



Tire Braking Traction

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. The purpose of this test procedure is to describe a method to determine the braking traction performance of passenger and light truck tires under specified conditions.

This procedure describes the test equipment, test conditions, and test tire preparation requirements.

1.2 Applicability.

1.2.1 This test procedure provides a method to determine the braking traction performance of passenger and light truck tires under specified conditions.

1.2.2 The measured surface friction values obtained with the equipment and procedures stated herein may not necessarily agree or correlate directly with those obtained by other surface friction measuring devices.

1.2.3 Specifications in this procedure refer to an industry defined 2k Skid Trailer Measurement System capable of 8.9 kN (2000 lbf) vertical test load.

1.3 Remarks.

1.3.1 This test uses a tow vehicle and a two (2) wheel test trailer with a specially instrumented axle to measure the fore-aft and vertical forces on a tire during braking. Test wheel speed and vehicle speed are also measured.

1.3.2 The procedure is used primarily for determining the braking traction performance of a tire relative to a specified control tire or to other tires tested under similar test conditions.

1.3.3 This test procedure closely follows ASTM F408 and ASTM E274, but may differ in some details.

2 References

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

2.1 External Standards/Specifications.

ASTM D2240

ASTM E1136

ASTM F408

ASTM F457

ASTM E274

2.2 GM Standards/Specifications.

GMW16590

2.3 Additional References.

- Component Technical Specifications (CTS)
- Engineering Source Approval Document
- European Tyre and Rim Technical Organisation (ETRTO) Yearbook (Current Issue), Brussels, Belgium (www.etrto.org)
- Rubber Manufacturers Association (RMA), Washington DC, (www.rma.org)
- The Tire and Rim Association, Incorporated (T&RA) Yearbook (Current Issue), Copley, Ohio (www.us-tra.org)

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3 Resources

3.1 Facilities. Refer to 4.2.1 for a description of the facility requirements.

3.2 Equipment.

3.2.1 The test vehicle system consists of a specially fabricated test trailer and tow vehicle.

3.2.1.1 Tow Vehicle. The tow vehicle shall have the capability of towing and maintaining the trailer at specified test speeds in the prescribed range. Speeds are to be kept constant to within specified limits through all levels of application of braking forces. The tow vehicle also serves as a test control and data readout center.

3.2.1.2 Towed Trailer. The test trailer is instrumented to measure the vertical and longitudinal forces at the tire/test surface interface with braking torque applied. The rate of brake application shall be sufficient to control the time interval between the brake application and peak braking force to be between specified tolerances.

3.2.1.3 Vertical Load. The trailer design must allow application of specified static vertical loads on the test wheel and a static down load of 10% to 15% of the static vertical load at the hitch point.

3.2.2 Test Control Tolerances.

3.2.2.1 Test Load: ± 22 N (± 5 lbf).

3.2.2.2 Test Speed: ± 0.8 km/h (± 0.5 mph).

3.2.2.3 Brake application ramp time should be targeted at $0.75 \text{ s} \pm 0.25 \text{ s}$ between initial brake application and peak braking force.

3.2.2.4 External Water Depth: $1.25 \text{ mm} \pm 0.25 \text{ mm}$ ($0.050 \text{ in} \pm 0.010 \text{ in}$) above surface texture depth.

3.2.2.5 Test Trailer Suspension: Each of the trailer wheels shall have a suspension capable of holding toe and camber changes to within ± 0.05 degrees with maximum vertical suspension displacements under both static and dynamic conditions.

3.2.3 Instrumentation.

3.2.3.1 The instrumentation system shall conform to the following overall requirements at operating temperatures between 4°C and 38°C (40°F and 100°F).

3.2.3.2 Overall System Accuracy Requirements. Overall error is not to exceed $\pm 1.5\%$ of applied load from 900 N (200 lbf) to full scale; for example, at 900 N (200 lbf), applied calibration force of the system output shall be determinable within ± 15 N (± 3 lbf). The tire force measuring transducer shall be of such design as to measure the tire-pavement interface force with minimum inertial effects. Transducers are recommended to provide an output directly proportional to force with hysteresis $< 1\%$ of the applied load, nonlinearity $< 1\%$ of the applied load up to the maximum expected loading, and sensitivity to any expected cross-axis loading or torque loading $< 1\%$ of the applied load. The force transducer shall be mounted in such a manner as to experience < 1 degree angular rotation with respect to its measuring plane at the maximum expected loading.

3.2.3.3 The exposed portions of the system shall tolerate 100% relative humidity (rain or spray) and all other adverse conditions, such as dust, shock, and vibrations, which may be encountered in highway operations.

3.2.3.4 Braking Forces. The braking force measuring transducer shall measure longitudinal reaction force within a range between 0 kN and 8.9 kN (0 lbf and 2000 lbf) generated at the tire-pavement interface as a result of brake application.

3.2.3.5 Vertical Load. The vertical load measuring transducer shall measure the vertical load at the test wheel during brake application. The transducer shall have the same specifications as those described in 3.2.3.2 and 3.2.3.3.

3.2.3.6 Vehicle speed measuring transducer shall provide speed resolution and accuracy of ± 0.4 km/h (± 0.25 mph). Output shall be directly viewable by the driver and shall be simultaneously recorded. Vehicle speed measuring systems shall conform to Method ASTM F457.

3.2.3.6.1 Test wheel speed measuring transducers attached to the wheel spindle shall provide speed resolution and accuracy of ± 0.4 km/h (± 0.25 mph) during all transient braking torque applications.

3.2.3.6.2 All speed signal conditioning and recording equipment shall provide linear output and shall allow data reading resolution to meet the requirements of 3.2.3.6 and 3.2.3.6.1.

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3.2.3.7 All strain gage transducers shall be equipped with shunt calibration resistors or equivalent that can be connected before or after test sequences. The resultant shunt calibration signal shall be at least 50% of the normal vertical load and shall be recorded.

3.2.3.8 A digital data acquisition system shall be used to record the unfiltered braking force, vertical load, test wheel speed, and vehicle speed. All data channels shall be simultaneously sampled at a minimum of 100 Hz.

Note: Vehicle speed can be analog filtered to remove noise if necessary for meter readout, etc., since this is basically a steady-state signal.

3.3 Test Vehicle/Test Piece.

3.3.1 Control Tire. ASTM E1136 which is a Uniroyal P195/75R14 Tiger Paw.

3.3.2 Test Tires. Test pieces provided by requestor.

3.4 Test Time.

Calendar time: 1 day

Test hours: 4 hours

Coordination hours: 4 hours

3.5 Test Required Information.

- Tire Size
- Tire Manufacturer
- Test Rim Width Code
- Test Load
- Test Pressure
- Test Speed
- Test Type (Peak only or Peak/Slide)
- Test Surface
- Test Surface Condition

3.6 Personnel/Skills. The test operator is to be fully trained in the operation of the tire braking traction skid trailer system.

4 Procedure

The typical braking traction test for General Motors is a peak/slide wet test at 32 km/h and 97 km/h followed by a peak-only dry test at 64 km/h. For specific tire development programs, the data requirements may vary and are noted on the tire Component Technical Specification (CTS). Therefore, refer to the tire CTS for the specific test procedures that may be required.

The braking traction measurements are conducted with a test tire mounted on the test trailer towed by a vehicle. The trailer contains a transducer, instrumentation, and actuation controls for the braking of the test tire.

The test apparatus is brought to specified test speed. The brake is progressively applied until sufficient torque results to exceed the maximum tire braking force (peak traction). The brakes can then be immediately released for peak only (or chirp) tests, or locked up to allow sliding traction measurements. Longitudinal force, vertical load, test wheel speed, and vehicle speed are recorded with the aid of suitable instrumentation and data acquisition equipment.

The slide and/or peak braking coefficients of the tire/road surface are determined for each application of brake torque.

4.1 Preparation.

4.1.1 Test Tires Preparation and Use.

4.1.1.1 All test tires should be approximately of the same age and shall have been stored at essentially the same conditions prior to testing.

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4.1.1.2 Test tires shall be stored in a moderate temperature environment and be protected from excessive heating by solar radiation.

4.1.1.3 Mount test and control tires using Rubber Manufacturers Association (RMA) approved methods on the appropriate test rim as specified in 4.2.2.2, avoiding the excessive use of bead lubricants and insuring the proper direction of rotation when mounted on the test trailer.

4.1.1.4 Remove labels and like items from the tread surface of the tire.

4.1.1.5 Tires shall not show visual evidence of grinding to correct runout or uniformity.

4.1.1.6 Check the test tires for the specified inflation pressure at ambient temperature, cold, just prior to testing. The test tire inflation pressure shall be as specified in 4.2.2.1.

4.1.1.7 All test tires shall be preconditioned prior to initial testing. Pretest conditioning is to be done only once per tire and prior to any actual test measurements.

4.1.1.7.1 Pretest tire conditioning shall be conducted on a dry surface. Each tire shall be chirped ten (10) times at 32 km/h (20 mph) under test load and meet the requirement in 3.2.2.3. It is recommended these chirps be applied and recorded under normal test control mode (not manual mode) for consistency of brake apply and to provide reference for actual test setup.

4.1.1.8 Measure and record durometer of each tire prior to break-in following ASTM D2240.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Standard Test Surfaces. Surfaces shall meet the requirements in 4.2.1.1.1 and 4.2.1.1.2.

4.2.1.1.1 Dry Test Surface. A clean, level or slightly graded, well maintained coarse aggregate asphaltic with peak and slide coefficients of this surface when measured with the ASTM E1136 tire at 64 km/h as follows:

- 64 km/h Peak Coefficient: 0.90 ± 0.05
- 64 km/h Slide Coefficient: 0.65 ± 0.05

4.2.1.1.2 Wetted Test Surface. A clean, level or slightly graded, concrete or asphaltic concrete which has been constructed or modified to exhibit the following recommended peak and slide coefficients when measured with the ASTM E1136 tire as follows:

- 32 km/h Peak Coefficient: 0.52 ± 0.10
- 32 km/h Slide Coefficient: 0.31 ± 0.10
- 97 km/h Peak Coefficient: 0.39 ± 0.10
- 97 km/h Slide Coefficient: 0.22 ± 0.05

4.2.1.1.2.1 Adequate wind fence protection must be provided to minimize the influence of wind on water distribution.

4.2.1.1.2.2 The wetted surface watering distribution system must provide adequate water depth control. Water depth must be maintained at $1.25 \text{ mm} \pm 0.25 \text{ mm}$ ($0.050 \text{ in} \pm 0.010 \text{ in}$) above peak surface texture depth.

4.2.1.1.2.3 Water Depth. The water depth measurement must be accurate to within $\pm 0.125 \text{ mm}$ ($\pm 0.005 \text{ in}$).

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.

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4.2.2.1 Test Load Conditions. Reference Table 1, where the tire load capacity is to be determined by the appropriate tire and rim standardizing body such as The Tire and Rim Association, Incorporated (T&RA) or European Tyre and Rim Technical Organisation (ETRTO).

Table 1: Tire Test Load Conditions and Inflation Pressures

Tire Type	Test Load	Inflation Pressure
Passenger Car	70% of the maximum tire load capacity	250 kPa
Light Truck Metric	70% of the 350 kPa maximum tire load capacity	350 kPa
Compact Spare	70% of the maximum tire load capacity	420 kPa
ASTM E1136 SRTT	4586 N (1031 lbf)	250 kPa

Note: SRTT = Standard Reference Test Tire.

4.2.2.2 Test Rim Width.

- As specified by the test request, ± 13 mm (± 0.5 in) rim width code
- ASTM E1136 control tire is to be tested on a 152 mm (6.0 in) rim width code

4.2.2.3 Normal Tests. All candidate tires of one construction shall be evaluated for 32 km/h and 97 km/h wet traction performance, prior to testing the same tires for dry traction performance, to minimize test variability caused by new tire burnish effects. An analysis of the wet traction data for test variability compliance should be done before the tires are used for dry testing (Appendix A, Sections A1, A2 and A3 as appropriate). Tires may be retested for wet traction if required prior to the dry testing. The same physical tire should be tested for both wet and dry traction.

4.2.2.4 Special Tests. A special tire braking traction test may include variations in test load, tire inflation pressure test speed, test surface or surface conditions.

4.3 Instructions.

4.3.1 Warm up electronic test equipment as required for stabilization.

4.3.2 Stabilize the test surface water flow and temperature.

Caution: Do not test when wind conditions interfere with wetting of the surface as specified in 4.2.1.1.2.

4.3.3 Install a test tire in the test position on the test trailer. A tire with a similar loaded radius and high cornering properties should be used opposite the test tire, off-side, to level the axle and to minimize trailer yaw during brake torque application. The off-side tire should have outside diameter within ± 13 mm (0.5 in) of test tire outside diameter.

4.3.4 Set the test trailer static weight on the test tire to the value specified in 4.2.2.1.

4.3.5 Adjust the tire inflation pressure to the specified value in 4.2.2.1.

4.3.6 When testing on an externally wetted test surface, offset the trailer test wheel outboard of the tow vehicle sufficiently to prevent the test tire from tracking of the tow vehicle tires. An offset distance of 305 mm to 406 mm (12 in to 16 in) is suggested. The test wheel offset should be outboard of the tow vehicle.

4.3.7 Record tire identification and other pertinent data required from Appendix B (Table B1) and Appendix C (Table C1).

4.3.8 On externally wetted surfaces, measure the water depth with a variable height probe type device to meet requirements of 4.2.1.1.2.2.

4.3.9 Adjust trailer and/or truck ride height to null any components of the vertical load, which are introduced into the fore-aft channel.

4.3.10 Record electrical calibration signals prior to and after testing each surface, or as needed to ensure valid data.

4.3.11 Perform pretest tire conditioning as described in 4.1.1.7 if using a new tire.

4.3.12 Normalize test wheel speed to vehicle speed prior to conducting any tire test.

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4.3.13 Take at least eight (8) measurements of the coefficients of interest for each test.

4.3.14 Test a control tire at the beginning and end of each test sequence and every third test in between those two tests. For example, C₁, T₁, T₂, C₂, T₃, T₄, C₃, where C represents a control tire and T represents a test tire.

4.3.14.1 Peak/Slide Testing. A single control tire may be tested repeatedly under wet conditions up to seven (7) times as long as the tread surface maintains a new appearance. This number will vary depending on the test surface. Control and test tires should only be tested once on dry surfaces.

4.3.14.2 Peak-Only (Chirp) Testing. Control and test tires can be tested multiple times on wet and/or dry surfaces. The number will vary depending on the test surface and surface conditions, but should usually be limited to 30 brake applies or until significant tread pattern scuffing or other damage is visible.

4.3.14.3 Miscellaneous. Additional candidate tires (> 2) may be tested between control tires for dry tests assuming test conditions remain stable and the time between control tire tests is minimized.

4.3.15 Three (3) tires of each candidate construction should be tested, preferably on different days, under each of the specified test conditions.

5 Data

5.1 Calculations. The techniques in this section are to be used to process the recorded braking traction data to calculate the metrics listed in Appendix A, Sections A1, A2 and A3 and Appendix B, Table B1.

5.1.1 Filtering.

5.1.1.1 Digitally filter the braking force, vertical load, test wheel speed, and vehicle speed using a five point moving average technique.

5.1.1.2 Digital Filtering Methodology. Calculate an average value for the first five (5) data points. Drop the first data point and add the sixth data point, calculate another five (5) point average value. Repeat this procedure for all remaining data points. This sequence is done individually on all the preceding channels. The following example illustrates the method using one (1) channel.

$$(pt1 + pt2 + pt3 + pt4 + pt5)/5 = PT1$$

$$(pt2 + pt3 + pt4 + pt5 + pt6)/5 = PT2$$

$$(pt3 + pt4 + pt5 + pt6 + pt7)/5 = PT3$$

5.1.1.3 A new set of data points (indicated by capital letters) are defined to represent the filtered data for each channel (i.e., Avg pt_x = PT_y).

PT1, PT2, PT3, etc.: Tractive force

PT1, PT2, PT3, etc.: Vertical force

5.1.2 Determining and Calculating Peak Braking Coefficient.

5.1.2.1 Using the digitally filtered data, PT1, PT2, PT3, etc., scan the longitudinal channel and determine the highest absolute filtered value, PT_y, prior to wheel lockup. Calculate an average peak braking force value using the highest filtered value, PT_y, and one (1) filtered point directly before, PT_{y-1}, and directly after it, PT_{y+1}. This three (3) point average is the peak braking force value developed for this individual lockup.

5.1.2.2 Determine the vertical load value from its respective digitally filtered data corresponding to the highest absolute value for braking force, from 5.1.2.1. Calculate an average vertical load value using this corresponding value and one (1) point directly before and directly after it. This three (3) point average is the vertical load value that corresponds to the average peak braking force for this individual lockup.

5.1.2.3 Calculate the peak braking coefficient by dividing the three (3) point average peak braking force, determined from 5.1.2.1 by the three (3) point average vertical load, as determined in 5.1.2.2. The peak braking coefficient should be reported to three (3) decimal places.

5.1.2.4 For each test, the mean and standard deviation for peak braking coefficient are calculated from the individual peak determinations.

5.1.2.5 Individual peak coefficients are deleted if they fall outside the mean ± 1.5 standard deviations.

5.1.2.6 The average peak coefficient and standard deviation are recomputed after any deletions, as outlined in 5.1.2.5.

5.1.3 Determining and Calculating Slide Braking Coefficient.

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