Designation: E 707 – 90 (Reapproved 2002)

Standard Test Method for Skid Resistance Measurements Using the North Carolina State University Variable-Speed Friction Tester[1]

This standard is issued under the fixed designation E 707; 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 skid resistance of paved surfaces or laboratory-prepared specimens using the North Carolina State University Variable-Speed Friction Tester.[2]

1.2 The Variable-Speed Friction Tester (VST) is a pendulum-type tester with a locked-wheel smooth rubber tire at its lower end. A stream of water at a selected water test velocity is directed by a nozzle along the specimen surface in the path of contact between the locked-pendulum tire and the specimen. The friction between the tire and the specimen is measured from the energy lost in the pendulum. The tester is suitable for field tests on pavement surfaces as well as laboratory use (see Note 1).

1.3 The values measured, VSN (variable-speed (tester) number), represent the frictional properties obtained with the apparatus and procedures stated herein and do not necessarily agree or correlate directly with those obtained by other skid-resistance measuring methods.

NOTE 1—Uneven pavement surfaces in the field may provide inaccurate VSN measurements. Extreme care should be taken when using the VST in the field.

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:*

E 274 Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire[3]

E 524 Specification for Standard Smooth Tire for Pavement Skid Resistance Tests[3]

E 867 Terminology Relating to Traveled Surface Characteristics[3]

3. Summary of Test Method

3.1 The test apparatus consists of a frame that supports a pendulum arm with a small rim (go-cart) wheel and a smooth, no tread-pattern tire mounted at the lower end of the arm. An adjustable nozzle, mounted on the frame, directs a thin sheet of water at the desired water test velocity that impinges at a low angle (3.5 ± 0.5°) on the specimen surface. This wets the contact area between the pendulum tire and the specimen.

3.2 The tester is positioned and leveled on a roadway pavement or on a laboratory floor stand that holds specimens such that the pendulum arm, when released from a horizontal position, will swing downward and prior to contact will exchange potential energy for kinetic energy. The vertical pendulum position is adjusted before each test to provide a specified maximum normal load between the tire and the specimen. The specified load is checked before each test by a strain gage, load cell, or other appropriate instrument. The nozzle pressure regulator is adjusted to give the desired water test velocity at the nozzle exit. With the pendulum arm and pointer in the horizontal starting position, the nozzle valve is opened, and the water stream is directed along the test surface. The pendulum arm is activated by releasing the pendulum trigger. This allows the pendulum arm and tire to swing downward to contact the test surface and swing upward to a stop and start the return swing. On the return swing the operator catches the pendulum and returns the pendulum upward until it latches in the starting position.

3.3 The skid resistance of the specimen is determined from the average of three consistent pointer readings indicated by the upward pendulum swing limit after contacting the specimen. The number indicated by the pointer is equal to 100 sin θ, where θ is the angle between the upward limit pointer position after the pendulum contacts the specimen in a test and the pointer position when the pendulum is allowed to swing

[1] This test method is under the jurisdiction of ASTM Committee E17 on Vehicle-Pavement Systems and is the direct responsibility of Subcommittee E17.23 on Surface Characteristics Related to Tire Pavement Slip Resistance.

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[2] Mullen, W. G., Whitfield, J. K., Gibson, David, and Matlock, T. L., Highway Research Program Project ERSD 110-76-2, “Implementation for Use of Variable Speed Friction Tester and Small Wheel Circular Track Wear and Polishing Machine,” Final Report. Highway Research Program, North Carolina State University, P.O. Box 5993, Raleigh, NC 27650.

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

without contacting the specimen.

4. Significance and Use

4.1 The Variable Speed Friction Tester provides a means to measure laboratory or field pavement surface friction properties for simulated vehicle operating speeds.

4.2 Simulated vehicle operating speeds are varied by varying the water speed or velocity as it passes over the specimen or pavement. A variable water-flow rate or velocity corresponds to a variable tire-over-pavement speed in a vehicle-operation sense.

4.3 Measurement of friction at various simulated vehicle operating speeds allows the establishment of friction-speed gradients on laboratory specimens or on field pavements.

5. Apparatus [2]

5.1 *Pendulum* (Fig. 1)—The pendulum, including wheel and tire, shall weigh 9.3 ± 0.2 kg (20.5 ± 0.9 lb). The distance from the pivot axis of the pendulum to the wheel axis shall be 457.0 ± 3.0 mm (18 ± 0.1 in.). Both axes shall be parallel in space. The period of oscillation of the pendulum shall be 1.4 ± 0.2 s.

5.2 *Wheel and Tire*—The tire shall be a smooth, no-pattern tread tire,[4] conforming to the rubber requirement of Specification E 524, having an approximate 4.10/3.50-5, 90-mm (3.5-in.) tread width. The tire shall be mounted on a suitable 25 by 75-mm (5 by 3-in.) rim.

5.2.1 The tire, inflated to 138 kPa (20 psi), shall be prepared for testing by turning it on a lathe. The tread shall be trued with an appropriate grinding tool to produce a "flat tread surface" or an infinite tread radius. The shoulder shall be beveled to provide a tread width of 75.0 ± 3.0 mm (3 ± 0.1 in.). The tread surface shall be ground to provide a tread surface that feels smooth to the touch and has a dull sheen.

5.2.2 The tire shall be conditioned for test measurements at each new tire position by operating the pendulum against a standard laboratory surface (Note 2) repeatedly until successive friction readings (VSN) do not vary by more than ±0.5 VSN (Note 3).

NOTE 2—A standard surface can be made using a porous grinding stone. Such a surface should yield VSN readings in the 55 to 65 range.

NOTE 3—Readings on a standard surface will increase initially until the tire position is conditioned at which time the readings will stabilize. As many as 150 tests may be required to condition a tire position.

5.2.3 A change in tire position due to excessive wear shall be made if check measurements against the standard laboratory surface vary consistently by more than ±1 VSN. Each new tire position shall be conditioned for test measurements following the procedure in 5.2.2.

5.3 *Nozzle*—The nozzle shall have an exit opening of 0.50 ± 0.01 by 75.0 ± 5.0 mm (0.0200 ± 0.0004 by 3.0 ± 0.2 in.) and shall be made of stainless steel or other corrosion-resistant material. The configuration of the nozzle cavity shall be such that the transition from supply hose cross section to nozzle exit cross section shall be as smooth as possible, particularly in the vicinity of the nozzle exit in order to minimize the likelihood of vortex generation and resultant poor exit flow pattern. The surface finish of the nozzle interior in the exit region shall be that obtainable with 600-grit metallurgical polishing paper with soap. The final polishing shall be in the direction of flow.

5.4 *Water System* (Fig. 2), consisting of a pressure tank, a pump to pressurize the tank, pressure gages, and pressure regulation valve(s) to control the steady-state exit velocity of

[4] A tire suitable for this purpose is available from McCreary Tire & Rubber Co., Indiana, PA.

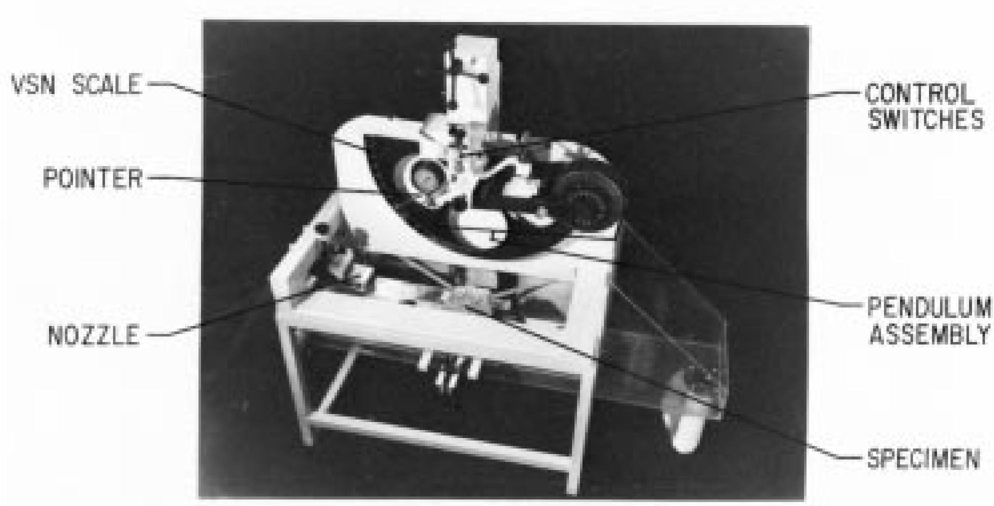

FIG. 1 Variable Speed Friction Tester (VST) Laboratory Setup

FIG. 2 Variable Speed Friction Tester Water System

the water stream from the nozzle. Multiple pressure regulation valves may be used to preset selected test velocities or a single valve may be used and adjusted to each new test velocity. A filter is incorporated in the water system to remove any particulate matter. The water system delivers water to the VST nozzle through a flexible rubber hose that may be varied in length to accommodate both laboratory and field use.

5.5 *Laboratory Floor Stand*, consisting of a steel frame that supports the pendulum unit during testing (see 5.1 through 5.3), holds the water system, holds and permits leveling of test specimens for testing, and collects the water from the nozzle for disposal.

5.6 *Strain Gage, Load Cell, or Other Appropriate Instrument*—A weighing system shall be used to ensure consistent pendulum load pressure.

NOTE 4—A viable weighing system may consist of a strain gage (EA-06-350DD—350 MICRO MEASUREMENT) mounted on the fixed tire axle on the pendulum arm. The axle should be a 16-mm (5⁄8-in.) drill rod, water hardened with a Rockwell hardness between C45–50. A reduced area shall be cut for mounting the strain gage and should achieve a movement of 125–250 MICRO-INCHES for the measurement of strain. The strain gage shall be calibrated by load cell on a regular basis.

6. Sampling

6.1 *Field*—When tests are conducted to measure pavement skid resistance in the field, a sufficient number of locations on any particular road section shall be selected to provide for an accurate assessment of the skid resistance of the pavement.

6.2 *Laboratory*—When tests are conducted on laboratory specimens, a sufficient number of pavement specimen preparations or replicates shall be measured to provide an accurate assessment of skid resistance.

7. Test Specimen

7.1 *Field*—The field test surface in the entire area occupied by the tester shall be free of loose particles and flushed with clean water. In the case of hot bituminous pavements, it is essential to flush the test area with water until the surface no longer feels warm to the touch to assure reliable test readings that have not been affected by settling of the tester into the surface during testing.

7.2 *Laboratory*—Laboratory test specimens shall be clean and free of loose particles and shall be rigidly mounted so as not to be moved during contact with the pendulum. Laboratory specimens shall have a test surface at least 90 mm (3.5 in.) wide by 150 mm (5.9 in.) long parallel to the direction of pendulum motion.

8. Preparation of Apparatus

8.1 *Laboratory*:

8.1.1 Assemble the apparatus by placing the pendulum unit and water system in the laboratory floor stand.

8.1.2 Join the pendulum unit nozzle hose to the water system unit and connect the water system unit to the laboratory water supply.

8.1.3 Level the pendulum unit by adjusting the laboratory floor stand with leveling screws or shims.

8.1.4 Level the VSN (variable speed number) scale arc by releasing the scale arc lock and aligning the 90° mark on the scale arc with the pendulum pointer while the pendulum is in the vertical position.

8.1.5 Rotate the wheel to the desired wheel index position. Engage the wheel rotation lock.

8.1.6 Release the vertical lock (Note 5), place the pendulum assembly in the raised position, and allow the pendulum to swing through from horizontal latched position to check zero VSN setting. Catch the pendulum on the return swing and place it in the latched position. Adjust the pendulum latch up or down on repeated swings until the pointer and pendulum read zero VSN.

NOTE 5—If the vertical lock specified is inadequate, a quick-setting, air-over-hydraulic system may be substituted.

8.1.7 Place the test specimen in the laboratory floor stand holder and secure in place using specimen lock.

8.1.8 Level the specimen by adjusting the holder leveling screws. This is checked by a spirit level placed alternately in orthogonal directions. The spirit level rests on a brass plate underlaid with sponge rubber that is laid on the specimen surface (Fig. 3).

8.1.9 To set the contact pressure, release pendulum vertical positioning lock and engage wheel rotation lock. With pendulum hanging vertically, gently lower the pendulum assembly until weight is fully supported by the test specimen. Check specified load reading. If not within ±0.23 kg (±0.5 lb), raise pendulum and relower until specified load is met. Tighten vertical positioning lock, release wheel rotation lock, and rotate pendulum counterclockwise to the horizontal latched position.

8.2 *Field*:

8.2.1 Assemble the apparatus for field use by placing the water system unit on the field-carrying unit. Connect the field length hose to the pendulum unit that is attached to a swing arm hoist for lateral and vertical mobility.

NOTE 6—A field traffic warning signal trailer equipped with an electrical generator can be modified to carry both the water system unit and pendulum unit. The water supply can be carried on a towing truck.

8.2.2 Lower the pendulum unit into position such that the swing is in the direction of traffic, perpendicular to the pavement surface.

8.2.3 Level the VSN arc following the procedure in 8.1.4.

8.2.4 Zero the VSN setting following the procedure in 8.1.6.

8.2.5 To set the contact pressure, release the pendulum vertical positioning lock. With the pendulum hanging downward, set the pendulum guide to hold the pendulum at right angles to the pavement surface, then lower the pendulum assembly until the weight is fully supported by the pavement. Check specified load reading. If not within ±0.23 kg (±0.5 lb), raise pendulum and relower until specified load is met. Tighten the vertical positioning lock, release the wheel rotation lock, disengage the pendulum guide, and rotate the pendulum counterclockwise to the horizontal latched position.

8.3 *Nozzle Calibration*:

8.3.1 To establish a nozzle calibration curve, measure the volume of water delivered from the nozzle for a set period of time over a range of pressures and calculate the water velocity at each pressure by dividing the volume of water accumulated over the set time by the nozzle exit orifice area. Plot the pressure versus velocity.

8.3.2 Use the calibration curve to select pressures corresponding to the desired test velocities.

8.4 *Water Pressure and Velocity Adjustments*:

8.4.1 A separate pressure may be preset to deliver water through the nozzle to correspond with each of four water test velocities.

8.4.2 To preset a pressure, select the desired velocity on the control switch to activate the appropriate control valve. Turn the water on. Adjust the control valve until the nozzle pressure gage reads the desired pressure for that velocity.

8.4.3 Repeat the procedure in 8.4.2 for three additional test velocities.

9. Procedure

9.1 *Tire Index Position*—Use the same ratchet position for all repetitions on a given pavement location. Change the index position when there is evidence of deterioration of the tread surface at that position as described in 5.2.3.

9.2 *Nozzle Adjustment*—With the pressure selected for the desired water test velocity, turn the water on and adjust the nozzle angle until the nozzle stream impinges on the test surface 25 mm (1 in.) upstream of the center of the contact path (Note 7). Repeat this procedure for each change of test velocity.

NOTE 7—The center of the contact path is the line of intersection of the plane of the pendulum arm extended to meet the plane of the pavement at an angle of 90°.

9.3 *Skid Resistance Measurement*—Place the pendulum and pointer in the horizontal latched position. Select the desired water test velocity. Press the test button that will open the nozzle valve and release the pendulum trigger in sequence. After the pendulum swings upward, catch it on the return stroke and latch it in the horizontal position. Read the pointer indication to the nearest whole VSN (Note 8). Rotate the tire until it is in the selected index position. Return the pointer to the starting position. Repeat the procedure twice more and average the three readings to obtain the VSN.

NOTE 8—A digital read-out system, such as a linear variable transducer differentiator (LVTD), may be added to the VST to facilitate VSN readings.

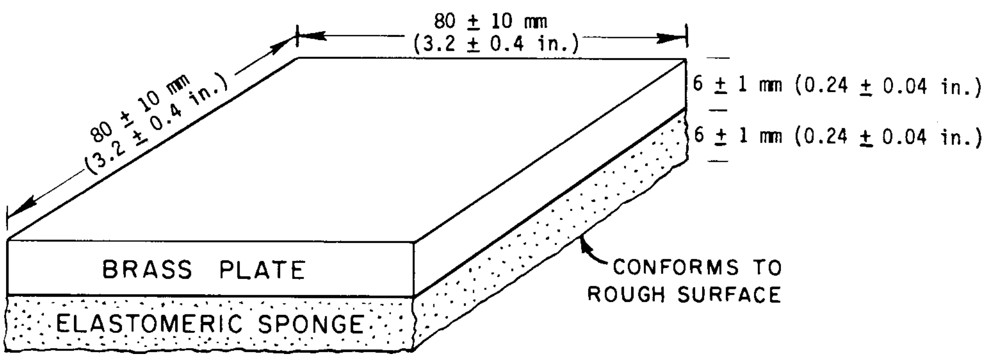

FIG. 3 Contact Pad for Leveling on Rough Surface Specimens

10. Calculation

10.1 Average the three individual pointer readings at a single water test velocity to obtain the VSN for the specimen tested at that velocity. Each individual reading must be within ±1 VSN to be included in the average VSN.

11. Report

11.1 Report the following information:

11.1.1 Site or sample identification,

11.1.2 Description of surface tested,

11.1.3 Water test velocities used,

11.1.4 Individual and average VSN values at each test velocity,

11.1.5 Plot of speed gradients, if applicable, and

11.1.6 Remarks.

12. Precision and Bias

12.1 Precision from field and laboratory tests using one instrument indicates that the range of three individual measurements should not exceed 1.3 VSN.

12.2 Bias determinations are not possible at this time due to the inability to establish a true value of friction for pavement surfaces.

12.2.1 Coefficients of determination for comparison of VSN and SN values in limited tests using both the Variable Speed Tester and the procedure in Method E 274 over the same field pavement surfaces are as follows:

Trailer and Water Velocity, km/h (mph)	Coefficient of Determination
48.3 (30)	0.962
64.4 (40)	0.958
80.5 (50)	0.967