

**The Measurement of Highway
Truck and Bus Tire
Rolling Resistance—
SAE J1380 AUG83**

SAE Information Report
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SAE Information Report

Report of the Truck and Bus Fuel Economy Committee, approved June 1982, revised August 1983.

1. Introduction—This information report is a companion document to SAE Recommended Practice, J1379, "Rolling Resistance Measurement Procedure for Highway Truck and Bus Tires." It provides background information and explanations related to the use of the measurement procedure and follows the same format as SAE J1379.

2. Scope

2.1 Basic Methods—The force, torque, and energy methods of measurement are all in common use and should yield the same test results. Effects of steering, traction, and non steady-state tire operations are excluded from the recommended practice because they are still in the research stage. Methods of correcting laboratory data to road conditions are being developed.

2.1.1 FORCE METHOD—The chief advantage of the force method is that the only parasitic losses in the measurement are tire spindle bearing losses and aerodynamic losses associated with rotation of the tire and wheel assembly. The main disadvantage is that the small longitudinal spindle force, which includes the rolling resistance, may be seriously affected by the very large tire vertical load or by transducer crosstalk. The elimination or compensation of both effects is necessary. A secondary disadvantage is that the loaded radius of the tire must be measured in order to convert spindle force to rolling resistance.

2.1.2 TORQUE METHOD—The torque method has the advantage that the measurement is direct and simple, as the rolling resistance is merely the torque reading divided by the laboratory test wheel radius. Equipment can be calibrated to read directly in rolling resistance if so desired. The main disadvantage of the torque method is that the parasitic losses contained in the measurement include test wheel losses as well as tire spindle rotational losses.

The parasitic losses are larger than for the force method and can be of the same order of magnitude as the rolling resistance itself. Another disadvantage is that speed-hunting oscillations in the drive motor can introduce errors.

2.1.3 ENERGY METHOD—The advantage of the energy method is the low cost and simplicity of instrumentation. No force or torque transducer is necessary. A voltmeter and an ammeter to measure the electrical energy input to the drive system are sufficient. The chief disadvantage of the energy method is that electrical losses are included in the measurement, in addition to all the other parasitic losses of the system. Thus, the parasitic losses are even larger than for the torque method. In some laboratory environments, special control may be needed to prevent line voltage fluctuations from creating power surges which can distort the readings.

3. Definitions

3.1 Rolling Resistance—No further background information is required in this section.

3.2 Rolling Resistance Coefficient—No further background information is required in this section.

3.3 Loaded Radius—No further background information is required in this section.

3.4 Maximum Load—The tire load limits specified by the Tire and Rim Association, Inc.,¹ are expressed in pounds (lb) or kilograms (kg), which are units of mass. For use as TRA design loads in the recommended practice, they must be converted to units of force, either the pound-force (lbf) or the Newton (N).

3.5 Rated Pressure—No further background information is required in this section.

3.6 Capped Air—No further background information is required in this section.

3.7 Regulated Air—No further background information is required in this section.

4. Test Equipment—Test equipment in use for the measurement of rolling resistance ranges from vehicles operated on roadways to machines simulating twin-roll dynamometers. The most common equipment is the 67.23 in (1.7076 m) diameter laboratory test wheel. An objective of this recommended practice is to provide a test procedure which the majority of test organizations can adopt as standard. Therefore, the test wheel serves as a standard for the procedure. However, flat-surface laboratory

test apparatus is being developed at a pace which may soon bring it into common use. The recommended practice can be used without modification when such equipment becomes commonly available. Note that results from a laboratory flat surface test machine and a laboratory test wheel may be somewhat different because of the greater deflection of a given tire under a given load on the curved test wheel surface.

4.1 Test Surface

4.1.1 TEST WHEEL DIAMETER—Most standard laboratory test wheels have a diameter of 67.23 in (1.7076 m)² derived from a surface distance conversion of 300 revolutions per mile.

4.1.2 WIDTH—Most laboratory test wheels have a surface width of at least 12 in (0.30 m).

4.1.3 TEXTURE—Rolling resistance has been shown to be a function of the surface texture on which the tire rolls. Rolling resistance is least on a polished smooth surface and increases with surface roughness. The selection of a medium-coarseness abrasive-type surface for this test procedure is designed to simulate results on a dry, well-maintained public roadway. The reference to 3M Safety-Walk is intended as one example of the type of surface texture recommended, not as a product endorsement. Periodic renewal of the surface may be necessary because of contamination or wear.

4.2 Test Rims—The test rim selected should represent a rim used as original equipment and conform to TRA specifications. Because of the wide variety of rims available for some tire sizes, and because the rim may affect rolling resistance, it is important to report test rim width and contour along with the test results. The rim runout limits are selected on the basis of commonly accepted original equipment specifications.

4.3 Alignment and Control Accuracies—The limits specified are necessary to provide inter-laboratory rolling resistance comparisons within $\pm 5\%$ of the nominally selected test conditions. The accuracies given are intended to cover variations about the specified mean values (standard deviations); they do not include perturbations due to tire and rim non-uniformities.

All of the alignment values can be measured without a tire or wheel installed on the spindle and the required accuracy can be maintained by using appropriate fixtures and commonly available measuring devices. A machine utilizing cantilevered spindles with a horizontal spin axis and horizontal radial load sees an increase in slip angle caused by the weight of the tire and wheel assembly. If the rotation of the roadwheel is such that the tangential force is upward, it would counteract the downward force of the tire/wheel weight. This would be beneficial to all three methods since it would minimize slip angle misalignment. Geometric corrections may still be necessary for misalignments.

Average ambient temperature should be measured adjacent to either sidewall approximately 15 in (0.4 m) from the tire. The ambient temperatures should be measured over a sufficient period of time during each step of the test to determine a representative average. Current research indicates that significant variations in rolling resistance can occur with variations in temperature. The functional relationship between rolling resistance and temperature appears to be linear over the temperature range of interest. However, the function may differ among tires of different constructions or made with different materials. Available laboratory test results show that rolling resistance varies with ambient temperature. The approximate range of variation is -0.08 to -0.14 lbf/°F (-0.64 to -1.12 N/°C) for highway truck tires at average dual load and inflation conditions. Since this is a significant effect, all rolling resistance data should be corrected to 75°F (24°C) by means of a suitable correction equation.³

4.3.1 FORCE METHOD—The geometric misalignment forces can be removed by a suitable static machine calibration, which can be combined with the spindle transducer crosstalk calibration. A bi-directional rotation test can also be used to estimate the misalignment force.

4.3.2 TORQUE METHOD—The effect of slip angle misalignment will be small if kept within the specified tolerance. The torque variation due to

² Conversion 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.

³ See for example, D. J. Schuring and G. L. Hall, "Ambient Temperature Effects on Tire Rolling Loss," Rubber Chemistry and Technology, 54, 5, 1981, 1113-1123.

speed-hunting oscillations can be filtered out electronically.

4.3.3 ENERGY METHOD—This method is affected by slip angle misalignment to the same degree as the torque method. It is desirable to control surface speed to ± 0.5 mph. If that is not possible (various motor speed controls have different control characteristics), the input electrical power should be averaged over several minimum-to-maximum speed cycles and the average speed for those cycles used in the rolling resistance calculation.

4.4 Instrumentation Accuracy—The values selected represent good instrumentation practice using modern equipment. In laboratories where more accurate instruments are available, better measurement resolution is encouraged. The specific values recommended are adequate for resolution within 0.5 lbf (2.2 N) on a tire carrying nominally 5000 lbf (22 000 N) of normal load and producing 25 lbf (111 N) of rolling resistance. Better absolute resolution may be readily available for tires carrying smaller loads. If good instrumentation practice and a combination of instrument accuracies provides repeatable data within 0.5 lbf (2.2 N) and $\pm 1\%$ of the maximum measured rolling resistance force for the tire in question, then such a system may be considered "equivalent" to the recommended accuracies.

4.4.1 FORCE METHOD—This method requires measurement of spindle force and loaded radius. The force measurement must be very precise; it requires careful selection or specification of current technology equipment.

4.4.2 TORQUE METHOD—This method requires precise measurement of input torque. Modern torque cells may require separate over-torque protection to provide the needed resolution.

4.4.3 ENERGY METHOD—This method requires precise measurement of electrical power and speed. Various combinations of voltage and amperage resolution are necessary depending on the typical voltage required for the particular motor running the test wheel at 50 mph (80 km/h). The speed resolution required for this method is higher than for the other methods because the average speed during the measurement interval is used in the calculation of rolling resistance.

4.5 Measurement of Load Interaction Effects—Force Method—Any force method measuring system can be subject to load interaction errors which might result from such sources as transducer design, gaging precision, and machine and transducer alignments. If the spindle force method of measurement is used, the influence of applied load on the observed spindle force must be carefully determined.

One satisfactory procedure is to measure the equilibrium rolling resistance for a selected tire in both the forward and the reverse directions. It is assumed that the bearing losses, windage losses, and tire rolling resistance are equal in magnitude but opposite in direction between forward and reverse rotation. However, the load interaction errors do not change direction with changes in rotation. The algebraic average of the forward and reverse readings is then representative of the load interaction error.

Another procedure for determining the load interaction effect is through use of mechanical fixturing. The difficulties involved in this technique can lead to calibration errors in practice.

An acceptable procedure, when repeated for multiple loads, provides an assessment of overall system load interaction errors as a function of the load. If expressed mathematically, it may be easily utilized during the data reduction process.

5. Test Conditions

5.1 Test Speed—A single speed is recommended for test efficiency because rolling resistance at equilibrium (steady state) is relatively insensitive to speed over the range from 20–60 mph.

As noted in Section 2, this procedure is limited to measurements at steady-state conditions only.

5.2 Load and Inflation Pressure—Testing of the tire in dual mounting or other special conditions is not included in this procedure. The recommended loads and inflation pressures cover the range of values experienced in actual vehicle usage. Since the primary application of the subject tire is in a dual configuration, the load and inflation pressure of the single test tire shall be related to the dual load and inflation as found in the Tire and Rim Association Handbook.

The single capped test condition in combination with the four regulated test conditions constitute the basis for predicting rolling resistance over a wide range of operating conditions (see paragraph 8.3). The accuracy of the predicted values may be compromised if other than these specific test points are used. Where such predictions are not needed, significant

information can be obtained by using the capped condition only.

5.3 Test Sequence—Experiments have shown that steady-state conditions are achieved more quickly for a step of decreasing rolling resistance. Thus, in order to minimize the duration of the total test and at the same time obtain the maximum degree of assurance that steady-state values are achieved at all test conditions, testing in the order of decreasing values of rolling resistance is recommended. Therefore, the initial warm-up is done at maximum thermal input; and the succeeding test conditions at minimal thermal adjustments.

6. Test Procedure

6.1 Break-In—For tires undergoing significant growth upon first operation, an initial break-in at 50 mph (80 km/h) under Maximum Load and Rated Pressure is recommended (see SAE J1379 definitions 3.4, 3.5, and 3.6). The recommended break-in period is 2 h under Capped Air conditions, followed by a cool-down to the ambient test room temperature of at least 6 h. This cool-down period would be the thermal conditioning recommended below (paragraph 6.2). If the tire has been undergoing other tests, such as temperature-rise tests, prior to the rolling resistance test, then break-in may not be necessary.

6.2 Thermal Conditioning—Thermal conditioning is recommended to avoid inadvertent testing of a tire which has just been removed from an extremely hot or cold storage location. Without such conditioning, the thermal state of the tire immediately prior to test could distort the test results and jeopardize comparison with other tires which have different thermal histories. The physical arrangement of many test laboratories is such that ambient conditions and the logistics of tire storage and preparation satisfy the thermal conditioning requirement and eliminate the need for any special arrangements.

6.3 Warm-Up—The duration of the warm-up time required at each set of test conditions depends on the tire itself. The recommended values have been found to be generally satisfactory. There is evidence that some tires may require more time, especially those with carcass material which has a thermally-sensitive modulus, e.g., nylon. Thus, the warm-up times given in the recommended practice are only a guide. The user of the procedure must ensure to his own satisfaction that a steady state has been achieved for each reading, especially when alternative test conditions are selected.

6.4 Measurement and Recording

6.4.1 IDENTIFICATION—No further background information is required in this section.

6.4.2 TEST VARIABLES—Measured values of load, inflation pressure, speed, etc. should be reported for data analysis purposes.

6.5 Measurement of Parasitic Losses—Parasitic losses consist of aerodynamic loss, bearing friction, and other sources of systematic errors which may be inherent in the measurement. Many sources of parasitic losses (e.g., bearing torque and laboratory test wheel drive belt losses) tend to be temperature dependent. The existence of such temperature dependence should be determined before relying upon a single parasitic loss measurement to correct a large set of data. If the parasitic losses are found to be temperature dependent, then either a parasitic loss measurement needs to be made immediately following each tire rolling loss measurement or one must make certain that a constant reference temperature has been reached for the measuring equipment prior to each tire measurement and before a parasitic loss measurement. Of the various possible measurement techniques, the two described in the procedure are most common.

6.5.1 SKIM READING—During a skim reading, the tire must be kept rolling without slippage while the tire load is reduced to the level at which the energy loss within the tire itself is practically zero. Various methods have been devised to approximate this condition in a reproducible fashion. Some laboratories attempt to control the load at some small value, e.g., 20 lbf (90 N). Others use a subjective evaluation or "feel" of the torque required to stop the tire. An actual measurement of the rotational velocity of the tire is probably the most reliable. In any case, the choice of the method used is left to the individual laboratory. The skim reading accounts for the parasitic losses under practically no-load conditions. In most instances, the reading adequately represents the parasitic losses under test load. If greater refinement of the data is necessary, additional information about the effect of load, for example, on bearing friction, must be determined.

6.5.2 MACHINE OFFSET READING—A machine offset reading accounts for the parasitic losses of the test machine exclusive of the losses in the rotating spindle which carries the tire and rim. The measurement is extremely simple, reliable, and reproducible. For this reason, most laborato-