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Standard Guide for Validating New Area Reference Skid Measurement Systems and Equipment[1]

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1. Scope

1.1 This guide covers validating area reference skid measurement systems (ARSMS) and related equipment. These systems have been used since 1976 to evaluate and correlate Test Method E 274 skid measurement systems used primarily as a pavement management tool by state Departments of Transportation. Also, this guide provides guidelines for the revalidation process following the replacement of components within an ARSMS.

1.2 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 method of validating a new ARSMS to replace an existing ARSMS that has provided quality correlation data for a very long time.

1.3 The values stated in inch-pound units are to be regarded as the standard since the ARSMS will be compared with state departments of transportation systems that all currently use inch-pound units. The SI values given in parentheses are provided for information only.

1.4 *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:*

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[1] This guide is under the jurisdiction of ASTM Committee E-17 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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E 274 Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire[2]
E 501 Specification for Standard Rib Tire for Pavement Skid-Resistance Tests[2]
E 556 Test Method for Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)[2]
E 867 Terminology Relating to ~~Traveled Surface Characteristics~~ Vehicle-Pavement Systems[2]
F 377 Practice for Calibration of Braking/Tractive Measuring Devices for Testing ~~of Pneumatic~~ Tires[3]
F 457 Test Method for Speed and Distance Calibration of a Fifth Wheel Equipped With Either Analog or Digital Instrumentation[3]

3. Terminology

3.1 *Definitions*:

3.1.1 Terminology used in this guide conforms to the definitions in Terminology E 867.

4. Summary of Guide

4.1 There are three phases to the process of validating new ARSMS equipment. Phase One is the calibration of all the equipment and instrumentation to be used in this process. Phase Two addresses the variables associated with the determination of a skid number (SN) and attempts to quantify the impact that each variable may have upon the accurate determination of an SN. Phase Three is the dynamic validation process, based upon the variables confirmed in Phase Two.

4.2 The approach is based upon Test Method E 274 but with much narrower tolerances and greater control of the many potential variables. The extra effort is required since the products are measurement tools which will be used to evaluate the variety of Test Method E 274 systems.

4.3 It is anticipated that the SN data produced by the two existing ARSMS and the SN data produced by each of the new ARSMS will have no significant difference.

4.4 The following three-phase procedural guide identifies the individual components or pieces, the evaluation process for each item, and the expected results.

5. Significance and Use

5.1 Friction characteristics of traveled surfaces are monitored by skid measurement systems, and the operating procedure for the use of these systems is Test Method E 274. However, dynamic measurement differences between these systems, that comply with the requirements of Test Method E 274, require that each of these systems be correlated to each other system. The most effective approach to accomplish this correlation is to compare each system to a singular, highly accurate system, or to a very limited number (two or three) of systems, in a controlled environment. The ARSMS's were designed to be such systems. Fig. 1 depicts a skid measurement system and shows the general location of the major components.

5.2 This guide defines the process of ensuring that the ARSMS's continue to accomplish their intended purpose.

6. Apparatus

6.1 *Voltmeter(s)*, capable of accurate measurement of line voltage and dc voltages common in strain gage instrumentation.

6.2 *Thermometer*, to monitor temperature within the truck cab during static calibrations.

[2] *Annual Book of ASTM Standards*, Vol 04.03.
[3] *Annual Book of ASTM Standards*, Vol 09.02.

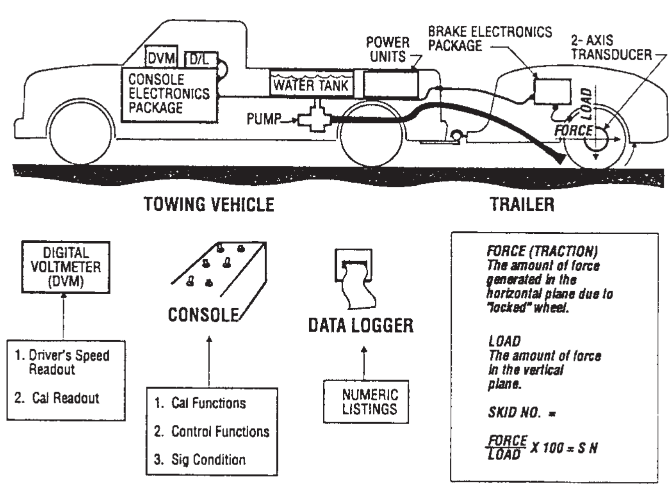

FIG. 1 Skid Measurement System

6.3 *Load Cell*, National Institute of Science and Technology traceable, 1000 lb (4448 N) and 2000 lb (8900 N) ranges are required in accordance with Practice F 377.

6.4 *Distance/Velocity Measurement System*, required in accordance with Test Method F 457.

6.5 *Tachometer*, to determine and monitor the speed of the water pump during calibration of the water system.

6.6 *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, a stopwatch, and a method to operate the water pump at various speeds.

6.7 *Static Water Distribution Gage, SDG*, a collector, set at the roadway level, that is divided into 22 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 tube thus allowing the water nozzle distribution to be evaluated.

6.8 *Multiple-Event Timer*, to determine the cycle time of the water delivery, brake apply, wheel lock-up, data averaging, and brake release events. Timer must have an accuracy of ±0.001 s.

6.9 *Recorder*, to record vehicle speed, ±0.1 mph (0.2 km/h), versus time.

6.10 *Infrared Photo-Electric Trigger System*, capable of activating the brake apply circuitry in a repeatable manner.

7. Phase One

7.1 All ARSMS's shall meet all requirements of the current version of Test Method E 274.

7.2 *Calibration of the Force Plate and Air Bearing Platform*:

7.2.1 Calibrate both axes of the calibration platform under simultaneous load conditions in accordance with Section 6 of Test Method F 377, with the following modifications:

7.2.1.1 Calibrate traction through a range from 0 to 800 lb (3560 N). (See 6.3.4 of Test Method F 377.)

7.2.1.2 Crosstalk shall be less than 0.5 % of the applied load. (See 6.3.4 of Test Method F 377.)

7.2.1.3 Use the reference load cell to calibrate the vertical load axis of the platform with zero traction force. Repeat using an applied traction force of 500 lb (2225 N). (See 6.3.10 of Test Method F 377.)

7.2.2 Adjust platform instrumentation zero and span to indicate correct values from National Institute of Science and Technology traceable load cells. Record calibration values.

7.2.3 Repeat the platform calibration two more times to verify repeatability, within tolerance specified in 7.2.1 or Test Method F 377 whichever is less.

7.3 *Towing Vehicle*:

7.3.1 Perform maintenance, as required, to ensure the tow truck is dependable and capable of functioning to minimize any delays to the program. Determine the normal load distribution of the truck and maintain this distribution during this process, within the range of fuel and water load variation. Determine the hitch height, with the trailer connected and ¼ tank of water, and repeat this measurement with a full tank of water. The measured difference in hitch height with full water versus ¼ water should not exceed 2 in. (50 mm).

7.3.2 Determine the effect of engine speed on system electronics such as excitation voltage, amplifier outputs, and noise. The system electronics must not be affected by engine r/min, and any electrical noise problems must be eliminated or these effects minimized and documented.

7.3.3 Determine the effect of cabin temperature upon the system electronics. Use the truck's heating and air conditioning system, combined with outside ambient air temperature, to vary the cabin temperature from 60 to 90°F (15 to 32°C). Document the temperature stability of the system, and if cabin temperature does affect the fidelity of the system electronics, eliminate or minimize the effect.

7.4 *Trailer*:

7.4.1 Set the weight distribution of the trailer at 1085± 5 lb (4828 ± 22 N), per wheel, with the tongue weight of 150 ± 25 lb (667 ± 111 N). Tire pressure is 24 ± 0.5 psi (165 ± 3 kPa) cold.

7.4.2 Determine the temperature stability of the transducer outputs. Record the zero, gain, and calibration voltage output, both traction and load, with the transducer and instrumentation system energized for one hour but with the brakes and tires at ambient conditions. Run 24 wet and 10 dry slide tests to put heat into the transducer. Stop, following the last dry slide, wait five minutes, and recheck the transducer zero, gain, and calibration voltage. Minimize and document any effect of transducer temperature upon transducer outputs.

7.5 *Distance and Velocity Measurement Device*:

7.5.1 If the distance and velocity measurement device used to generate speed and distance data for the skid system is a separate subsystem, calibrate this subsystem in accordance with Test Method F 457 standards with the following modification:

7.5.1.1 All three speed calibration runs must agree with the calibrated speed within ±0.2 mph (0.3 km/h). (See 6.4.2 of Test Method F 457.)

7.5.2 If the truck drivetrain is normally used to generate speed and distance data for the skid system, its outputs must be calibrated and adjusted to match that of a calibrated distance and velocity device. The truck and trailer are to be loaded to their normal load condition with tire pressures set at their recommended inflation pressure cold. Select a high-quality distance and velocity measurement device, calibrated to Test Method F 457 standards, to be used to calibrate the on-board distance and velocity measurement system. Run a measured mile and adjust the device to obtain 5280 ± 5 ft (1609 ± 1.5 m) distance at each calibrated speed: 20, 40, and 60 mph (32, 64, and 97 km/h). Repeat the process two more times at each speed. The distance outputs must repeat within ±5 ft (1.5 m) on all runs. The speed output of the drivetrain device must agree with the calibrated speed output within ±0.2 mph (0.3 km/h).

NOTE 1—If a fifth wheel is selected, ensure that it has been balanced and has minimal radial run out. The fifth-wheel mount should be positioned such that the fifth-wheel frame is horizontal in the down position. Prior to the calibration, set the fifth-wheel tire pressure in accordance with the manufacturer's recommendations, and warm-up the system for 5 miles (8 km) at 40 mph (64 km/h).

7.6 *Water System*:

7.6.1 Determine the water pump driven speeds at 20, 40, and 60 mph (32, 64, and 97 km/h) with normal truck loading conditions:

7.6.1.1 Full fuel and water loads,

7.6.1.2 Distance and velocity measurement device installed,

7.6.1.3 Cold tire pressures set, and

7.6.1.4 Air shock pressure set.

7.6.2 Operate the truck at calibrated speeds of 20, 40, and 60 mph (32, 64, and 97 km/h) to obtain the water pump driven speed for each corrected speed.

NOTE 2—The transmission must be in the gear normally used for skid testing.

7.6.3 Using the water volume measurement system, determine that the quantity of water delivered matches Test Method E 274 requirements within ±5 %, instead of ±10 %, under all conditions. Run three repeats at each of the three water pump speeds, equating to 20, 40, and 60 mph (32, 64, and 97 km/h), with a full water tank for the water quantity tests. Run three repeats at each water pump speed with a ¼ full water tank. Repeatability is to be within 5 % of the average.

7.6.4 Determine that the position of the water nozzle meets the geometry requirements of Test Method E 274.

7.6.5 If the system uses a movable water nozzle, actuate the water nozzle positioning system three times and measure nozzle angle, ground clearance, tire/nozzle center alignment, and water to ground contact point each time to determine that the system repeatedly places the nozzle correctly.

7.6.6 Using the static water distribution gage, determine the distribution of water at each of the three water pump speeds. Make three runs at each speed. Take pictures of the static water distribution gage following each run to check for repeatability. The difference between any two column readings shall not exceed 10 % of the maximum column height.

7.7 *Cycle Timing*—Using timing equipment capable of accurate measurements of 0.001 s, determine the cycle time and sequence of the water delivery, brake apply, wheel lock-up, data averaging, and brake release events. Repeat two more times to determine repeatability within 0.01 s.

7.8 *Tires*:

7.8.1 Select sufficient quantity of Specification E 501 tires including spares, as dictated by the test matrix developed elsewhere in this guide, to conduct the correlation. The tires must be from the same batch and be selected on the basis of their ability to meet the nominal values of the specifications in Specification E 501.

7.8.2 Mount, balance, and break-in tires in accordance with Test Method E 274.

7.8.3 Mark the tires with a radial sidewall stripe to assist in determining lock-up, and number each tire. Record all tire data by tire number for later reference.

7.9 *Wheel Transducer Calibration*:

7.9.1 Calibrate both axes of the wheel transducer in accordance with Test Method E 556 with the following modifications:

7.9.1.1 Tolerance on crosstalk is 0.5 % instead of 1 %. (See 7.4.1 in Test Method E 556.)

7.9.1.2 If the traction crosstalk into load measurement requires transducer rotation, the load crosstalk into traction must be rechecked. (See 7.4.1 in Test Method E 556.)

7.9.1.3 Minimizing traction crosstalk into load has priority over load crosstalk into traction. (See 7.4.1 in Test Method E 556.)

7.9.1.4 Nonlinearity and hysteresis of wheel transducer load and traction values must not exceed 0.5 % of maximum applied load, above 200 lb (890 N). (See 8.10 in Test Method E 556.)

7.9.1.5 Calibration of the traction output must span 0–800 lb (3560 N) with an initial vertical load of 1085 ± 5 lb (4828 ± 22 N). Repeat the traction calibration with the vertical load at 1250 ± 5 lb (5562 ± 22 N). (See 8.11 in Test Method E 556.)

NOTE 3—Repeat each step of the calibration process two more times to verify repeatability within the tolerance specified in 7.9.1 or Test Method E 556, whichever is less.

8. Phase Two

8.1 *Sensitivity of Wheel Force Calibration to Variations in Operating Parameters*:

8.1.1 The change in offset, span, or both, of wheel force transducer outputs, due to variations in operating parameters, is to be determined. The operating parameters to be varied include:

8.1.1.1 Hitch height; level tongue ±1 in. (25 mm),

8.1.1.2 Test tire inflation pressure: 24 and 30 psi (165 and 206 kPa),

8.1.1.3 Air shock pressure: 60 ± 10 psi (411 ± 69 kPa), and

8.1.1.4 On-board power: line power and truck power.

8.1.2 Set up the system for normal traction calibration, and set one of the above parameters to the high-limit value. Perform the traction calibration, as described in Phase One, and minimize any differences from the original traction calibration. Reset the chosen parameter to the low-limit value, and repeat the traction calibration. Again, minimize any differences from the original traction calibration. Repeat this process until all parameters have been investigated at both the high and low limits. Record the results of all the preceding calibrations.

8.2 *Longitudinal Skid Positioning Evaluation*—The start of the skid cycle will be initiated automatically by means of a photo-electric system. Each truck will be equipped with an infrared light source/receiver. A repositionable reflector will be located at the appropriate trigger point. Place a reference pylon at the designated point for wheel lock-up during the skid tests. Locate the infrared reflector at the point the skid is to be initiated such that the test wheel will lock at the designated point (reference pylon). This step will require some trial and error. Run twelve skids at each of three speeds, 20, 40, and 60 mph (32, 64, and 97 km/h) on the selected pad. After each skid, measure the distance (*F*) between the designated lock-up point and the actual lock-up point as noted by an observer stationed near the reference pylon. The distance *F* shall not exceed 1 ft (305 mm) for any of the 36 skids. If *F* values greater than one occur, determine the cause of the problem and adjust the subsystem.

9. Phase Three

9.1 *Dynamic Validation*:

9.1.1 To ensure that the new ARSMS is equivalent to the ARSMS being replaced, a dynamic comparison or correlation must be performed. Prior to the correlation, the calibration and error minimizing steps of Phase One and Phase Two must have been completed within the previous 30 days.

9.1.2 The correlation should consist of 108 skid pairs, using three different speeds, typically 20, 40, and 60 mph (32, 64, and 97 km/h), three different pavement types, with twelve repeats per each condition. Prior to the test runs, new (broken-in) Specification E 501 tires from the same batch, shall be installed on the test wheel of each ARSMS. To reduce the effect of friction and construction differences between test tires, each ARSMS will use each tire for an equal number of runs. This may be accomplished by first completing the three speeds and three surfaces with only six repeats. The tires will then be switched between systems. The remaining six repeats of the matrix will then be performed. If more than two systems are compared, the same test tire must be used for the same number of repeats on each system.

9.1.3 Statistical analysis of the results should indicate no significant difference between the ARSMS's by the use of the Student's *t*-test. If a significant difference is observed, re-evaluate each system variable in a static and dynamic condition and correct, reduce, or statistically account for the anomaly with a correlation equation. Repeat the dynamic test matrix until a satisfactory correlation is reached.

9.2 *Validation Interval*:

9.2.1 All active ARSMS's are to be validated on an annual basis utilizing the procedure described in this guide. The correlation between all active ARSMS's shall be conducted at a single site and all ARSMS's shall be operated together.

9.3 *Results*:

9.3.1 A summary report of the validation results is to be supplied to ASTM Committee E17 following each correlation.

9.3.2 Detailed results of the calibration and correlation of each ARSMS are available from the organization operating that ARSMS. See Note 4.

NOTE 4—Currently these results are available by contacting either TRC, Inc., 10820 State Route 347, East Liberty, OH 43319; or TTI, Safety Division, Texas A & M University System, College Station, TX 77843–3135.

10. Keywords

10.1 correlation; load cell; skid measurement systems; skid number; transducer calibration; tires; water