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Standard Practice for Calibration of Braking/Tractive Measuring Devices for Testing Tires[1]

This standard is issued under the fixed designation F377; 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 practice gives procedures for the calibration of:
reference load cells
calibration platform systems by using a reference load cell
static calibration of braking/tractive force on locked wheels of tire test trailers, instrumented vehicles, and laboratory tire testing machines by using the calibration platform system as a calibration fixture.

1.2 The values stated in SI units are to be regarded as standard. The values 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]

E74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines

F538 Terminology Relating to the Characteristics and Performance of Tires

3. Terminology

3.1 *Definitions:*

3.1.1 *bias, n*—the difference between the average measured test result and the accepted reference value; it measures in an inverse manner the accuracy of a test.

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

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

4. Summary of Practice

4.1 Reference-load cells shall be calibrated using procedures and equipment traceable to the National Institute of Standards and Technology (NIST), or appropriate national standards organization.

NOTE 1—Practice E74 may be used as an alternative method for load-cell calibration.

4.2 The calibrated reference-load cell is used to calibrate the calibration-platform systems or used as the longitudinal force sensor. The tire test trailer, instrumented vehicle, or laboratory tire testing machine is calibrated with the platform.

5. Significance and Use

5.1 Calibration is essential in the use of various test platforms and devices to insure that the test results generated by these test devices are accurate, repeatable and meaningful. This standard gives the necessary instructions for the calibration of all of the test devices cited in the Scope.

6. Apparatus

6.1 The calibration system consists of the following basic components:

6.1.1 *Platform*—The platform on which the test wheel is placed shall have a flat high friction top surface. The platform shall be of sufficient dimensions to support the entire tire contact patch throughout the calibration process. A low friction bearing (an air bearing is recommended) permitting free horizontal motion and capable of sustaining a vertical load equal to the largest anticipated wheel load shall support the platform. The longitudinal movement shall be sufficient to obtain the necessary required force levels. The platform may also be instrumented with integrated transducers (Force Sensors) to measure vertical and longitudinal forces.

6.1.2 *Force Generation Apparatus*—A system, capable of developing a longitudinal force sufficient for the calibration of the operating range of the device, shall be used. The force shall be applied along the longitudinal centerline of the platform.

6.1.3 *Force Sensors*—Sensors to measure applied forces in the vertical and longitudinal directions that shall be used to calibrate braking/tractive measuring devices. These sensors can be integrated force transducers located in the platform, scales or tension load cells. Sensors shall have sufficient

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[1] This practice is under the jurisdiction of ASTM Committee F09 on Tires and is the direct responsibility of Subcommittee F09.10 on Equipment, Facilities and Calibration.

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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.

measurement range to cover the maximum anticipated test wheel forces. Sensors shall be mounted in a manner such that cross-axis forces will not adversely affect the accuracy. The force sensor instrumentation shall have the capability to allow for the recording of data, such as a chart recorder, data logger, or visual output that allows for manual logging of data.

6.1.4 *Reference Load Cell*—The force standard that provides direct traceability to NIST or appropriate national standards organization that shall be used to certify other force sensors or weights used within this standard. If integrated platform transducers are not used, the reference load cell may be used as the longitudinal force sensor during calibration of the braking/tractive measuring device. The reference load cell shall have sufficient measurement range to cover the maximum anticipated forces.

7. Calibration of the Reference Load Cell and Force Sensors

7.1 Three procedures are covered: *(1)* calibration of the reference-load cell, *(2)* calibration of the longitudinal force sensor, and *(3)* calibration of the vertical load sensor. Repeat the appropriate calibrations when any relevant component is changed or altered (see ASTM Manual 7). Repeat the calibrations annually unless the changes between the most recent calibration equation values and those from the previous calibration do not exceed 0.1%. Calibration intervals may be lengthened to a maximum of 2 years provided that these changes do not exceed 0.1% of the value. Record the ambient temperature during load cell calibrations. Force sensor gain values (or their equivalent) shall be consistent throughout sections 7.3 and 7.4.

7.2 *Reference Load Calibration:*

7.2.1 Set up the reference load cell, indicator and required equipment to perform the calibration. List all equipment used, including signal conditioning and output devices. Record equipment identification and calibration dates.

7.2.2 Set the bridge-excitation voltage and gain, or its equivalent, in accordance with the instructions on the unit being used.

7.2.3 Adjust the "bridge zero," or its equivalent, to "zero." Be certain that the reference load cell is not being stressed.

7.2.4 Using force measuring instruments or weights known to 0.01% or better of applied force, perform a calibration on the reference load cell. Class F weights of 8.9N (2 lb) or greater have a tolerance of 0.01%. Apply the calibration forces in at least 8 appropriately spaced increments to a maximum of not less than the anticipated maximum force seen in use. Allow all force indicators to come to rest at each increment and record the force readings.

7.2.5 Determine bias values at each applied force.

7.2.6 The biases of the reference-load cell and indicator system shall be 0.25% or less of the known applied force (minimum of ±2.2 N (±0.5lbf)).

7.3 *Calibration of Longitudinal Force Sensor* Fig. 1—Subsection 7.3 does not apply when the reference load cell is used as the longitudinal force sensor during calibration of the braking/tractive measuring device.

7.3.1 Mount the reference-load cell such that its longitudinal axis is parallel to the direction of motion of the platform within ±2° and in line with the applied force. If necessary, place a tension spring in the longitudinal force application system to allow for longitudinal motion.

7.3.2 Apply sufficient force to both channels of the system through the full range of expected calibration forces to exercise to platform. Release all forces.

7.3.3 Set the bridge-excitation voltage and gain, or its equivalent, for all instrumentation in accordance with the instructions on the unit being used.

7.3.4 Adjust the "bridge zeros," or its equivalent, to "zero" on all instrumentation. Be certain that the reference load cell and platform are not being stressed.

7.3.5 Using weights known to 0.1% of applied load or better, apply a test load, representative of a load which will be encountered on the braking/tractive test device to be calibrated, to the top of the platform near the geometric center of the top. The platform must be maintained level within ±0.25° during calibration. Record all force readings.

NOTE 2—The platform may be sensitive to the support structure used during calibration. Therefore during calibration, the platform shall be supported in a manner similar to that which will subsequently be used during the calibration of the braking/tractive measuring device.

7.3.6 Apply the longitudinal calibration force in at least 6 approximately equally spaced increments to a maximum of not less than the anticipated maximum longitudinal wheel force seen in use. Allow all force indicators to come to rest at each increment and record the force readings.

7.3.7 Repeat 7.3.3 and 7.3.6 as necessary to collect at least 12 calibration points.

7.3.8 Determine longitudinal force bias values at each applied force.

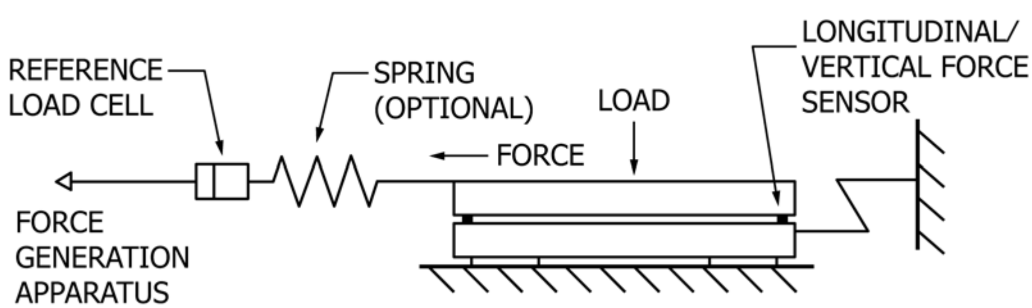

FIG. 1 Force Calibration of a Platform Force Transducer

7.3.9 The biases of the longitudinal force sensor and indicator system shall be 1.0 % or less of the applied force and 0.5 % or less than the maximum applied force (minimum of 0.1% of anticipated maximum braking/tractive measuring device test force or 4.4 N (1lbf) whichever is greater).

7.3.10 Determine cross talk of longitudinal force, read as part of the vertical load at each applied longitudinal force. The bias of the vertical load sensor and indicator system at each applied longitudinal force shall be ±1.0 % or less (minimum of ±4.4 N (±1lbf)) of the applied vertical load.

7.4 *Calibration of Vertical Load Sensor:*

7.4.1 Level the vertical load sensor (platform with integral transducers or appropriate scale) within ±0.25°.

7.4.2 Set the bridge-excitation voltage and gain, or its equivalent, for all instrumentation in accordance with the instructions on the unit being used. Use gain values (or their equivalent) from 7.3.3 if a two-axis platform with integral transducers is utilized.

7.4.3 Adjust the "bridge zeros," or its equivalent, to "zero" on all instrumentation. Be certain that the platform or scale is not being stressed.

7.4.4 Using force measuring instruments or weights known to 0.1 % of applied load or better, apply the vertical calibration force to the top of the platform/scale near the geometric center of the top in at least six approximately equally spaced increments. The platform/scale shall be maintained level within ±0.25° during calibration. Begin at a load less than the minimum test load of the braking/tractive measuring device and continue to a load greater than or equal to the anticipated maximum wheel load. Allow all force indicators to come to rest at each increment and record all force readings.

NOTE 3—The platform may be sensitive to the support structure used during calibration. Therefore during calibration, the platform shall be supported in a manner similar to that which will subsequently be used during the calibration of the braking/tractive measuring device.

7.4.5 Repeat 7.4.1 through 7.4.4 as necessary to collect at least 12 calibration points.

7.4.6 Determine vertical load bias values at each applied force.

7.4.7 The biases of the vertical sensor and indicator system shall be 1.0 % or less of the applied force and 0.5 % or less than the maximum applied force (minimum of 0.1% of anticipated maximum braking/tractive measuring device test force or 4.4 N (1lbf) whichever is greater).

7.4.8 Determine cross talk of vertical load, read as part of the longitudinal force at each applied vertical load. The bias of the longitudinal force sensor and indicator system at each applied vertical load shall be ±1.0 % or less (minimum of ±4.4 N (±1lbf)) of the applied longitudinal force.

8. Calibration of Braking/Tractive Force on a Locked Wheel (Fig. 2, Fig. 3, or Fig. 4)

8.1 Three procedures are covered: *(1)* for vertical calibration of the test wheel load cell, *(2)* for longitudinal driving tractive force calibration of the test wheel load cell, and *(3)* a procedure identical to *(2)* above except for direction of the applied force, ie. for the longitudinal braking force calibration of the test wheel load cell. Repeat the appropriate calibrations when any relevant component is changed or altered (see ASTM Manual 7). At a minimum, repeat the calibrations annually. Record the ambient temperature during load cell calibrations. Force sensor gain values (or their equivalent) must be consistent throughout sections 8.3 and 8.4.

8.2 *Equipment Preparation:*

8.2.1 Prior to starting calibration verify all reference equipment is in calibration in accordance with Section 6. List all equipment used, both test vehicle and reference force measurement, signal conditioning and output devices. Record equipment identification and calibration dates.

8.2.2 Turn on the test vehicle system instrumentation and calibration system instrumentation suitably in advance to allow warm-up before attempting calibration.

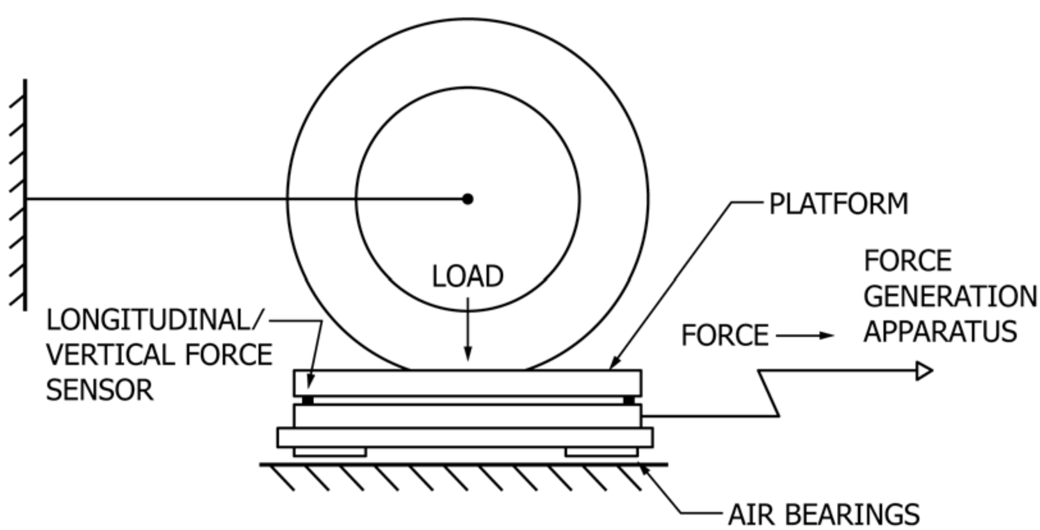

FIG. 2 Force Calibration of a Locked Wheel

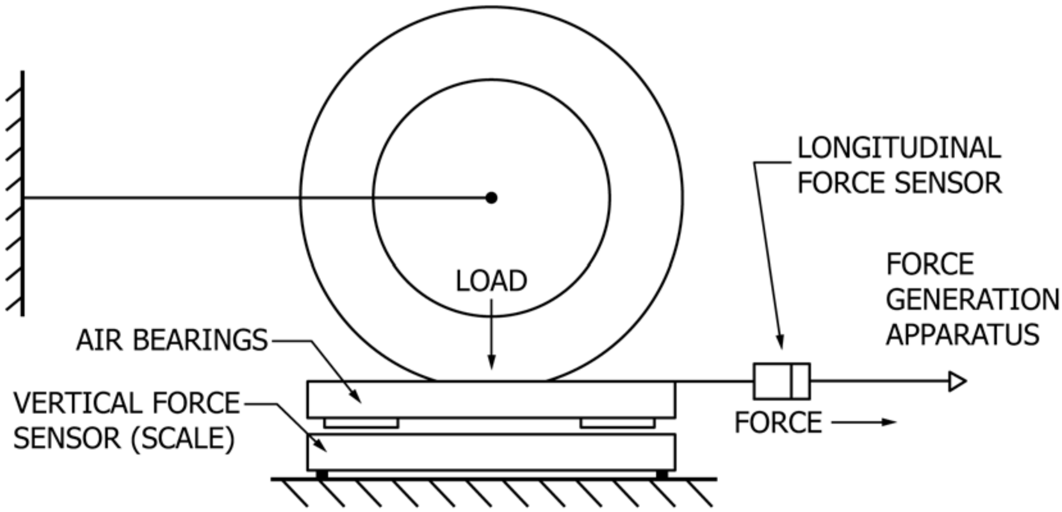

FIG. 3 Force Calibration of Locked Wheel (Alternate Method)

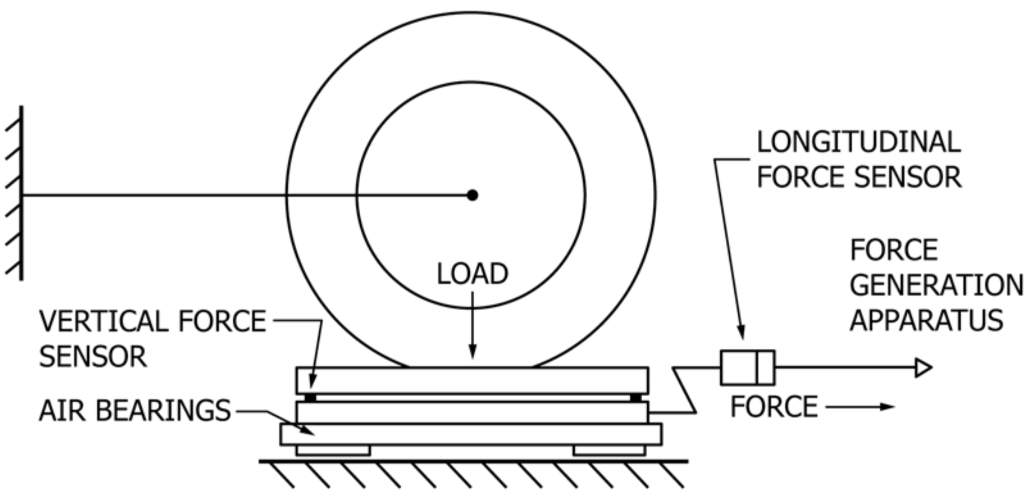

FIG. 4 Force Calibration of a Locked Wheel (Alternate Method)

8.2.3 If necessary, clean the low friction bearing or air bearing plate surface to allow for free movement of the platform.

8.2.4 Position the test wheel over the platform such that the test wheel is located as near as possible to the geometric center of the platform throughout each calibration procedure. If necessary, to maintain normal vehicle orientation and to prevent movement, place blocks with a high friction surface under the other vehicle wheels so that the test wheel mounting face is perpendicular to level within 1°. In the case of a trailer, the hitch point should be externally secured by a fixture or by the tow vehicle. If the tow vehicle is used, engage the brakes and block the wheels to prevent slippage.

8.2.5 Level the platform to within 0.25° and align it laterally within 3° of the trailer or vehicle longitudinal axis along the centerline of the test wheel. Maintain platform level throughout all calibration procedures.

8.3 *Vertical Calibration Procedure:*

8.3.1 Ensure the system force sensors are not stressed by lifting the test wheel from the calibration platform. Verify that the test wheel is locked/unlocked from rotation as appropriate to the test device. The suspension may be further unloaded by tapping the test wheel with a mallet. Adjust the zeros/gains of all systems.

8.3.2 Start the data-logging device and lower the test wheel onto the platform. Increase the load in no less than four increments until the full weight (not less than the anticipated maximum test load) has been placed on the platform. Allow all force indicators to stabilize at each increment. Maintain proper test wheel loadcell rotation (for example, trailer level) throughout the procedure. If not using a data-logging device, take simultaneous readings of both the forces indicated by the test wheel instrumentation and the calibration instrumentation at every increment. Lift the test wheel off the platform, again recording all forces.

8.3.3 Repeat 8.3.2 as necessary to collect at least 12 calibration points.

8.3.4 Determine bias of the vertical test wheel indicator system at each applied vertical load. Bias values shall be less than 1.5 % (minimum of ±13.3 N (±3lbf)) of the applied vertical load.

8.3.5 Determine cross talk of vertical load, read as part of the longitudinal force at each applied vertical load. Longitudinal test wheel indicator system bias at each applied vertical load shall be ±1.5 % or less (minimum of ±13.3 N (±3lbf)) of the applied longitudinal force.

8.4 *Longitudinal Driving Tractive Force Calibration Procedure:*

8.4.1 Assemble the force generation apparatus in the orientation for driving traction and align it laterally within 3° along the centerline of the test wheel.

8.4.2 Ensure the system force sensors are not stressed by releasing the test wheel or by lifting the test wheel from the platform and removing the stress on the force transducers. The suspension may be further unloaded by tapping the test wheel with a mallet. Lock the test wheel as appropriate to the test device and attempt to rotate the wheel to ensure engagement. Adjust the zeros/gains of all systems.

8.4.3 Lower the test wheel onto the platform and apply an appropriate vertical load. Set proper test wheel loadcell rotation (for example, trailer or vehicle level).

8.4.4 Start the data logging device and operate the force generation apparatus to increase the force on the test wheel in no less than four increments up to the maximum anticipated longitudinal force or until the plate begins to slip under the tire, whichever occurs first. Allow all force indicators to stabilize at each increment. If not using a data-logging device, take simultaneous readings of both the forces indicated by the test wheel instrumentation and the calibration instrumentation at every increment. Release the force. Record the forces.

8.4.5 Repeat 8.4.2 through 8.4.4 as necessary to collect at least 12 calibration points.

8.4.6 Determine bias of the longitudinal test wheel indicator system at each applied longitudinal force. Bias values shall be less than 1.5 % (minimum of ±13.3 N (±3lbf)) of the applied longitudinal force.

8.4.7 Determine cross talk of longitudinal force, read as part of the vertical load at each applied longitudinal force. Vertical test wheel indicator system bias at each applied longitudinal force shall be ±1.5 % or less (minimum of ±13.3 N (±3lbf)) of the applied vertical load.

8.5 *Longitudinal Braking Force Calibration Procedure:*

8.5.1 Perform the procedure listed in 8.4 in the opposite orientation.

9. Report

9.1 The calibration should be documented to establish acceptable performance of equipment to this standard.

9.2 Report all calibration data, including date, test tire, wheel offset, vehicle identification, ambient temperature and load cell identification, values for cross-talk, and bias values.

9.3 Use the calibration equations or other results in all testing operations until such results are superseded by another calibration.

10. Precision and Bias

10.1 The vertical load measurement by the calibration platform has been estimated to be biased by an amount less than or equal to 1.2 % of applied vertical load with a 95 % repeatability interval. The longitudinal force measurement by the calibration platform has been estimated to be biased by an amount less than or equal to 0.7 % of applied longitudinal force plus 0.4 % of applied vertical load with a 95 % repeatability interval.

11. Keywords

11.1 braking traction; calibration; driving traction; force transducer; load cells; traction measuring devices