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# SURFACE VEHICLE RECOMMENDED PRACTICE

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## Rolling Resistance Measurement Procedure for Passenger Car, Light Truck, and Highway Truck and Bus Tires

***Foreword***—This SAE Recommended Practice provides methods for determining rolling resistance of passenger car, light truck, and highway truck and bus tires under controlled conditions. The procedure is intended to provide a way of gathering data on a uniform basis, to be used for various purposes (for example, tire comparisons, determination of load or pressure effects, correlation with test results from fuel consumption tests, etc.).

A companion document, SAE Information Report J1270, Measurement of Passenger Car, Light Truck, and 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.

***1. Scope***—This SAE Recommended Practice applies to the laboratory measurement of rolling resistance of pneumatic passenger car, light truck, and highway truck and bus tires.

The procedure applies only to the steady-state operation of free-rolling tires at zero slip and inclination angles; it includes the following three basic methods:

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

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

**1.3 Power Method**—Measures the power input to the test machine and converts it to rolling resistance.

***2. References***

**2.1 Applicable Publication**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1270—Measurement of Passenger Car, Light Truck, and Highway Truck, and Highway Truck and Bus Tire Rolling Resistance

2.1.2 TIRE AND RIM ASSOCIATION—Tire and Rim Association, 175 Montrose West Avenue, Suite 150, Copley, OH 44321.

Tire and Rim Association Yearbook

***3.*** ***Definitions*—**The following definitions apply wherever the terms and expression are used in this document and in SAE J1270.

**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 molded on the tire sidewall and listed as the load limit in the tire load tables of the current Tire & Rim Association, Inc. (T&RA) Yearbook or in corresponding tables published by similar organizations concerned with standardization. For light truck tires, maximum load is defined as the maximum load (or load limit) given for *single* tire operation. For highway truck and bus tires, maximum load is defined as the maximum load (or load limit) given for *dual* tire operation.

**3.5** **Base Inflation Pressure—**Base inflation pressure is the inflation pressure molded on the tire sidewall together with maximum load (see 3.4). Base inflation pressure is the inflation pressure corresponding to the maximum load listed in the tire load tables of the current TRA Yearbook or in corresponding tables published by similar organizations concerned with standardization.

**3.6** **Capped Inflation Pressure—**The state of capped inflation pressure is achieved by inflating the tire to the required pressure prior to testing, while the tire is at ambient temperature of the test area, and then sealing the air in the tire during testing with a valve, cap, or some other seal.

**3.7** **Regulated Inflation Pressure—**The state of regulated inflation pressure is achieved by inflating the tire to the required pressure independent of its temperature, and maintaining this inflation pressure during testing.

**3.8** **Ambient Temperature—**The term ambient temperature refers to the temperature of the air measured during a rolling resistance test at a fixed location near the tire. The location of ambient temperature measurement is to be fixed at a lateral distance of 0.4 m (16 in) from a point on either rim flange farthest from the test surface. (See Figure 1 of SAE J1270).

**3.9** **Ambient Reference Temperature—**All rolling resistance data are referred to an ambient reference temperature of 24 °C (75 °F).

***4.*** ***Test Equipment*—**The equipment most commonly used for this procedure is the laboratory test wheel.

**4.1** **Test Surface**

4.1.1 TEST WHEEL DIAMETER—The diameter of the laboratory test wheel most commonly used is 1.708 m (67.23 in)[1].

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

4.1.3 TEXTURE—The surface must have a medium-coarse (80-grit) texture.

1. Conversion of SI units to U.S. customary units is handled with regard to the intended precision of the quantity in question.

**4.2 Test Rims—**Test rims must have an approved contour and width as specified by the Tire & Rim Association, Inc., or similar organizations for the size of the tire tested. The standard rim for testing is the design rim for a particular tire, although other approved rims may be used. The rim width and contour used must be reported with the test results. The rim runout must meet the specifications given for new rims.

**4.3 Alignment and Control Accuracies—**All test conditions must be maintained at their specified levels, because any deviation will affect the accuracy of rolling resistance data. The following alignment and control accuracies are specified such that their combined effect on rolling resistance does not surpass a standard deviation of 0.5 N (0.1 lbf) for passenger car and light truck tires, and 2.2 N (0.5 lbf) for highway truck and bus tires.

Except for special considerations discussed for each of the three methods in 4.3.1, 4.3.2, and 4.3.3, the test parameters must be maintained within the following (±) limits:

| | |
|---|---|
| Tire Load Fore-Aft Offset | 0.2 mm (0.01 in) |
| Tire Load Angular Offset: | 0.3 degree |
| Tire Slip Angle: | 0.1 degree |
| Tire Inclination Angle: | 0.3 degree |
| Tire Load: | 20 N (5 lbf) for passenger car tires<br>35 N (8 lbf) for light truck tires<br>45 N (10 lbf) for highway truck and bus tires |
| Inflation Pressure: | 1.5 kPa (0.2 psi) |
| Test Wheel Speed: | 2 km/h (1 mph) |
| Ambient Temperature: | See 5.5 |

If these levels cannot be achieved, corrections must be applied, particularly for alignment (7.2) or ambient temperature (7.4).

4.3.1 FORCE METHOD—Load misalignment, as well as interactions between load and spindle force transducers ("crosstalk"), can introduce severe errors of the spindle force reading. Such errors must be minimized (see 7.2).

4.3.2 TORQUE METHOD—Torque variations due to speed hunting oscillations may cause significant rolling resistance errors. Machine induced torque variations must be kept small and averaged over several complete oscillation periods.

4.3.3 POWER METHOD—Because rolling resistance calculation requires a constant value of speed during the measurement interval, variations in surface speed can cause significant errors. Therefore, the following speed accuracy is required for this method:

| | |
|---|---|
| Test Wheel Speed: | ±0.3 km/h (0.2 mph) for passenger and light truck tires<br>±0.8 km/h (0.5 mph) for highway truck and bus tires |

**4.4 Instrumentation Accuracy—**The instrumentation used for readout and recording of test data must be sufficiently accurate and precise to provide rolling resistance measurements with a standard deviation of no greater than:

0.5 N (0.1 lbf) for passenger car and light truck tires
2.2 N (0.5 lbf) for highway truck and bus tires

To achieve this accuracy, measurements common to all three methods of rolling resistance determination must be maintained within the following (±) accuracies:

| | |
|---|---|
| Tire Load: | 10 N (2 lbf) for passenger car tires<br>20 N (4 lbf) for light truck tires<br>30 N (6 lbf) for highway truck and bus tires |
| Inflation Pressure: | 1 kPa (0.1 psi) for passenger car and light truck tires<br>1.5 kPa (0.2 psi) for highway truck and bus tires |
| Temperature: | 0.2 °C (0.5 °F) |
| Speed: | 1 km/h (0.5 mph) |

4.4.1 FORCE METHOD—In addition to the common accuracies specified previously, the use of this method requires the following (±) accuracies:

| | |
|---|---|
| Spindle Force: | 0.5 N (0.1 lbf) for passenger car and light truck tires<br>1.0 N (0.2 lbf) for highway truck and bus tires |
| Loaded Radius: | 1 mm (0.04 in)<br>2.5 mm (0.10 in) for highway truck and bus tires |

4.4.2 TORQUE METHOD—In addition to the common accuracies specified previously, the use of this method requires the following (±) accuracies:

| | |
|---|---|
| Torque Input: | 0.3 N·m (3 lbf·in) for passenger car tires<br>0.5 N·m (5 lbf·in) for light truck tires<br>0.6 N·m (6 lbf·in) for highway truck and bus tires |

4.4.3 POWER METHOD—In addition to the common accuracies specified previously, the use of this method requires the following (±) accuracies:

| | |
|---|---|
| Power: | 10 W for passenger car tires<br>15 W for light truck tires<br>20 W for highway truck and bus tires |
| Test Wheel Speed: | 0.2 km/h (0.1 mph) for passenger car and light truck tires<br>0.3 km/h (0.2 mph) for highway truck and bus tires |

***5. Test Conditions*—**The recommended test consists of several test points at which the equilibrium rolling resistance and the equilibrium inflation pressure are determined.

**5.1 Load and Inflation Pressure—Standard Test—**The initial measurement of rolling resistance is taken at capped inflation pressure, where the pressure is allowed to rise as it would in service. This measurement is followed by several consecutive measurements at regulated inflation pressures. The loads and pressures appear in Tables 1 to 3:



**TABLE 1—STANDARD TEST FOR PASSENGER CAR TIRES**

| Test Point No. | Tire Load % of Max Load | Tire Inflation Pressure Base Pressure (±) Increment |
|---|---|---|
| 1 | 90 | –50 kPa (–7.3 psi) Capped |
| 2 | 90 | +70 kPa (+10.2 psi) Regulated |
| 3 | 50 | –30 kPa (–4.4 psi) Regulated |
| 4 | 50 | +70 kPa (+10.2 psi) Regulated |

**TABLE 2—STANDARD TEST FOR LIGHT TRUCK TIRES**

| Test Point No. | Tire Load % of Max. Single Load | Tire Inflation Pressure % of Base Pressure | |
|---|---|---|---|
| 1 | 100 | 100 | Capped |
| 2 | 70 | 60 | Regulated |
| 3 | 70 | 110 | Regulated |
| 4 | 40 | 30 | Regulated |
| 5 | 40 | 60 | Regulated |
| 6 | 40 | 110 | Regulated |

**TABLE 3—STANDARD TEST FOR HIGHWAY TRUCK AND BUS TIRES**

| Test Point No. | Tire Load % of Max. Dual Load | Tire Inflation Pressure % of Base Pressure | |
|---|---|---|---|
| 1 | 100 | 100 | Capped |
| 2 | 100 | 95 | Regulated |
| 3 | 75 | 70 | Regulated |
| 4 | 50 | 120 | Regulated |
| 5 | 25 | 70 | Regulated |

**5.2 Load and Inflation Pressure—Alternate Test—**If tire pressure rise information is available from other sources, an alternate test may be used. For this test, all data points are taken at regulated pressure. The loads and pressures appear in Tables 4 to 6.

**TABLE 4—ALTERNATE TEST FOR PASSENGER CAR TIRES**

| Test Point No. | Tire Load % of Max. Load | Tire Inflation Pressure Base Pressure (±) Increment |
|---|---|---|
| 1A | 90 | –30 kPa (–4.4 psi) Regulated |
| 2 | 90 | +70 kPa (+10.2 psi) Regulated |
| 3 | 50 | –30 kPa (–4.4 psi) Regulated |
| 4 | 50 | +70 kPa (+10.2 psi) Regulated |

**TABLE 5—ALTERNATE TEST FOR LIGHT TRUCK TIRES**

| Test Point No. | Tire Load % of Max. Single Load | Tire Inflation Pressure % of Base Pressure | |
|---|---|---|---|
| 1A | 100 | 110 | Regulated |
| 2 | 70 | 60 | Regulated |
| 3 | 70 | 110 | Regulated |
| 4 | 40 | 30 | Regulated |
| 5 | 40 | 60 | Regulated |
| 6 | 40 | 110 | Regulated |

**TABLE 6—ALTERNATE TEST FOR HIGHWAY TRUCK AND BUS TIRES**

| Test Point No. | Tire Load % of Max. Dual Load | Tire Inflation Pressure % of Base Pressure | |
|---|---|---|---|
| 1A | 100 | 120 | Regulated |
| 2 | 100 | 95 | Regulated |
| 3 | 75 | 70 | Regulated |
| 4 | 50 | 120 | Regulated |
| 5 | 25 | 70 | Regulated |

Exchanging point 1 of the standard test by point 1A of the alternate test does not affect the overall accuracy of the test. The remaining points 2, 3, etc., are identical with those of the standard test.

**5.3 Test Sequence—**It is recommended that the measurements be made in a sequence resulting in steadily decreasing values of rolling resistance. For most tires, the sequence shown in 5.1 and 5.2 accomplishes this objective.

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

**5.5 Ambient Temperature—**The ambient temperature surrounding the test tire should be held between 20 °C (68 °F) and 28 °C (82 °F). An average ambient temperature is recorded for each of the test points. All rolling resistance values must be adjusted to the Ambient Reference Temperature of 24 °C (75 °F) (see 7.4).

## *6. Test Procedure*

**6.1 Break-In—**Tires that undergo significant permanent change in their dimensions or material properties upon first operation require a break-in and cooling period prior to the start of the test. Break-in is accomplished by operating the tire at test point 1 (5.1) for a period of time as follows: 1 h for passenger car and light truck tires, 2 h for highway truck and bus tires. After the break-in, a minimum cool down period to test room temperature is required for the following: 2 h for passenger and light truck tires, 6 h for highway truck and bus tires.

**6.2 Thermal Conditioning—**Test tire and rim must be placed in the thermal environment of the test location to achieve thermal equilibrium before testing. The following period of time is needed; 2 h or more for passenger and light truck tire, 6 h or more for highway truck and bus tires. If the standard test is used (5.1), the tire must be inflated on the test rim at least 1 h before testing.

**6.3 Warm-Up—**The tire must be run on the test surface under each set of conditions long enough to achieve a steady-state value of rolling resistance.

The following warm-up time is required for the first condition:

30 min for passenger car tires
60 min for light truck tires
90 min for highway truck and bus tires

For each of the remaining conditions, the following warm-up time is required:

10 min for passenger car tires
15 min for light truck tires
30 min for highway truck and bus tires

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, if applicable.

*6.4.1.1 Tire Identification*

a. Manufacturer
b. Brand name
c. Tire size and load range (if applicable)
d. Tire maximum load (see 3.4)
e. Tire base inflation pressure (see 3.5)
f. Serial number
g. Break-in information
h. Use - history of tire
i. Other pertinent information

*6.4.1.2 Test Machine Identification*

a. Test wheel diameter
b. Test wheel surface texture and general condition
c. Tire mounting configuration
d. Method of parasitic loss determination
e. Other pertinent information

*6.4.1.3 Test Conditions*

a. Date and time
b. Rim width and contour
c. Rotational direction (clockwise or counter-clockwise) determined for the tire side with serial number.

6.4.2 TEST VARIABLES—The following test data must be recorded immediately after the warm-up period for each load-pressure combination:

a. Warm-up time period
b. Speed
c. Load
d. Inflation pressure
e. Spindle force, input torque, or input electrical power, as appropriate
f. Loaded radius (required for force method)
g. Ambient temperature (see 5.5)

**6.5 Measurement of Parasitic Losses—**Parasitic losses can be determined by different techniques. Two commonly used methods for estimating parasitic losses are:

6.5.1 SKIM READING—Load on the tire must be reduced to a value just sufficient to maintain tire rotation at test speed without slippage. The following skim loads are recommended:

100 N (20 lbf) for passenger car tires
150 N (35 lbf) for light truck tires
220 N (50 lbf) for highway truck and bus tires

6.5.2 MACHINE OFFSET READING—The tire and wheel assembly is removed from the test surface. At test speed, input torque or input electrical power is read (whichever applies). Note that this method does not apply if the force method is used. Note also that the parasitic losses of the rotating tire and wheel assembly are not measured and must be determined separately.

## *7. Data Reduction*

**7.1 Net Readings via Subtraction of Parasitic Readings—**Parasitic losses must be subtracted from the gross readings to yield net spindle force, net torque, or net electrical power (whichever applies). Two commonly used techniques for estimating the effect of parasitic losses are:

7.1.1 SKIM READING (FOR FORCE, TORQUE, AND POWER METHOD)—Subtract the skim reading from the reading for each test condition.

7.1.2 MACHINE OFFSET READING (FOR TORQUE AND POWER METHOD)—Subtract the machine offset reading and, in addition, the tire spindle bearing loss from the reading for each test condition.

**7.2 Compensation for Load-Spindle Force Interaction and Load Misalignment—**Compensation for both load-spindle force interaction ("crosstalk") and load misalignment must be determined for each of the test points (5.1 or 5.2). This is accomplished either by recording the spindle force for both forward and reverse tire rotation, or by dynamic machine calibration. If spindle force is recorded for forward and reverse direction (at each test condition), compensation is achieved by subtracting the "reverse" value from the "forward" value and dividing the result by two. If dynamic machine calibration is elected, the compensation terms may be easily incorporated in the data reduction process.

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

7.3.1 FORCE METHOD

$$F_R = F_X(1 + R_L/R) \qquad \text{(Eq. 1)}$$

where:

$F_R$ = rolling resistance, N (lbf)
$F_X$ = magnitude of net tire spindle force, N (lbf)
$R_L$ = loaded radius, m (in)
R = test wheel radius, m (in)

7.3.2 TORQUE METHOD

$$F_R = T/R \qquad \text{(Eq. 2)}$$

where:

$F_R$ = rolling resistance, N (lbf)
T = net input torque, N·m (lbf·in)
R = test wheel radius, m (in)