SURFACE VEHICLE RECOMMENDED PRACTICE

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

RATIONALE

This revision is being done to primarily address issues with the formatting of the equations within the documents. Various revisions over time have resulted in technical errors within those equations as unintended consequences of the revisions. The revised document has corrected all of those known issues.

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 J1270, 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.

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2. REFERENCES

2.1 Applicable Documents

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 Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

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

2.1.2 Tire and Rim Association Publications

Available from The Tire and Rim Association, Inc., 4000 Embassy Parkway, Suite 390, Akron, OH 44333, www.us-tra.org.

Tire and Rim Association Yearbook

2.1.3 Other Publications

D.J. Schuring and G.L. Hall, "Ambient Temperature Effects on Tire Rolling Loss," Rubber Chemistry and Technology, Vol. 54. No. 5, pp. 1113-1123 (1981).

3. DEFINITIONS

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

3.1 AMBIENT REFERENCE TEMPERATURE

All rolling resistance data are referred to an ambient reference temperature of 24 °C (75 °F).

3.2 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 inches) from a point on either rim flange farthest from the test surface. (Refer to Figure 1 of SAE J1270.)

3.3 BASE INFLATION PRESSURE

Base inflation pressure is the inflation pressure corresponding to the maximum load listed in the tire load tables of the current Tire and Rim Association, Inc. (TRA) Yearbook or in corresponding tables published by similar organizations concerned with standardization.

3.4 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.

3.5 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.

3.6 MAXIMUM LOAD

Maximum load is molded on the tire sidewall and listed as the load limit in the tire load tables of the current TRA 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.

3.7 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 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.

3.9 ROLLING RESISTANCE COEFFICIENT

Rolling resistance coefficient is the ratio of the rolling resistance to the load on the tire.

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 inches).[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.

4.2 Test Rims

Test rims must have an approved contour and width as specified by the Tire and 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.

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

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 inch)
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 35 N (8 lbf) for light truck tires 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 5.6

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 ±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 20 N (4 lbf) for light truck tires 30 N (6 lbf) for highway truck and bus tires
Inflation Pressure:	1 kPa (0.1 psi) for passenger car and light truck tires 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 1.0 N (0.2 lbf) for highway truck and bus tires
Loaded Radius:	1 mm (0.04 inch) 2.5 mm (0.10 inch) 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 0.5 N·m (5 lbf·in) for light truck tires 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 15 W for light truck tires 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 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. A single-point, standard reference condition (SRC) for passenger car (PC) and light truck (LT) tires is also described, which may be used for the purpose of high volume comparisons.

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 Standard Reference Condition (SRC) for PC and LT Tires

Load: 70% of maximum load
Tire Inflation Pressure: Base inflation pressure +20 kPa (2.9 psi), regulated

5.5 Test Speed

The test speed is 80 km/h (50 mph).

5.6 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 hour for passenger car and light truck tires, 2 hours 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 hours for passenger and light truck tires, 6 hours 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 hours or more for passenger and light truck tire, 6 hours 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 hour 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 minutes for passenger car tires
60 minutes for light truck tires
90 minutes for highway truck and bus tires

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

10 minutes for passenger car tires
15 minutes for light truck tires
30 minutes 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 3.6)

e. Tire base inflation pressure (see 3.3)

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 5.6)

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.