



Tire Rolling Resistance Test

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This standard is written to describe, in general terms, the methods used by GM to determine rolling resistance.

1.1.1 Rolling Resistance (RR) data are used for various purposes including correlation with test results from fuel consumption tests, tire comparisons, determination of load, pressure, and speed effects.

1.1.2 Method A. This version of the test procedure is the current standard method variant for testing tire rolling resistance to a single point RR test, based on ISO 28580. This standard is written for passenger car tires, using a 1.5 m thru 3.0 m rolling resistance test dynamometer under controlled laboratory conditions. In the context of globalization and supplier integration, determination of the rolling resistance of tires shall be performed according to ISO 28580.

1.1.3 Method B. This version of the test procedure is the current standard method variant for RR measurement of multiple, load, pressure, and speed conditions, based on SAE J2452. This standard is written for passenger car and light truck tires using a 1.7 m to 2.0 m rolling resistance test dynamometer under controlled laboratory conditions. Determination of rolling resistance of tires shall be performed using the procedure commonly referred to as the stepwise coast down method based on SAE J2452.

1.2 Applicability.

- Method A. For all passenger vehicle tires.
- Method B. It is restricted to controlled laboratory tests on passenger car and light truck tires. This standard applies to 1.7 m to 2.0 m drum RR measurements, force and torque method.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ISO 8767 ISO 28580 SAE J2452

2.2 GM Standards/Specifications.

GMW16590

2.3 Additional References.

- SAE Technical Paper 1999-01-0787: New Parameters for Comparing Tire Rolling Resistance

3 Resources

3.1 Facilities.

- Method A. Measuring institute and tire manufacturer test stands.
- Method B. Any test facility (General Motors or outside) that is providing data to the Method B variant procedure.

Note: Any outside testing facilities must have demonstrated an acceptable correlation with GM prior to submitting RR data.

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3.2 Equipment.

3.2.1 Method A. a 1.5 m thru 3.0 m rolling resistance test dynamometer

3.2.2 Method B.

3.2.2.1 Dynamometer and Controllers. Equipment required for 2.0 m RR testing consists of a 1.7 m to 2.0 m diameter laboratory test dynamometer, as well as the associated controllers and instrumentation as required for the test method in use. Refer to SAE J2452 for more detail.

3.2.2.2 Road Wheel. The road wheel surface dimensions and tolerances must conform to standards as described in SAE J2452.

3.2.2.2.1 The bare, without surface treatment, test drum must be between 1.70 m and 2.08 m in diameter.

3.2.2.2.2 The width of the drum test surface must be sufficient to accommodate the full tread width of the test tire-wheel assembly.

3.2.2.2.3 The surface of the test drum should be covered with 3M 80 degree grade (3M type or equivalent) to provide a first approximation to outdoor public highway surfaces.

3.2.2.3 Machine Control and Alignment. The test equipment must conform at all times to the machine control and alignment specifications (Table 1) in order to minimize variation in RR test data. For force method equipment, a crosstalk compensation method must be in place (most commonly the averaging of forward and reverse data). Refer to SAE J2452 for details.

Table 1: Machine Control and Alignment Specifications

Parameter	Tolerance
Tire Load	Greater of 20 N or 0.5%
Inflation Pressure	1.5 kPa
Test Wheel Speed	1.5 km/h
Ambient Temperature	4 °C
Loaded Radius	1 mm
Tire Load Fore Aft Offset	0.2 mm
Tire Load Angular Offset	0.3°
Tire Slip Angle	0.1°
Tire Inclination Angle	0.2°

3.2.2.4 Instrumentation Accuracy. Instrumentation accuracy must adhere to standards set per SAE J2452.

3.2.2.5 Machine Control Accuracy. Machine control accuracy must adhere to standards set per SAE J2452.

3.2.2.6 Test Wheels. The test wheel must have a contour and width as specified on the work request, and the wheel should be the recommended size for the particular tire to be tested. Test wheel run out must meet specifications for new wheels; radial run out ≤ 0.25 mm, lateral run out ≤ 1.14 mm. Wheel width must be reported with test results.

Note: All efforts should be made to use the correct wheel width, but under some circumstances a wheel width within 1.5 cm may be used with the agreement of the requester of the data.

3.2.2.7 Tire Loaded Radius. Tire loaded radius values must be measured and provided with all test data. These data are later used to estimate flat surface rolling resistance values.

3.2.2.8 Test Measurement Methods. Two (2) test methods are in common usage (Force Method and Torque Method). The two (2) methods should yield the same test result, and all RR data reported to and stored in GM databases must be provided in terms of net tire spindle force. See brief discussion of each test method in 3.2.2.8.1 and 3.2.2.8.2.

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3.2.2.8.1 Force Method. This method directly measures the longitudinal spindle force of the test tire-wheel assembly. The major disadvantage of this method is that axle and load cell misalignment can introduce significant error.

3.2.2.8.2 Torque Method. This method measures the steady state torque required to turn the test drum while the test tire-wheel assembly is loaded against it. The RR at the tread surface can be calculated by dividing net torque by the test wheel radius. The primary disadvantage of this method is that parasitic losses are large relative to measured RR and must be subtracted from the gross torque value. Additionally, the loaded radius of the tire must be measured to accurately convert RR force at the tread surface to RR force at the spindle.

3.3 Test Vehicle/Test Piece.

3.3.1 Method A. Passenger vehicle test tires.

3.3.2 Method B. Passenger and light truck tires. A sample size of four tires should be tested to determine rolling resistance levels for a given construction.

3.4 Test Time.

Calendar time:	1 d
Test time:	Passenger tire: 2.5 h Light Truck tire: 3.5 h
Coordination time:	1 h

3.5 Test Required Information.

3.5.1 Method B. Exact list of required information is determined by the local test site. Required information includes tire size, construction number, load rating, service description, and wheel width.

3.6 Personnel/Skills. Method B. Test operator should have adequate training and be familiar with the local operators' procedure.

4 Procedure

Method B. Test is performed according to the SAE J2452 procedure. Some additional details and clarifications have been provided in this document.

4.1 Preparation. Method B. A test tire is mounted on the wheel specified in the tire test request. If tires had been kept in temperature conditions significantly different than target temperature, allow tires time to reach the target temperature range prior to testing. The tire is then inflated to the maximum inflation pressure shown on the tire sidewall. The test assembly must then be placed for a minimum of 3 h in an area where ambient temperature is maintained at a constant temperature of $24^{\circ}\text{C} \pm 4^{\circ}\text{C}$.

4.2 Conditions. Operating conditions are limited to free rolling tires at steady state rolling resistance with zero slip and inclination angles.

4.2.1 Environmental Conditions.

- Method A. According to ISO 28580.
- Method B. Test area shall be maintained at $24^{\circ}\text{C} \pm 4^{\circ}\text{C}$ ($75^{\circ}\text{F} \pm 7^{\circ}\text{F}$).

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 Method B.

4.2.2.1.1 Warm Up Conditions. Refer to SAE J2452 for a discussion on test tire warm up. GM North America (GMNA), uses a fixed time of 30 minutes for passenger tires and 45 minutes for truck based on the RR equilibrium criteria.

4.2.2.1.2 Test Conditions (Load, Pressure, and Speed). The stepwise coast down test is run at multiple test conditions in order to quantify rolling resistance over a given range of load, pressure, and speed. Refer to SAE J2452 for a discussion of these test conditions. Test loads and inflation pressures for each test step must conform to conditions described in SAE J2452. Speed conditions must conform to SAE J2452. The skim step is an added test condition set at a very low load (100 N for passenger and 150 N for light truck) required to define

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the parasitic losses of the equipment. By subtracting the skim step, the machine to machine differences can be minimized. Refer to SAE J2452 regarding discussion of the skim step.

These test conditions are all summarized in Appendix A, Tables A1 thru A6 for clarification.

4.3 Instructions.

4.3.1 Method A. Test will be performed according to ISO 28580.

4.3.2 Method B.

4.3.2.1 Installation and Warm Up. After mounting and thermal conditioning is completed as described, the test assembly is then installed in the test machine and inflated. The outer diameter is measured with a pi tape or other methods with validated accuracy. The tire is loaded, and accelerated to a stabilization speed of 80 km for the appropriate warm up time (30 minutes for passenger tires and 45 minutes for light truck tires).

4.3.2.2 Data Collection at Each Test Condition. After the tire is stabilized for the first test condition, the data is collected during the defined speed sweeps and road wheel directions. The load and inflation pressure values are then changed for the next test step condition. The test assembly is again allowed to stabilize at the new test step condition (10 minutes for passenger tires and 15 minutes for light trucks), and data is again collected for the defined speed sweep and road wheel directions. This process continues until RR has been measured for all defined test conditions.

5 Data

5.1 Calculations.

5.1.1 Method A. See ISO 28580 for calculation details.

5.1.2 Method B. A summary of the data analysis is provided in Appendix B: Rolling Resistance Data Analysis Procedure for Method B for the details of this analysis.

5.1.2.1 The machine measured RR data are adjusted to account for deviations in ambient temperature from the ambient reference temperature.

5.1.2.2 The temperature corrected RR values are adjusted as appropriate to determine the net tire spindle force.

5.1.2.2.1 If force method is used, data are compensated for crosstalk and axle misalignment.

5.1.2.2.2 If torque method is used, transform torque data to spindle data.

5.1.2.2.3 In both cases, parasitic losses (skim step) is subtracted from the measured data.

5.1.2.3 The appropriate correlation equation is applied to the net spindle force data to correct for any machine differences to yield correlated RR data (comparable to the Tire and Wheel System (TWS) Master RR Station (DynoH 2.0 m Drum)).

5.1.2.4 The correlated RR data are then regressed to determine the RR response surface, defined with a five (5) coefficient equation. RR response surface coefficients are determined, recorded, and used to calculate other parameters as needed.

5.2 Interpretation of Results.

5.2.1 Method A. The measurement results shall be compared to the results for the reference tires in the specifications. The rolling resistance coefficient (c_R) for the test tire and the c_R reference value for the reference tire shall be determined.

5.2.1.1 Rolling Resistance Coefficient c_R . Tire rolling resistance is characterized by a rolling resistance coefficient written as c_R and equal to: $c_R = F_R/F_z$

By definition, a coefficient is a value without units. In this case, rolling resistance force (F_R) and tire radial load (F_z), are both expressed in newtons in compliance with standard international units. The rolling resistance coefficient c_R is, as it should be, a value without units. The expression "kg/t" is often favored, with this test method.

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5.2.1.1.1 Example. Force (F_R) is often expressed using the old unit of "kilogram force" and load using "tonne force", in which case the coefficient is expressed in kilogram/ton. A coefficient of 0.012 is, therefore, equivalent to a coefficient of 12 kg/t. The expression "12 kg/t" means that if the tire is supporting a load of one (1) tonne, 12 kg need to be applied to avoid losing speed due to rolling resistance. To take another illustration, when a vehicle is being driven with tires having a rolling resistance coefficient of 12 kg/t, it is using the same amount of energy as if it were climbing a slope of 1.2%.

5.2.2 Method B. See sourcing documents.

5.3 Test Documentation.

5.3.1 Method A. The results shall be represented in a test report with reference to this test procedure.

5.3.2 Method B. The test results documentation should include:

- Test results report (generated by Global Tire-Wheel Test System (GTWTS) if submitting Extensible Markup Language (XML) files).
- Test result data files (XML format) including a composite XML.
- .dat files.

The list of required test data parameters is given in Appendix C, Table C1. A sample test system report is given in Appendix D, Figure D1. In Appendix E, Figure E1, an example of the Excel Report that can be found in the attachments section of the test system. This Excel report form is the most convenient for copying data from the report.

Note: For data being loaded into the GTWTS, submit electronically the test results data files (XML format) and other supporting files listed. GMW16590 defines the electronic file details, (e.g., file types, file naming convention, and detailed file formats) for the GTWTS.

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

7 Notes

7.1 Glossary.

Ambient Reference Temperature: Variation in tire RR occurs with changes in ambient temperature, so RR values must be adjusted to a reference ambient temperature of 24 °C. Refer to SAE J2452 for more information.

Ambient Temperature: The temperature of the air measured at a fixed location near the test tire during a rolling resistance test. This temperature is measured at a lateral distance of 0.4 m from either rim flange at the point farthest from the test surface, See SAE J2452. Units are in degrees Celsius.

Base Inflation Pressure: The minimum pressure associated with the maximum load capacity of the tire. The maximum inflation pressure as molded on the tire sidewall, can be used with the table shown in Appendix A, to determine the correct base inflation pressure.

Capped Inflation Pressure: Capped inflation pressure involves inflating the tire, prior to testing, to the required pressure while the tire is at the ambient temperature of the test area, and then sealing the tire with a valve, cap, or other method. As a result of capping, tire inflation pressure will increase during testing as the tire increases in temperature.

Crosstalk (Force Measurement Method Only): The error in machine spindle force measurement due to load misalignment and interaction between load and spindle force transducers. Units are in Newtons.

Gross Tire Spindle Force (Force Measurement Method Only): The force obtained by subtracting the appropriate crosstalk and axle misalignment values from the machine measurements. Units are in Newtons.

Loaded Radius: The minimum perpendicular distance between the loaded tire-wheel assembly axis of rotation and the surface on which it is rolling. Units are in millimeters.

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Machine Measurements: Tire spindle force, or torque measurements which are obtained at the test machine prior to any compensation for crosstalk and axle misalignment, parasitic losses, or ambient temperature. Units are in Newtons for the force method and Newton meters (Nm) for the torque method.

Master Test Station: The test station to which all other test stations are correlated. For GM, this is the 2.0 m Drum Reference, Dyno H.

Maximum Load: The maximum load a tire is capable of carrying for extended periods of time. The maximum load value is molded into the tire sidewall and listed as the maximum load corresponding to the tire's load index. For light truck tires, maximum load is defined as the maximum load, or load limit, as specified for single tire operation. Units are in Newtons.

Net Tire Spindle Force: (Force Measurement Method Only): The forces at the machine spindle due to tire RR only. It is obtained by subtracting the appropriate parasitic loss from the gross tire spindle force. Units are in Newtons.

Parasitic Loss: The error in tire RR measurement due to machine friction and tire wheel assembly aerodynamic losses. Units are in Newtons for the force method and Newton meters (Nm) for the torque method.

Regulated Inflation Pressure: Regulated inflation pressure involves inflation of the tire to required pressure independent of its temperature, and then maintaining this inflation pressure during testing via an external regulation device. In this case, tire inflation pressure will remain constant during testing regardless of tire temperature.

Rolling Resistance: The scalar sum of all contact forces tangent to the test surface and parallel to the wheel plane of the tire. In the case of Method B, RR is reported and stored in two (2) forms. The first is the curved RR at spindle, and the second is the flat RR at the surface. Both units are in Newtons.

Rolling Resistance Coefficient (RRc) Method B: The ratio of tire RR to tire radial load. For example, the RRc at the Standard Reference Condition (SRC) would be defined as the SRC RR (N) divided by the SRC load (N). Units are Newton per Newton of radial load.

Rolling Resistance Equilibrium: A tire is said to have achieved equilibrium when its RR does not change over time under constant operating conditions. In the context of this laboratory test, equilibrium is attained when the tire's contained air temperature has stabilized for a given load, inflation, speed, and ambient temperature, resulting in a relatively constant RR.

Skim: The skim step is an added test condition set at a very low load (100 N for passenger and 150 N for light truck) required to define the parasitic losses of the equipment.

Standard Mean Equivalent Rolling Force (SMERF): The average RR of a tire at the SRC load and inflation pressure over a driving cycle with a specified speed time profile. This value implicitly weights the RR for each speed in the cycle, using the length of time spent at that speed during the cycle. The final SMERF value is obtained by combining the weighting of individual SMERFs calculated using the standard Environmental Protection Agency (EPA) urban and highway driving cycles. More specifically, this weighting is 55% for the EPA Urban Federal Test Procedures (FTP) Cycle and 45% for the EPA Highway Fuel Economy Cycle. Refer to SAE Technical Paper 1999-01-0787 for detail on the development and usage of SMERF. Units are in Newtons. After removing the near zero points in the average speed calculations, GM uses an urban speed of 42.17 km/h and a highway speed of 78.19 km/h.

Note: The definitions are used to further describe the GM RR test and test methods. They do not necessarily have SAE International (SAE) equivalents.

Standard Reference Condition (SRC): A single set of standardized values of tire load, inflation pressure, and speed specified such that tires can be compared at a single condition. The SRC depends on tire type and size, e.g., for the stepwise coast down test, standard load passenger car tires have an SRC tire load of 70% of the maximum load, inflation pressure of 260 kPa, and speed of 80 km/h. Refer to Appendix A: Rolling Resistance Test Conditions for Method B for a list of SRC for stepwise coast down tests.

Standard Reference Condition Rolling Resistance (SRC RR): A single RR value corresponding to the SRC tire load, inflation pressure, and speed. This value is useful in comparing different tire constructions at a single test condition. Units are in Newtons.

Stepwise Coast down Method: This method is described in SAE J2452. It involves multiple test conditions where load, inflation pressure, and speed are varied. In this method, test speeds range between 15 km/h and 115 km/h.

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