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Standard Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)[1]

This standard is issued under the fixed designation E556/E556M; 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 calibration of the force (or torque) transducer and associated instrumentation of a mounted test wheel by using a calibration platform.

1.2 This test method is a static calibration, simulating the traction force between a tire and the pavement.

1.3 In the case of a force-measuring system, the instrumentation readout is directly proportional to the calibration force input.

1.4 In the case of a torque-measuring system, the instrumentation readout is a measure of the calibration force input and the effective tire radius.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *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

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *calibration platform*—a moving platform for applying a force in the contact plane of a tire, and associated means for measuring the applied force. The calibration platform consists of a rigid plate with a high friction surface, in contact with the tire footprint, supported on a frictionless, preferably air, bearing. It may also be instrumented to measure vertical forces (loads).

3.1.2 *calibration reference signals*—repeatable signals in the range of expected wheel-force transducer system loading. These signals could either be constant voltages or preferably produced by a strain-gage calibration shunt resistor.

3.1.3 *crosstalk*—the undesired effect of force readings appearing on an unloaded axis of a transducer while applying force to another.

3.1.4 *horizontal traction (traction)*—a force acting in a horizontal axis through the wheel transducer; that is, locked wheel drag force.

3.1.5 *hysteresis*—the maximum difference between corresponding transducer outputs (of the wheel force transducer system) at increasing and decreasing applied calibration force, expressed as a percentage of full load. Proven outliers are excluded.

3.1.6 *nonlinearity*—the maximum deviation of the transducer output(s) (of the wheel force transducer system) from the best-fit linear relation to the applied calibration force, expressed as a percentage of full scale. Proven outliers are excluded.

3.1.7 *test wheel*—a wheel and test tire assembly mounted to a test vehicle by means of a force or torque transducer.

3.1.8 *vertical load (load)*—force acting in a vertical axis through the wheel transducer; that is, weight.

3.1.9 *wheel force transducer system*—a force-to-electrical signal converter system including transducer(s), associated signal condition, zeroing, amplifying, recording, and monitoring instrumentation.

4. Summary of Test Method

4.1 The vertical static loads (forces) on the test wheel(s) and hitch are established. If the tester is of the trailer type, it must

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[1] This test method is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.21 on Field Methods for Measuring Tire Pavement Friction.

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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.

be connected to its tow vehicle. Traction forces are applied to the locked wheel(s) at the tire-platform interface. The calibration platform consists of a bearing that is frictionless in all directions of the horizontal plane supporting a rigid plate with a high friction surface. The force applied to this platform is measured by suitable electronic force transducers.

4.2 Wheel transducer linearity and hysteresis are determined from an electronic digital meter (*x-y* chart optional) and are correlated with the tow vehicle instrumentation. Techniques are given for establishing reference signals to be used as calibration points.

4.3 With calibration platforms having force-measurement capability in the vertical direction, test wheel load (force) is recorded as a function of the applied tractive calibration force.

4.4 With a wheel transducer having normal load (force)-measuring capability, the transducer output is compared with the corresponding vertical output of the calibration platform.

5. Significance and Use

5.1 Wheel force or torque transducers are used under dynamic test conditions, and the measurements are subject to many error sources. The static calibration recommended by the present standard cannot eliminate all error sources. Its significance is in providing an accurate calibration of the transducer and the associated electronics, readout, and recording equipment.

5.2 Calibration result may be used to either make mechanical or electronic adjustments until the readout agrees with the calibration input. Alternatively, calibration curves or tables may be prepared to be used as corrections to measured results.

6. Apparatus

6.1 The calibration apparatus shall consist of the basic components described below, and calibrated in accordance with 6.3 of Practice F377.

6.1.1 A calibration platform for applying tractive forces at the tire-platform interface of a test wheel, with a calibrated internal or external reference force transducer to measure these forces. Capability of measuring vertical forces (wheel loads) is also desirable.

6.1.2 A system for generating traction forces applied through the calibration platform.

6.1.3 Instrumentation for recording or indicating transducer outputs, including digital meters and optionally an *x-y* recorder.

6.1.4 Level, tire pressure gage and thermometer.

6.1.5 Scale(s) accurate within 0.5 % of maximum expected axle load for the test trailer.

7. Preparation of Apparatus

7.1 *Site*—Select a sheltered, level paved area. (A hard surface, preferably under cover, is desirable.)

7.2 *Calibration Platform and Associated Instrumentation*—Prepare the calibration platform and associated instrumentation by following established set-up procedures and the manufacturer's manuals where applicable.

7.3 *Test Tires*—Set the inflation pressure under normal vertical load (force). Inflation pressure shall be 24.0 ± 0.5 psi (165.0 ± 3.5 kPa) at ambient temperature (cold).

7.4 *Traction Tester Instrumentation*—Check the test vehicle instrumentation by following established set-up procedures for the system with reference to the recommended procedure in the manufacturer's manual, where applicable. Set all gains and offsets at values normally used during friction testing. Record the settings.

7.4.1 *Force-Type Transducer*—Load crosstalk into traction: if, with full normal load back on the test wheel, the traction output is different from zero by more than 1 % of the applied normal load, adjust by either rotating the transducer (if provisions for rotation have been made) or by changing the hitch height, that is, tilting the trailer to orient the transducer horizontal axis parallel to the calibration plane. Then apply 500 lb of traction force and note the change in load reading. If more than 1 % crosstalk, check transducer leveling and repeat this test.

7.4.2 *Torque Type Transducer*—Use steps 7.4 and 7.4.1, substituting the torque output for the traction. If the load into torque crosstalk is greater than 1 % of the applied normal load, refer to the manufacture since there are normally no user adjustments.

7.5 *Test Trailer*— Position the trailer coupled to its tow vehicle on level ground and set the trailer variables such as tire pressure, hitch height, and inflation pressure of air shock absorbers where present to the normal operating values. Measure the hitch height from level ground to the center of the hitch. Decouple the trailer and weigh it at each point of support, maintaining its relative level. Correct the weights if needed to comply with Test Method E274. Recouple the trailer to the towing vehicle.

NOTE 1—The tow vehicle should have ½ tank of water, and a full fuel load before leveling the trailer.

7.6 *Wheel Transducer*— With the test wheel loaded, the wheel transducer traction output should be adjusted to zero. Then remove 500 lb of the load and recheck traction zero.

7.7 Record all measures, weights, and dimensions, and the trailer leveling adjustments that give zero transducer outputs.

8. Frequency of Calibration

8.1 It is recommended that the system be calibrated according to all sections of this specification at least once a year.

8.2 For routine test to indicate normal system operations only, it may be sufficient to abbreviate the procedure in Section 9.

8.3 Calibration should be performed at least once a month according to 8.2.

8.4 The calibration should be performed whenever the measured test results are inconsistent with previous values for a given test site.

9. Procedure

9.1 Determine that the calibration platform has been suitably calibrated within a reasonable period of time (see 6.1), one year.

9.2 If the test vehicle is of the trailer type, hitch and align it with the tow vehicle. The calibration may be performed with auxiliary electrical power for the instrumentation. In this case, after completing the calibration, check the system when powered by the vehicle electrical system with the engine running, to assure that the output(s) have not changed. The preparations described in Section 7 shall have been performed.

9.3 Place the test wheel(s) on the calibration platform(s) using blocks, if needed, under the other wheels to maintain a level plane of support for all system tires.

9.4 With the test wheel raised clear of the platform, zero the output(s) of the calibration platform in accordance with established operating procedures. Zero the wheel transducer output(s). (**Warning—**Make sure that wheel brakes do not drag.)

9.5 Align the calibration platform(s) and the associated force application system(s) with the test tire(s) and lower the test wheel onto the platform.

9.6 The platform shall be level within ±0.25° prior to the calibration.

NOTE 2—Increased accuracy may be obtained by maintaining the aforementioned level throughout the calibration procedure.

9.7 Record the ambient temperature. To meet this standard, calibration can only be done when the ambient temperature is between 40 and 100°F (4 and 38°C).

9.8 Use digital meter(s) and optionally *x-y* recorder(s) to observe the wheel-force transducer system signals at the input to the system recorder.

9.8.1 With the trailer level and with full vertical load and zero traction force applied to the test wheel(s), adjust the system vertical load indicator to correspond with the platform vertical load value.

9.8.2 Lock the test wheel and apply a midrange tractive force (typically 500-lbf 2.2 kN) via the platform to the test wheel. Adjust the system traction indicator to correspond with the platform traction value. Return the traction force to zero.

9.9 Record the wheel-transducer vertical load output and the force-place transducer vertical output, on both the system recorder and meter while increasing and decreasing the vertical force applied by at least 20 % of the static wheel load value in 100 lbf (445 N) increments. This can be done by adding 200 lb (shot bags) to the trailer wheel load.

9.10 Establish the linearity and hysteresis characteristics for the vertical transducer output, if applicable, using the data in 9.9.

9.11 Record the wheel transducer output(s) (horizontal traction and vertical load) versus the platform traction and vertical load readings on both the system-recorder and the meter while increasing and decreasing the traction force by 100 lbf (445 N) increments through the full calibration range (typically 0 to 50 % of vertical load).

NOTE 3—For a two-wheeled towed test trailer, the test wheel vertical load should decrease linearly from the zero traction value as the applied traction force increases at a slope proportional to the *H/L* ratio of the trailer[3] where *H* is the initial hitch height and *L* is the initial hitch-to-axle length (see Test Method E274). The non-test wheel vertical load (force) should remain constant at the zero traction value.

9.12 If the test wheel load and traction values obtained in 9.9 and 9.11 agree with the platform values within ±1 %, apply system load and traction calibration signals and record for the future reference. If differences greater than 1 % are found, the system may require maintenance or the crosstalk should be rechecked as described in 7.6.

NOTE 4—Some calibration platforms use ball or roller bearing (instead of air bearings). Any side force on the wheel under calibration will generate additional friction forces in the calibration platform and cause erroneous readings and hysteresis.

9.13 Perform the calibration procedure of Section 9 for the second wheel transducer, if applicable.

10. Report

10.1 The calibration report shall contain the following information:

10.1.1 Skid measuring system identification,

10.1.2 Wheel-transducer identification,

10.1.3 Date,

10.1.4 Test equipment identification in accordance with calibration report(s),

10.1.5 Test tires identification,

10.1.6 Static weight at wheels and hitch,

10.1.7 Setting of the skid tester variables,

10.1.8 Measured values *H* (hitch height) and *L* (length from hitch to wheel center).

10.1.9 Tow vehicle standardization details,

10.1.10 Instrumentation check-out details,

10.1.11 Orientation of the transducer-sensitive axis,

10.1.12 Statement of loading conditions under which the readouts are zeroed,

10.1.13 Loading conditions under which the reference calibration points are applicable,

10.1.14 Record of the on-board and external indicator outputs of each transducer output versus increasing and decreasing traction force and vertical load (force),

10.1.15 Statement of calibration values, linearity, and hysteresis characteristics for the transducer and its associated readout,

10.1.16 Correlation of external meter output with on-board meter or recorder output,

10.1.17 Report section for a second transducer, if applicable, and

10.1.18 Remainder of operating coefficients established in Section 9, ambient temperature range during the calibration, and notes on calibration procedures.

11. Precision and Bias

11.1 As a rule of thumb, instrumentation bias should be approximately 10 times greater than the desired bias of the measurement. This would require the calibration to be made

[3] Kearns, R. W., and Ward, J. F., "The Static Force Calibration of a Skid Resistance Measuring System," National Institute of Standards and Technology, Washington, DC, 1973.

within 0.1 SN (skid number). To obtain this bias for skid testers in the midrange of measurements (that is, SN = 40) and with a 1000 lbf (4450 N) vertical wheel load, the bias would have to be ±1 lbf (±5 N). Such an accuracy is difficult to obtain in practice, primarily because of the uncertain tire response. The recommended bias is 1 % or better.[4]

11.2 Test precision with a system so calibrated is referenced in Test Method E274.

[4] Hegmon, R. R., Gillespie, T. D., and Meyer, W. E., "Measurement Principles Applied to Skid Testing," *Skid Resistance of Highway Pavements*, ASTM STP 530, ASTM, 1973.