Designation: F408 – 99 (Reapproved 2015)

Standard Test Method for Tires for Wet Traction in Straight-Ahead Braking, Using a Towed Trailer[1]

This standard is issued under the fixed designation F408; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement of braking traction of tires designed for passenger cars or light trucks. Such braking traction measurements are applicable to conditions wherein the vehicle is traveling straight ahead on a wet, paved surface.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E274 Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire

E1337 Test Method for Determining Longitudinal Peak Braking Coefficient of Paved Surfaces Using Standard Reference Test Tire

F377 Practice for Calibration of Braking/Tractive Measuring Devices for Testing Tires

F457 Test Method for Speed and Distance Calibration of Fifth Wheel Equipped With Either Analog or Digital Instrumentation

F538 Terminology Relating to the Characteristics and Performance of Tires

F1650 Practice for Evaluating Tire Traction Performance Data Under Varying Test Conditions

3. Terminology

3.1 *Definitions:*

3.1.1 *braking force, [F], n—of a tire*, the negative longitudinal force resulting from braking torque application. **F538**

3.1.2 *braking force coefficient, n—of a tire*, the ratio of braking force to normal force. **F538**

3.1.3 *braking force coefficient, peak, n—of a tire*, the maximum value of tire braking force coefficient that occurs prior to wheel lockup as the braking torque is progressively increased. **F538**

3.1.4 *braking force coefficient, slide, n—of a tire*, the value of braking force coefficient obtained on a locked wheel. **F538**

3.1.5 *braking torque, [ML^2/ T^2], n—of a vehicle*, the negative wheel torque. **F538**

3.1.6 *lockup, n—of a wheel*, the condition of a wheel in which its rotational velocity about the wheel spin axis is zero and it is prevented from rotating in the presence of applied wheel torque.

3.1.7 *longitudinal force, [F], n—of a tire,* the component of the tire force vector in the X' direction. **F538**

3.1.8 *normal force, [F], n—of a tire*, the component of a tire force vector in the Z' direction. **F538**

3.1.9 *skid number (SN), n*—slide braking force coefficient multiplied by 100. **F538**

3.1.10 *test run, n*—a single pass of a loaded tire over a given test surface. **F538**

3.1.11 *tire axis system, n*—the origin of the tire-axis system is the center of the tire contact where the X'-axis is the intersection of the wheel plane and the road plane with a positive direction forward, the Z'-axis is perpendicular to the road plane with a positive direction downward, and the Y'-axis is in the road plane, its direction being chosen to make the axis system orthogonal and right-hand.

3.1.11.1 *Discussion*—See Fig. 1. **F538**

3.1.12 *tire forces, [F], n*—the external forces acting on a tire by the road. **F538**

3.1.13 *torque, [FL], n—of a wheel*, the external torque applied to a tire from a vehicle about the wheel spin axis.

3.1.13.1 *Discussion*—Driving torque is positive wheel torque; braking torque is negative wheel torque. **F538**

[1] This test method is under the jurisdiction of ASTM Committee F09 on Tires and is the direct responsibility of Subcommittee F09.20 on Vehicular Testing.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

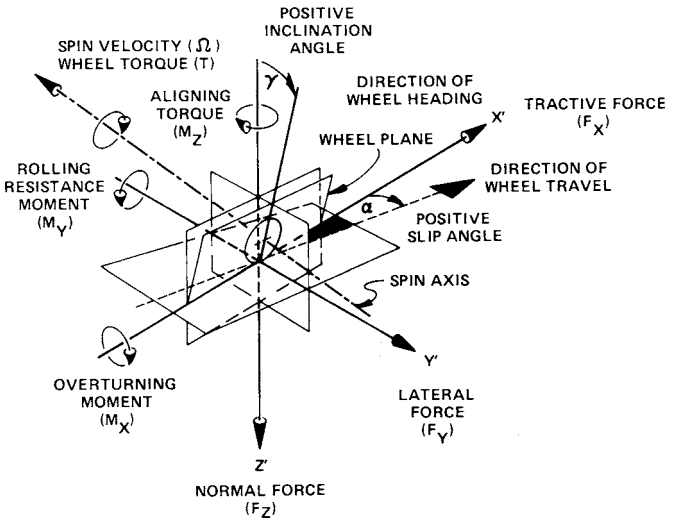

FIG. 1 Tire-Axis System

3.1.14 *vertical load, n*—the normal reaction of the tire on the road which is equal to the negative of the normal force. **F538**

4. Summary of Test Method

4.1 The measurements are conducted on tires mounted on a trailer towed by a vehicle. Brakes are applied firmly until one or both test tire(s) are locked and then held locked for a period of at least 1.5 s at speeds ranging from 32 km/h (20 mph) to 96 km/h (60 mph).

4.2 Recommended vehicle test speeds are: 32, 64, and 96 km/h (20, 40, and 60 mph).

5. Significance and Use

5.1 The measured values are traction properties of tires obtained with the towed trailer described here on a given road surface, under given environmental conditions (ambient and road surface temperature, humidity, wind speed and direction, purity and film depth of water used to wet the road surface). They are carried out in accordance with the stated test procedures and reflect the performance of the total tire-vehicle environmental system. A change in any of these factors may change the measurements on a subsequent run of the test.

5.2 These test methods are suitable for research and development purposes, where tires are compared during a single series of tests. They may not be suitable for regulatory statutes or specification acceptance, because the values obtained may not necessarily agree or correlate either in rank order or absolute traction performance level with those obtained on other road surfaces (or the same surface after additional wear), under other environmental conditions, or other towed trailers, or other test devices, or with results obtained with other test procedures.

6. Apparatus

6.1 The apparatus consists of tow vehicle and trailer. Vehicle and trailer must comply with all applicable state and federal laws when operated on public roads.

6.2 *Tow Vehicle:*

6.2.1 The tow vehicle shall have the capability of towing the trailer at specified speeds in the range from 32 to 96 km/h (20 to 60 mph), which are to be kept constant to within 0.8 km/h (0.5 mph), even at maximum level of application of braking forces.

6.2.2 The tow vehicle shall be equipped with the following accessories:

6.2.2.1 Equipment to actuate brakes on towed trailer,

6.2.2.2 A water tank to store sufficient water to supply the watering system unless external watering is used,

6.2.2.3 Recording equipment to record signals from transducers installed on the towed trailer,

6.2.2.4 Hitch with adjustable height for towing the trailer, and

6.2.2.5 Optional equipment to monitor and control brakeline pressure, brake application rate, and water application rate.

6.3 *Towed Trailer*—The trailer shall be equipped with a tow hitch and one or two test wheels which shall be instrumented as described. A self-watering system is optional (see 6.3.6). Trailers shall be designed to accommodate the range of passenger car and light truck rim sizes to be tested.

6.3.1 The hitch height shall be no higher than the loaded tire radius, and the distance from hitch ball to axle centerline shall be no less than ten times the hitch height. For external watering, the trailer hitch on the tow vehicle shall be so arranged that the trailer tires will run in tracks separate from the tire tracks of the tow vehicle. The minimum track offset of the test tire(s) with respect to the track of the tow vehicles should be 0.3 m (12 in.).

6.3.2 The trailer shall have provisions for adjustment of vertical load from 65 to 110 % of the appropriate maximum load as specified in the current yearbook of the appropriate tire and rim standards organization. To meet this requirement for all rim sizes, two or more trailers designed for different load ranges and equipped with appropriate wheel adaptors may be necessary.

6.3.3 Each of the test wheels shall be equipped with a typical or special automotive hydraulic brake system which can apply sufficient braking torque to initiate and maintain lockup of the test wheel(s) for the duration of the test.

6.3.4 Each of the test wheels shall have a suspension capable of limiting change of toe and camber to within ±0.05° with maximum vertical suspension displacements. Suspension arms and bushings shall have sufficient rigidity necessary to minimize free play and compliance under application of maximum braking forces. The suspension system shall provide adequate load-carrying capacity and be of such a design as to isolate suspension resonance.

6.3.5 The brake application system shall be able to control the time interval between initial brake application and wheel lockup within a range of 0.2 to 0.5 s with a repeatability of ±0.1 s.

6.3.6 The trailer may be optionally equipped with a pavement-wetting system, less the storage tank, which is mounted on the tow vehicle. The water being applied to the pavement ahead of the test tires shall be supplied by a nozzle suitably designed to ensure the water layer encountered by the

test tire has a uniform cross section at all test speeds with a minimum splash and over-spray (see Note 1). The nozzle configuration and position shall ensure that the water jets shall be directed toward the test tire and pointed toward the pavement at an angle of 20 to 30°. The water shall strike the pavement 0.25 to 0.46 m (10 to 18 in.) ahead of the center of tire contact. The nozzle shall be located 25 mm (1 in.) above the pavement or the minimum height required to clear obstacles which the tester is expected to encounter, but in no case more than 100 mm (4 in.) above the pavement. The water layer shall be at least 25 mm (1 in.) wider than the test tire tread and applied so the tire is centrally located between the edges. The volume of water per unit of wetted width shall be directly proportional to the test speed. The quantity of water applied at 32 km/h (20 mph) shall be 300 mL/min per mm of width (2.0 gal/min per inch of width) of wetted surface. The rate of water application at speeds of 64 and 96 km/h (40 and 60 mph) shall be 600 and 900 mL/min per mm of width (4.0 and 6.0 gal/min per inch of width) of wetted surface, respectively. The nominal values of rate of water application shall be maintained within ±10 %. The water shall be reasonably clean and contain no chemicals such as wetting agents or detergents.

NOTE 1—A suitable nozzle design is described in detail in Test Method E274.

6.4 *Instrumentation*—Each test wheel position on the trailer shall be equipped with a wheel rotational velocity measuring system and with transducers to measure the braking force and vertical load at the test wheel.

6.4.1 *General Requirements for Measurement System*—The instrumentation system shall conform to the following overall requirements at ambient temperatures between 0 and 43°C (32 and 110°F):

6.4.1.1 Overall system accuracy, force: ±1.5 % of vertical load or traction force from 450 N (100 lbf) to full scale,

6.4.1.2 Overall system accuracy, speed: ±1.5 % of speed or ±0.8 km/h (±0.5 mph), whichever is greater,

6.4.1.3 *Shunt Calibration*—All strain-gage transducers shall be equipped with shunt calibration resistors that can be connected before or after test sequences. The calibration signal shall be at least 50 % of the full scale for the transducer, and

6.4.1.4 *Ruggedness*—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 regular operation.

6.4.2 *Vehicle Speed*—To measure vehicle speed, a fifth wheel or non-contact precision speed-measuring system should be used. Output shall be directly visable to the driver and shall be simultaneously recorded. The fifth wheel or precision speedometer used to measure vehicle speed shall have specifications in accordance with Test Method F457.

6.4.3 *Braking Forces*—The braking force-measuring transducers shall measure longitudinal force generated at the tire-road interface as a result of brake application within a range from 0 to at least 125 % of the applied vertical load. The transducer design and location shall minimize inertial effects and vibration induced mechanical resonance. The transducer shall have an output directly proportional to the force with less than 1 % hysteresis and less than 1 % nonlinearity at full scale. It shall have less than 2 % cross-axis sensitivity at full scale. The transducer shall be installed in such a manner as to experience less than 1° angular rotation with respect to its measuring axes at a maximum expected braking torque.

6.4.4 *Vertical Load*—The vertical load-measuring transducer shall measure the vertical load at each test wheel during brake application. The transducer shall have the same specifications as those described in 6.4.3.

6.4.5 *Signal Conditioning and Recording System*—All signal conditioning and recording equipment shall provide linear output with necessary gain and data reading resolution to meet the requirements of 6.4.1. Additionally, it shall have the following specifications:

6.4.5.1 *Minimum Frequency Response*—d-c flat (±1 %) to 30 Hz full scale,

6.4.5.2 Tire vertical load, braking force, vehicle and wheel speeds and a time base must be recorded in phase (0 to 30 Hz ±5°),

6.4.5.3 *Signal-to-Noise Ratio*—at least 20/1,

6.4.5.4 Gain shall be sufficient to permit full-scale display for full-scale input signal level,

6.4.5.5 Input impedance shall be at least ten times larger than the output impedance of the signal source,

6.4.5.6 It must be insensitive to vibrations, acceleration, and changes in ambient temperature. The error in reading shall not exceed 1 % full scale when subjected to vibrational acceleration of 49.0 m/s^2 (5 *g*'s) in the 0.5 to 40-Hz frequency range and operating temperature range from 0°C (32°F) to 43°C (110°F),

6.4.5.7 It shall not be affected by storage temperature variations between – 29°C (–20°F) and 71°C (160°F), and

6.4.5.8 Chart recorders, if used, shall have an adjustable chart speed capable of at least 25 mm/s.

6.4.6 *Power Supply*—The power supply for transducers and recording system shall meet or exceed requirements specified by transducer and recorder manufacturers.

7. Selection and Preparation of Test Tires

7.1 Test tires should be approximately of the same age and have been stored essentially at the same conditions.

7.2 Trim the test tires to remove all protuberances on the tread surface caused by mold air vents or flashes at mold junctions.

7.3 Mount the test tires on rims specified by the appropriate tire and rim standards organization using conventional mounting methods. Ensure proper bead seating by the use of a suitable lubricant and the subsequent warm-up procedures. Excessive use of lubricant should be avoided to prevent slipping of the tire on the wheel rim.

7.4 Tire break-in may be used to improve repeatability of results. Break-in mileage should be accumulated for a given tire equally on the front and rear axles of the vehicle used for break-in operation. Break-in the test tires for a minimum of 80 km (50 miles) at test load and inflation at speeds of 80 to 96 km/h (50 to 60 mph), where permissible, without excessive

cornering, braking, or acceleration to avoid uneven wear. New tire average wear prior to testing shall not exceed 10 % of the new tire tread depth.

7.5 Place the mounted test tires near the test site in such a location that they all have the same ambient temperature prior to testing and shield them from the sun to avoid excessive heating by solar radiation.

7.6 Check the test tires for the specified inflation pressure at ambient temperature (cold), just prior to testing. The test tire inflation pressure shall be that recommended by the appropriate tire and rim standards organization for the test load.

8. Preparation of Apparatus

8.1 *Towed Trailer:*

8.1.1 Install the test tires on the towed trailer.

8.1.2 Load each of the wheels of the towed trailer to the specified test load.

8.1.3 Adjust the hitch height and transverse position as necessary for a given test.

8.1.4 Check the wiring connections between tow vehicle and the trailer for opens and shorts.

8.2 *Instrumentation and Equipment:*

8.2.1 Install the fifth wheel, when used, in accordance with the manufacturer's specifications and locate it as near as possible to the mid-track position of the tow trailer.

8.2.2 The rate of braking application shall be such that the time interval between initial application of force and wheel lock-up is within ±0.1 s of a specified value to be used for any tire comparison set (see Note 2). This specified value for any tire set shall be in the range from 0.20 to 0.50 s.

NOTE 2—The tolerance for time interval is necessary, because the rate of brake application may have an influence on the peak braking coefficient obtained. The term "tire set" refers to a number of tires tested on the towed trailer simultaneously.

9. Calibration

9.1 Calibrate the assembled system with its own instrumentation.

9.2 *Load Force*—Calibrate the transducers for measuring vertical load in accordance with a dead-weight procedure using Class F weights, the calibration of which is traceable to the National Institute of Standards and Technology (NIST).

9.3 *Braking Force*—Place each test wheel on a suitable calibration platform which has been calibrated in accordance with Practice F377. The calibration platform shall have an accuracy of within ±0.5 % of the applied force and a hysteresis of within± 0.25 % of the applied force over the range of forces to be calibrated. Load the test wheel vertically to the minimum test load. Level the trailer and ensure that trailer level does not vary during this procedure to minimize transducer misalignment. Align the transducers longitudinally and laterally, such that the braking force sensitive axis is horizontal and the load force sensitive axis is vertical. Braking force alignment can be accomplished by minimizing braking force output for large variations of load. Load force alignment can be accomplished by comparing load force output to a standard load cell and minimizing load error for large variations of braking force. Measure the test wheel load within± 0.5 % accuracy during both vertical and longitudinal force calibration. Take care to ensure that the applied braking force and the braking force transducer sensitive axis are in the same vertical plane. Perform the braking force calibration incrementally to at least 50 % of vertical load or 3600 N (800 lbf), whichever is less. Repeat this procedure at several vertical loads including minimum and maximum test load.

9.4 *Speed*—Calibrate the fifth wheel or vehicle speed measuring system in accordance with Test Method F457.

10. General Test Conditions

10.1 Conduct all tests on smooth and level surfaces. The surface shall have a uniform grade of not more than 2 % and shall not deviate more than 6.35 mm (0.25 in.) when tested with a 3-m (10-ft) straightedge.

10.2 The test surface shall have a pavement of uniform age, composition, and wear. The test surface shall be free of loose material or foreign deposits.

10.3 If external watering is used, water the test surface at least ½ h prior to testing in order to equalize the surface temperature and water temperature. It is recommended that external watering be continuously supplied throughout testing each day.

10.3.1 Apply the minimum amount of water necessary to keep the test surface uniformly wet throughout testing. The amount of water shall be sufficient to keep the tops of protruding asperities wet.

10.4 Measure the skid number of the test surface accordance with Test Method E274 at 64 km/h (40 mph).

10.5 Do not test when wind conditions interfere with wetting of the surface as specified in 10.3.1.

11. Procedure

11.1 Refer to Practice F1650, especially Section 7, for details on tire testing sequence and control tire testing and other details for a comprehensive traction evaluation. This practice also will be used for calculating corrected traction performance parameters if there is any significant time trend or other perturbation in the testing program.

11.2 Approach the test site in a straight line at the specified test speed. The test speed shall lie in the range from 32 to 96 km/h (20 to 60 mph). Recommended values are 32, 64, and 96 km/h (20, 40, and 60 mph).

11.3 Start the recording system.

11.4 Deliver water to the pavement ahead of the test tire approximately 0.5 s prior to brake application (for internal watering system).

11.5 When the trailer tires reach the test site, apply the trailer brakes until the wheels are locked, and hold them for a period of at least 1.5 s, while maintaining the specified test speed to within 0.8 km/h (0.5 mph). The test should be run at the same spot on the test pad when approaching from the same direction.

11.6 Stop the recording system.

11.7 Repeat 11.1 – 11.5 by making a run in the opposite direction.

11.8 Repeat 11.1 – 11.6 at least four times at each test speed for each test surface.

11.9 Test consecutive sets of tires by repeating 11.1 – 11.7, provided that the tests are completed within one day.

11.10 One set of tires shall be designated as a control set. Test the control tires adjacent to each set of test tires, for example in the sequence *CTTCTTC* ..., etc., where *C* = control tire and *T* = test tire.

12. Calculation of Traction Coefficients

12.1 Determine the time at which wheel lockup occurs.

12.2 Calculate the sliding tire braking force coefficient, μ_s, for each test using the following equations:

$$\mu(t) = \frac{f_h(t)}{f_v(t)} \quad (1)$$

$$\mu_s = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} \mu\,(t)dt \quad (2)$$

where:

$\mu(t)$ = dynamic tire braking force coefficient in real time,
$f_h(t)$ = dynamic braking force in real time, N (or lbf),
$f_v(t)$ = dynamic vertical load in real time, N (or lbf),
t_1 = start of averaging period (0.2 s after wheel lockup occurs),
t_2 = end of averaging period (1.2 s after wheel lockup occurs), and
μ_s = sliding tire braking force coefficient.

12.2.1 Using Eq 1 for dynamic tire braking force coefficient, calculate the peak tire braking force coefficient, μ_p, by determining the highest value of $\mu(t)$ before lockup occurs. Analog signals should be filtered to remove noise. Digitally recorded signals may be filtered using a five point moving average technique (this technique is described in detail in Test Method E1337).

12.3 Calculate the average values $\bar{\mu}_s$ and $\bar{\mu}_p$ of peak braking coefficient by averaging four or more repeated runs for each set of test and control tires for each test condition.

13. Evaluating Traction Performance

13.1 *Absolute Performance (Based on Measured Coefficients)*—Refer to Practice F1650 for the necessary operations to evaluate traction performance when expressed in terms of the measured coefficients; see Sections 7, 8 or 9 for details. This gives (*1*) a recommended tabular format for measured traction data, (*2*) calculation procedures to determine if any time trend or other transient perturbation occurred during any test program, and (*3*) calculation alogorithms to obtain corrected traction performance parameters free of the influence of trends or other perturbations. The correction calculations are given for two correction methods: (*1*) Method A in Section 8, using the initial control tire test as a reference or base point for correction, or (*2*) Method B in Section 9, using the grand average of all control tire tests (in a test program) as the reference point for correction.

13.2 *Relative or Comparative Performance*—Section 10 of Practice F1650 gives the procedure for calculating relative traction performance in terms of a "traction performance index" or TPI. This procedure assigns the control or other selected reference tire the value of 100. Values of TPI above 100 indicated superior traction performance. Relative performance may be evaluated on the basis of as measured or corrected traction coefficients, and this evaluation requires an additional column(s) for these parameters in the table of results.

14. Report

14.1 The report shall include the following information:

14.1.1 A statement that the testing was conducted in accordance with Test Method F408.

14.1.2 A record of test operation information as specified in Table 1.

14.1.3 A table of results for each measured parameter, as specified in 7.5 of Practice F1650, with an additional column for as measured or corrected TPI, or both.

14.2 A citation as to which correction procedure was used (see Practice F1650, Section 11).

15. Precision and Bias

15.1 *Precision*—Data are not yet available for making a statement on the repeatability or reproducibility of the test method.

15.2 *Bias*—There are no standards or reference values with which the results of this test method can be compared; therefore bias cannot be evaluated.

16. Keywords

16.1 braking traction; peak tire traction; skid number; skid trailer; sliding tire traction; tires; tire braking force coefficient; traction measurement; wet traction