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Standard Guide for Evaluation, Calibration, and Correlation of E274 Friction Measurement Systems and Equipment[1]

This standard is issued under the fixed designation E2793; 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 guide describes the evaluation, calibration, and correlation of Test Method E274 friction measurement systems as conducted at a Field Test Center (FTC).[2] The evaluation, calibration and correlation process; using the specialized equipment, facilities, surfaces, trained personnel, and Area Reference Friction Measurement Systems (ARFMS) available at each FTC; are conducted using the procedures described below.

1.2 The FTC complies with the requirements of Guide E1890. Guide E1890 requires a more stringent calibration process and requires all ARFMS system be correlated together once a year on three surfaces at three speeds with twelve repeats each for a total of 108 pairs.

1.3 This guide is offered as a process to identify and quantify the variables that affect system performance, to minimize the effect of these variables, and to provide a means to relate Test Method E274 friction measurement systems to reference skid measurement systems.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *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:*[3]

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

E501 Specification for Rib Tire for Pavement Skid-Resistance Tests

E524 Specification for Smooth Tire for Pavement Skid-Resistance Tests

E556 Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)

E867 Terminology Relating to Vehicle-Pavement Systems

E1890 Guide for Validating New Area Reference Skid Measurement Systems and Equipment

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

3. Terminology

3.1 *Definitions:*

3.1.1 *Area Reference Friction Measurement System (ARFMS), n*—a Test Method E274 type measurement system that meets the requirements of Guide E1890.

3.1.2 *Calibration Platform, n*—a frictionless moving platform for applying a tractive force in the contact plane of a tire, and associated means for measuring the applied horizontal and vertical force. Also referred to as a "force plate."

3.1.3 *Field Test Center (FTC), n*—a facility with the needed test equipment, Area Reference Friction Measurement System, test pavements and expertise to evaluate, calibrate and correlate Test Method E274 skid measurement systems.

3.2 Other terminology used in this guide conforms to the definitions in Terminology E867.

4. Summary of Guide

4.1 There are three phases to this guide. Phase one records and reports the static and dynamic condition and accuracy of

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[2] Currently, two FTC's are available. One is located at Texas Transportation Institute (TTI) near College Station, Texas. The other FTC is located at the Transportation Research Center Inc. (TRC) near East Liberty, Ohio.

[3] 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.

the visiting system in an "as arrived" condition with no changes being made. During phase two, each subsystem is evaluated and if necessary, adjusted to insure compliance with tolerances outlined in Test Method E274. Phase three is the final dynamic correlation between the visiting system and the ARFMS.

4.2 An additional service of the FTC will be to calibrate the calibration platform or force plate used by the visiting agency.

4.3 A detailed report will be generated and presented to the visiting agency describing all static and dynamic test results.

5. Significance and Use

5.1 Friction characteristics of road surfaces are monitored by friction measurement systems, and the operating procedure for the use of these systems is found in Test Method E274. However, mechanical or electronic system anomalies, over time, could result in measurement errors or inaccuracies. This requires that each of these systems be evaluated, calibrated and correlated on a regular basis. The interval between calibrations depends on the frequency of use, maintenance and other factors. If any repairs are made to the system that may affect the calibration, the system should be recalibrated before further use. Generally, calibrations and correlations are recommended to be performed on an annual basis by one of the FTCs.

5.2 This guide defines the process of ensuring that Test Method E274 systems produce consistent and accurate data and correlating the Test Method E274 systems to national benchmark Test Method E274 systems.

6. Apparatus

6.1 *Area Reference Friction Measurement System (ARFMS),* a Test Method E274 type measurement system that meets the requirements of Guide E1890.

6.2 *Three Test Pavements (pads),* with an asphalt, concrete or seal coat surface having a uniform low, medium, and high friction that spans the typical operating range and used to correlate multiple Test Method E274 systems. Similar macro texture, of the pads, should be avoided. A recommended range of SN40R for the low friction pad to be below 30, the medium friction pad between 30 and 50 and the high friction pad above 50. The length and width shall be suitable for the entire water/lockup cycle of Test Method E274 systems at the highest designated test speed. The test surfaces shall be homogeneous, level, and free of contaminants and traffic. A nonpolishing surface is recommended. A suggested length and width is 400 ft (122 m) by 12 ft (4 m).

6.3 *Two Load Cells,* calibrated annually and National Institute of Science and Technology (NIST) traceable, 1000 lb (4448 N) and 2000 lb (8900 N). Accuracy is required in accordance with Practice F377.

6.4 *Two Calibration Platforms,* with digital instrumentation as described in Test Method E556 and have been calibrated in accordance with Practice F377. The top surfaces of the platforms are to be installed at the same height as the surrounding floor. Air or hydraulic cylinders are required for applying the horizontal test load.

6.5 *Two Jacks,* for lifting each test wheel.

6.6 *System Readouts for the test instruments,* should be capable of accurate measurement of applied loads.

6.7 *Water Volume Measurement System,* to calibrate the water pumping ability of the water system. Consists of: a collector to capture all water pumped during a fixed time interval, a device to measure the volume of water pumped, and a stopwatch.

6.8 *Static Water Distribution gauge (SDG),* a collector, set at floor level, which is divided into twenty-two sections of equal width, ⅝ in. (16 mm), so that each section catches water from the water nozzle and feeds it into a separate reservoir and viewing tubes thus allowing the water nozzle distribution to be evaluated and photographed.

6.9 *Speed Measurement System,* to measure vehicle speed, ±0.1 mph (0.2 km/h). A fifth wheel calibrated to Test Method F457, precision GPS or precision radar is recommended.

6.10 *Precision Pressure Gauge,* for the calibration of tire pressure gauges. Accuracy of ±0.25 % full scale or better.

6.11 *Inclinometer,* with a measuring resolution of 1 min.

6.12 *Force Plate Calibration Fixture,* a system, capable of developing a precision longitudinal and vertical force sufficient for the calibration of a calibration platform throughout its operating range as described in Practice F377.

NOTE 1—The following procedures (Sections 7, 8, 9 and 14) are for one test wheel, usually the left. On systems using two test wheels, these procedures must be repeated for the opposite side.

7. 'As Arrived' Correlation

7.1 Visiting systems that have been in use in their current state, upon arrival, should be correlated with the FTC ARFMS on three surfaces at the systems normal test speed and optionally at one to two additional test speeds (see Note 3), with twelve repeats each. This will be done with either a Specification E501 or Test Method E524 test tire on each system as requested by the visiting personnel. The visiting system and the ARFMS should attempt to measure in the same lateral and longitudinal location for each pair of skids. The twelve repeats will be averaged and the mean and standard deviation will be reported, for each system, for each of the three surfaces. These values will be referred to as the "As Arrived Correlation Data."

8. Physical Measurements

8.1 Physical measurements of the visiting system will be conducted and recorded in the 'as arrived' condition, before any changes are made. These measurements consist of: water nozzle height, horizontal angle, and lateral position relative to tire centerline, for each nozzle used. Also, the distance from the bottom of the hitch coupler to the floor, distance from the end of the nozzle to the trailer axle center, distance from the trailer axle center to the floor, and the distance from the center of the hitch to the center of the trailer axle will be recorded.

8.2 Angle of the trailer tongue and direction (up or down) along with the trailer lean angle will be recorded.

8.3 Hitch height, above ground level, is measured and recorded at a half tank.

8.4 The angular rotation of the force transducer(s) shall experience less than 1 degree angular rotation with respect to its measuring plane. This may be measured on the calibration platform, during the 'Static Force Evaluation and Calibration', using a precision inclinometer attached to the test wheel and operating the platform from 0 to 800 lb (0 to 362 kg) horizontal force.

8.5 Any changes to these measurements, to comply with Test Method E274, are to be made and recorded as "Final."

9. Static Force Evaluation and Calibration

NOTE 2—Any changes made by the following steps may make the previous calibration/correlation performed by one of the FTCs invalid. Changes should only be made by qualified personnel.

9.1 Determine that the calibration platform has been suitably calibrated within one year in accordance with Practice F377.

9.2 Drain or fill the water tank to obtain one-half tank of water onboard the friction measurement system truck.

9.3 Back the trailer onto the calibration platforms ensuring it is square and centered.

9.4 Set truck tire, trailer tire and air shock pressures to user specified pressures (trailer tires should be set to 24 psi (1.65 bars)).

9.5 Apply external air and power to skid system.

9.6 Start the truck data system and go to the bridge forces screen.

9.7 Record the as arrived calibration values (for example: bias, zero, gain, shunt, or static) for the horizontal force and vertical force channels.

9.8 If the skid system is new, or has had upgrades that affect the calibration, skip to 9.10. If the skid system has been in use in its current state, make an "As Arrived" evaluation of the system by performing these steps:

(a) Perform daily startup procedure per standard practice by the user.

(b) Raise the test wheel above platform and record both Load and Traction values from the skid system and the calibration platform.

(c) Lower the test wheel back onto the force plate and "float" the plate, ensuring the plate surface is level in both directions. Record both Load and Traction values from the skid system and the calibration platform (Load should be approximately 1085 lb (492 kg), and Traction should be nearly zero).

(d) Float platform and lock brake. Record both Load and Traction values from the skid system and the calibration platform with an applied force of 0, 500, and 800 lb. Record computed skid number for each condition from the platform and skid system.

(e) Measure and record wheel rotation from 0 to 800 lb applied force. If greater than 1° rotation, repairs must be made.

(f) Repeat on 2nd side if a two-sided system.

(g) From the data collected, determine if system meets the 1 % loading and crosstalk requirements of Test Method E274.

9.9 Measure and record tongue angle and hitch height (from ground to the bottom of the coupler).

9.10 Separate trailer from truck, install the tongue load cell fixture under the trailer hitch and adjust to the same angle as when attached to hitch.

9.11 Weigh and record the "As Arrived" weight of each wheel and the tongue.

9.12 If all "As Arrived" values collected are within specifications per Test Method E274, reconnect truck and trailer and check trailer alignment. Skip to 9.20.

9.13 Adjust weights as needed to meet specifications per Test Method E274 and document "As Final."

9.14 Reconnect truck and trailer and check trailer alignment.

9.15 Configure system (according to manufacturer procedure) to read accurate values directly from the transducer.

9.16 Measure horizontal force-into-vertical force cross talk by first recording vertical force on test wheel and plate with zero horizontal force applied then lock the brake and pull 500 lb (226 kg) horizontal force. Compare the difference in vertical force value on the platform to the difference in vertical force value from the test wheel transducer. The difference between the change in the transducer force and platform force should be 1 % or less or 5 lb (2.2 kg). If not, rotate the wheel transducer or adjust the hitch height, within manufactures limits.

9.17 With zero horizontal force applied, measure the vertical-into-horizontal cross talk by first recording the wheel transducer horizontal force at full vertical force (approximately 1085 lb (492 kg)) then reduce the wheel weight by 500 lb (226 kg) and record wheel horizontal force again. The difference between two horizontal force values should be less than 5 lb (2.2 kg). If not, rotate the wheel transducer or adjust the hitch height slightly, within manufactures limits.

9.18 If the hitch height was changed or transducer was rotated, repeat the steps in 9.16 and 9.17 until both axes exhibit a cross talk less than 1 %. Record the changes as Final values.

9.19 Using the air bearing platform, calibrate the friction measurement system vertical and horizontal force channels in accordance with the manufacturer's instructions.

9.20 Make a "Final" run, with the plate floating and the brake locked, increasing horizontal force to 200, 300, 400, 500, 600, 700, 800 lb (91, 136, 181, 227, 272, 318, 363 kg), and decreasing back to 500 lb (227 kg), recording horizontal and vertical force from platform and the skid system data system at each step as well as skid number if available.

9.21 Test Method E274 recommends overall system accuracy (applied versus measured SN) be 1½ % of reading from 200 lb (91 kg), horizontal force, to full scale. If the calibration process indicates the system is outside these recommendations remedial action should be taken.

9.22 With additional weights on the test wheel fender, utilize an air jack under the test wheel axle to reduce the indicated platform load from 1200 lb (544 kg) to 900 (400 kg) and back to 1200 lb (544 kg) in steps of 100 lb (45 kg), while

recording skid system vertical load for each step. Calculate hysteresis which should be less than 1 % of the applied load. Nonlinearity should be less than 1 % of the applied load as well.

9.23 When finished, record the horizontal and vertical force calibration shunt and other computed constants.

9.24 Record the skid system cycle time.

10. Tire Pressure Gauge Calibration

10.1 Using the FTC pressure gauge calibrator, calibrate the visiting system tire pressure gauge by applying air pressure to the gauge at 20, 24, and 28 psi (1.38, 1.65, and 1.93 bar).

10.2 Record the results in the "As Arrived" column. Any changes in the gauge to bring it into agreement will require the above steps to be repeated and entered into the "Adjusted" column. The final accuracy of the gauge must be ±0.5 psi (±0.03 bar) at 24 psi (1.65 bar).

NOTE 3—The following sections require the selection of test speeds. The primary test speed is 40 mph (64 km/h) and one test speed below and one test speed above the primary speed need to be selected to evaluate the visiting system. Suggested test speeds are 20, 40 and 60 mph (32, 64 and 97 km/h) or 30, 40 and 50 mph (48, 64 and 80 km/h). The speed calibration, water calibration, and departure correlation are conducted at the three speeds selected. 20, 40, and 60 mph (32, 64 and 97 km/h) are the example speeds for the remainder of this document.

11. Speed and Distance Calibration

11.1 Evaluate the visiting system speed measurement system utilizing a calibrated speed measurement system such as a fifth wheel, radar gun, or high quality GPS.

11.2 Set truck tire, trailer tire and air shock pressures to user specified pressures (trailer tires should be set to 24 ± 0.5 psi (1.65 ± 0.03 bar) at ambient temperature.

11.3 Operate the visiting system on the FTC facilities at 20, 40 and 60 mph (32, 64 and 97 km/h) as indicated on the FTC's readout for a sufficient distance to accurately verify the indicated digital vehicle speed. Report the values as the "As Arrived" speeds along with the arrival calibration values for speed and distance.

11.4 Calibrate the distance measurement by driving the surveyed course distance and following the friction measurement system manufacturer's instructions for distance calibration.

11.5 If needed, make any manufacturer's recommended adjustments to the system to correct the system values to the FTC's readout values, within ±1.5 % of the indicated speed or ±0.5 mph, whichever is greater. Record the system calibration values, including calibration values for distance, left and right trailer wheel speed, and digital vehicle speed.

11.6 Operate the system at 20, 40, and 60 mph (32, 64 and 97 km/h) as indicated on the FTC's readout for a sufficient distance to accurately verify the indicated left and right trailer wheel speeds and the digital vehicle speed as applicable. Report the values as the "Final." Conduct a skid test at each of the three speeds and record the resultant test speed the computer reports. Also record the vehicle speedometer and tachometer indication at each of the three FTC readout speeds.

12. Water Flow and Distribution

12.1 The water nozzle flow and distribution are calibrated on the FTC underground water pit using the water flow collector and the static distribution gauge.

12.2 Set up and secure the truck and trailer for the water system calibration.

12.3 Either place the truck drive wheels on rollers or raise off the floor on jack stands.

12.4 Start the truck, bring the truck up to one of the test speeds, and activate the water system. When the speed is stable, slide the water flow collector under the nozzle. After one minute remove the collector and stop the truck wheels. Record the speed and amount of collected water as "As Arrived" in gallons per minute (mL/min).

12.5 Repeat the 12.4 procedure at each test speed.

12.6 If the water flow rate is not within the allowable 10 % minimum and maximum in accordance with Test Method E274, change pulleys, clean the system, or perform other maintenance on the water delivery system to bring the values into specification.

12.7 Repeat the 12.4 procedure three times at each of the test speeds. Record the results as "Final" along with any service work performed.

12.8 With the flow collector removed, operate the truck and system at one of the three test speeds. Capture the water from the nozzle into the static distribution gauge until the outboard tubes show visible water. After each run label the menu board with: state, unit number, speed, run number and date then photograph to document the distribution of the water from the nozzle. Repeat this process at each of the test speeds, changing the menu board to reflect the correct speed and run number.

12.9 If the system is equipped with two test wheels and both nozzles are connected to the same pumping system, only an observation of the flow from the opposite side nozzle would need to be made to insure that no holes are blocked. If separate pumping systems are used for each side, this procedure (Section 12) must be conducted for both left and right nozzles.

13. Force Plate Calibration

13.1 If a force plate is provided along with the visiting friction measurement system, the force plate is calibrated in accordance with Practice F377 standard procedures using the FTC Force Plate Calibration Fixture.

14. Final Correlation

14.1 Visiting systems, after any required adjustments, to bring them into compliance with Test Method E274, will be correlated with the FTC ARFMS on three surfaces at the three test speeds with twelve repeats of each surface / speed combination for a total of 108 pairs. This will be done with the same type of tire used in the 'As Arrived' correlation, either a Specification E501 or Test Method E524 test tire, preferably from the same batch on each system, measuring in the same location of each surface. The twelve repeats will be averaged and the mean and standard deviation will be reported, for each

system, in each of the three surface/speed (9) conditions. These values will be referred to as the "Departure Correlation Data."

15. Documentation

15.1 Document the year, make, model, VIN and description of the truck including type of water pump system. Document the trailer manufacturer, model, serial number, year of acceptance, and year of last update, if available. Record the type of data acquisition system along with current software revision number. Also record or photograph any other items of interest relating to the system, the operator(s), tow vehicle interior view showing data acquisition system, and the water distribution nozzle. Have the person responsible for the visiting system; provide information as to the owner of the system and address along with the names of the manager and operators.

16. Report

16.1 Provide the client with a report detailing the results of the evaluation and calibration of each of the sub systems, the results of the arrival and departure correlations including the correlation equations, graphs, any repairs or adjustments made to the systems, photographs of the system, and any recommendations for improvements or adjustment to their data as determined by the correlation equations. List any subsystem that did not meet the requirements of Test Method E274. One copy of the report is placed in the FTC's permanent records and one copy is forwarded to the other FTC.

17. Frequency of System Correlation and Calibration

17.1 It is recommended that the visiting system be correlated and calibrated to Sections 1 through 16 of this guide at least once a year.

17.2 A verification that the skid system is functioning correctly should be performed once a month at the agency's home facility.