

2.2 Torque Method—Measures the torque input to the test machine and converts it to rolling resistance.

2.3 Energy Method—Measures the energy input to the test machine and converts it to rolling resistance.

3. Definitions—The following definitions apply wherever the terms and expressions are used in this recommended practice and in SAE Information Report J1380.

3.1 Rolling Resistance—Rolling resistance of the free-rolling tire is the scalar sum of all contact forces tangent to the test surface and parallel to the wheel plane of the tire.

3.2 Rolling Resistance Coefficient—Rolling resistance coefficient is the ratio of the rolling resistance to the load on the tire.

3.3 Loaded Radius—Loaded radius is the perpendicular distance from the axis of rotation of the loaded tire to the surface on which it is rolling.

3.4 Maximum Load—Maximum load is a force equivalent to the maximum dual (D) tire load limit specified in the tire load tables of the current Tire and Rim Association, Inc. (TRA) Yearbook.

3.5 Rated Pressure—Rated pressure is the cold inflation pressure specified for the maximum dual (D) tire load limit (maximum load) in the tire load tables of the current Tire and Rim Association, Inc. (TRA) Yearbook.

3.6 Capped Air—The term capped air refers to the process of inflating the tire to the required pressure while it is at ambient temperature of the test area, and then sealing off the pressure in the tire with a valve, cap or some other seal. As the tire is run under load, increases in temperature will cause the capped air in the tire to increase in pressure.

3.7 Regulated Air—The term regulated air refers to the process of inflating the tire to the required pressure independent of its temperature, and maintaining this inflation pressure while the tire runs under load. This is most commonly done by using a regulated pressure source attached to the tire through a rotating union.

4. Test Equipment—The laboratory test wheel is most commonly used for this procedure because of its widespread availability.

4.1 Test Surface

4.1.1 TEST WHEEL DIAMETER—The diameter of the laboratory test wheel most commonly used is 67.23 in (1.7076 m).[1]

4.1.2 WIDTH—The width of the test surface must exceed the tread width of the test tire.

4.1.3 TEXTURE—A medium coarseness, abrasive-type (80 grit) surface texture is recommended, such as Medium-grit 3M Safety-Walk.

4.2 Test Rims—Test rims should have an approved contour and width as specified by the Tire and Rim Association, Inc., for the size of the tire tested. The rim width and contour used should be reported with the test results. The radial and lateral rim runout should not exceed 0.070 in (1.8 mm).

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[1] Conversions between U. S. Customary Units and metric units are made in accordance with "Rules for SAE Use of SI Metric Units (SAE J916c)." The conversion factors between units depend on the precision of the base measurement to be converted.

4.3 Alignment and Control Accuracies—All test parameters should be maintained at their specified levels. Deviation from these levels will cause variations of rolling resistance. If these levels cannot be achieved as indicated in the SAE Information Report, J1380, corrections for these effects may be attempted (particularly for alignment or temperatures). All parameters should be measured and recorded with the rolling resistance values. The three measurement methods are differently affected by variations in test parameters. Except for more stringent limits specified below for each of the three methods, the test parameters should be maintained within the following limits:

Tire load application normal to test surface: ±0.3 deg
Wheel plane alignment normal to test surface: ±0.3 deg
Slip angle on test surface: ±0.1 deg
Tire load: ±10 lbf (±44 N)
Inflation pressure: ±0.2 psi (±1.4 kPa)
Speed: ±1 mph (±2 km/h)
Ambient temperature: 75 ± 5°F (24 ± 3°C)

4.3.1 FORCE METHOD—Misalignment of the applied load may cause a significant spindle force component to appear in the direction of the rolling resistance. Therefore, the following more stringent limit is recommended for this method:

Tire load application normal to test surface: ±0.05 deg

4.3.2 TORQUE METHOD—Slip angle misalignment can cause a significant input torque that will be read as rolling resistance. Therefore, the following more stringent limit is recommended for this method:

Slip angle on test surface: ±0.05 deg

4.3.3 ENERGY METHOD—Slip angle misalignment can cause a significant electrical power input that will be read as rolling resistance. Also, the rolling resistance calculation requires a constant value of speed during the measurement interval because variations in surface speed can cause significant errors. Therefore, the following more stringent limits are recommended for this method:

Slip angle on test surface: ±0.05 deg
Speed: ±0.5 mph (±0.8 km/h)

4.4 Instrumentation Accuracy—The instrumentation used for readout and recording of test data must be sufficiently accurate and precise to provide repeatable measurements of rolling resistance data. The absolute error limits specified below should produce a composite error of less than ±0.5 lbf (±2.2 N) and ±1% of the maximum rolling resistance measurement data. Refer to SAE Information Report, J1380, for the assumptions leading to the accuracy level and for appropriate changes in accuracies for specific applications. Measurements common to all three methods of rolling resistance determination should be maintained within the following accuracy limits:

Tire load: ±6 lbf (±26 N)
Inflation pressure: ±0.2 psi (±1.4 kPa)
Average temperature: ±0.5°F (±0.2°C)
Speed: ±0.5 mph (±0.8 km/h)

4.4.1 FORCE METHOD—In addition to the common accuracies specified above, the use of this method requires the following recommended accuracies:

Spindle force: ±0.20 lbf (±0.8 N)
Loaded radius: ±0.1 in (±2.5 mm)

4.4.2 TORQUE METHOD—In addition to the common accuracies specified above, the use of this method requires the following recommended accuracy:

Torque input: ±6 lbf-in (±0.7 Nm)

4.4.3 ENERGY METHOD—In addition to the common accuracies specified above, the use of this method requires the following recommend accuracies:

Electrical power: ±20 W
Surface speed: ±0.2 mph (±0.3 km/h)

4.5 Measurement of Load Interaction Effects—Force Method—The influence of applied load on observed spindle force must be determined for a test facility in a suitable manner. Since the load interaction effect (instrumentation 'crosstalk') is generally stable for a given measuring system, it can usually be expressed as a polynomial, which can be utilized during the data reduction process.

5. Test Conditions—The recommended test consists of an initial measurement of rolling resistance after the tire inflation pressure is allowed to rise as it would in service, followed immediately by four consecutive measurements at regulated inflation pressures in a test matrix of four loads and three inflation pressures, all at a constant speed.

5.1 Test Speed—The recommended test speed is 50 mph (80 km/h).

5.2 Load and Inflation Pressure—The test loads and inflation pressures shown in the following table are based on dual (D) listings in the Tire and Rim Association Handbook for the test tire size designation (see definitions 3.4 and 3.5).

Tire Load	Inflation Pressure
% of Maximum Load	% of Rated Pressure
100	100 capped
100	95 regulated
75	70 regulated
50	120 regulated
25	70 regulated

5.3 Test Sequence—It is recommended that the four measurements in the matrix of regulated pressures be made in a sequence which results in steadily decreasing values of rolling resistance. For most tires, the sequence shown in 5.2 accomplishes this objective.

6. Test Procedure—The test procedure should be conducted in the following sequence:

6.1 Break-In—Tires that undergo significant permanent growth upon first operation may require a break-in and cooling period prior to the start of the test. Break-in can be accomplished by operation of the tire at initial test conditions for a period of two (2) hours, followed by a cool-down period of at least six (6) hours.

6.2 Thermal Conditioning—The tire should be placed in the thermal environment of the test location for a period of time sufficient to achieve thermal equilibrium before testing. A minimum of six (6) hours is recommended. The tire may be mounted on the test rim at any time before, during, or after thermal conditioning, provided the temperature of the mounting area is similar to that of the test location. Otherwise, the tire should be mounted prior to thermal conditioning.

6.3 Warm-Up—The tire should be run on the test surface under each set of conditions for a period of time sufficient to achieve a steady-state value of rolling resistance. A minimum period of ninety (90) minutes is recommended for the capped pressure condition and thirty (30) minutes for each regulated pressure condition. The achievement of steady-state conditions can be verified by monitoring the rolling resistance.

6.4 Measurement and Recording

6.4.1 IDENTIFICATION—The following information for the identification of each test should be recorded:
1) Tire manufacturer and brand name
2) Tire size
3) Tire serial number, in-board or out-board side of machine.
4) Other pertinent tire identification
5) Test rim width and contour
6) Test machine and position identification
7) Test surface texture identification
8) Date and time
9) Test operator identification
10) Tire mounting configuration to establish direction of rotation
11) Break-in

6.4.2 TEST VARIABLES—The following test data should be recorded immediately following warm-up for each load pressure combination:
1) Warm-up time
2) Speed
3) Load
4) Inflation pressure
5) Spindle force, input torque, or input electrical power
6) Loaded radius
7) Average ambient temperature

6.5 Measurement of Parasitic Losses—Parasitic losses must be determined by a suitable technique. Two commonly used methods are:

6.5.1 SKIM READING—Load on the tire must be reduced to a value just sufficient to maintain rotation at the test speed without slippage; spindle force, input torque or input electrical power is read (whichever applies).

6.5.2 MACHINE OFFSET READING—The tire is removed from the test surface. At test speed, spindle force, input torque or input electrical power is read (whichever applies).

7. Data Reduction

7.1 Net Readings Via Subtraction of Parasitic Readings—Parasitic losses must be deducted by using applicable techniques. The result of the deduction is net spindle force, net torque, or net electrical power (whichever applies). Two commonly used techniques for obtaining the parasitic readings are:

7.1.1 SKIM READING—Subtract the skim reading from the reading for each test condition.

7.1.2 MACHINE OFFSET READING—Subtract the machine offset reading the spindle bearing loss, and the aerodynamic loss from the reading for each test condition.

7.2 Load Interaction Compensation—Force Method—The load interaction effect (instrumentation 'crosstalk') on the observed rolling resistance must be calculated for the actual applied load and the appropriate compensation made at each test condition.

7.3 Rolling Resistance Calculation—Rolling resistance must be calculated by using a formula appropriate to the measuring method.

7.3.1 FORCE METHOD

$$F_R = F_X \left(1 + r_L/R\right)$$

Where: F_R = Rolling resistance, lbf (N)
F_X = Net tire spindle force, lbf (N)
r_L = Loaded radius, in (m)
R = Test wheel radius, in (m)

7.3.2 TORQUE METHOD

$$F_R = T/R$$

Where: F_R = Rolling resistance, lbf (N)
T = Net input torque, lbf-in (Nm)
R = Test wheel radius, in (m)

7.3.3 ENERGY METHOD

U. S. Customary Units	SI Units
$F_R = 0.503\,(VA - P)/U$	$F_R = 3.60\,(VA - P)/U$

Where: F_R = Rolling resistance, lbf (N)
V = Volts applied to machine drive
A = Amperes drawn by machine drive
U = Test surface speed, mph (km/h)
P = Parasitic power per paragraph 7.1, watts

8. Data Analysis—For some purposes, additional conversion and analysis of the data are desirable. The calculations shown below are presented for convenience and easy reference.

8.1 Rolling Resistance Coefficient—The rolling resistance coefficient is calculated by dividing the rolling resistance by the load on the tire:

$$C_R = F_R/F_Z$$

Where: C_R = Rolling resistance coefficient
F_R = Rolling resistance, lbf (N)
F_Z = Tire load, lbf (N)

8.2 Power Consumption—The expression used in the power consumption calculation depends on the units desired.

8.2.1 WATTS

U. S. Customary Units	SI Units
$P = F_R U/0.503$	$P = F_R U/3.60$

Where: P = Power consumption, W
F_R = Rolling resistance, lbf (N)
U = Test surface speed, mph (km/h)

8.2.2 HORSEPOWER

U. S. Customary Units	SI Units
$P = F_R U/375$	$P = F_R U/2685$