



Designation: F2913 – 19

Standard Test Method for Measuring the Coefficient of Friction for Evaluation of Slip Performance of Footwear and Test Surfaces/Flooring Using a Whole Shoe Tester¹

This standard is issued under the fixed designation F2913; 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 method² determines the dynamic coefficient of friction between footwear and floorings under reproducible laboratory conditions for evaluating relative slip performance. The method is applicable to all types of footwear, outsole units, heel top lifts and sheet soling materials, also to most types of floorings, including matting and stair nosing, and surface contaminants on the flooring surface, including but not limited to liquid water, ice, oil and grease. The method may also be applied to surfaces such as block pavers, turf and gravel.

1.2 Special purpose footwear or fittings containing spikes, metal studs or similar may be tested on appropriate surfaces but the method does not fully take account of the risk of tripping due to footwear/ground interlock.

1.3 The values stated in the ASTM test method in metrics are to be regarded as the standard. The values in parentheses are for information.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ This test method is under the jurisdiction of ASTM Committee F13 on Pedestrian/Walkway Safety and Footwear and is the direct responsibility of Subcommittee F13.30 on Footwear.

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² This standard is derived from SATRA TM144, Friction {Slip Resistance} of Footwear and Floorings, copyright SATRA Technology Centre Ltd., Kettering Northamptonshire, NN16 8SD, United Kingdom.

2. Referenced Documents

2.1 ASTM Standards:³

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

F1646 Terminology Relating to Walkway Safety and Footwear

F2508 Practice for Validation, Calibration, and Certification of Walkway Tribometers Using Reference Surfaces

2.2 Other References:

BS EN ISO 4287 Geometrical product specification (GPS). Surface texture: Profile method. Terms, definitions and surface texture parameters⁴

EN 10088-2 Stainless steels - Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes⁵

F2913-11 Slip test training video⁶

ISO 13287

3. Terminology

3.1 For general definitions of terms, refer to the Terminology F1646.

3.2 Definitions:

3.2.1 *footbed (removable), n*—also known as ‘insock,’ a component typically made of a foam material with a leather or fabric cover/sockliner and often shaped or contoured covering the entire insole board which can be inserted between the foot and insole board.

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.

⁴ Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., <http://www.bsigroup.com>.

⁵ Available from European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium, <http://www.cen.eu>.

⁶ Available at ASTM F13 web page <http://www.astm.org/COMMITTEE/F13.htm>, under Additional Links.

3.2.2 *slider, n*—flat rectangular specimen used in calibrating test surfaces (see 10.5.1) or a circular test specimen prepared from footwear sheet materials (see Note 2), or both.

3.2.3 *slider 96, n*—a pre-described rectangular test specimen intended for use in calibrating test surfaces (see 10.5.1).

4. Summary of Test Method

4.1 The footwear item and underfoot surface are brought into contact, subjected to a specified vertical force for a short period of static contact then moved horizontally relative to one another at a constant speed. The horizontal frictional force is measured at a given time after movement starts and the dynamic coefficient of friction is calculated for the particular conditions of the test.

5. Significance and Use

5.1 This non-proprietary laboratory test method allows for the reproducible testing of whole footwear and footwear-related soling materials for evaluating relative slip performance. Other ASTM test methods generally employ a standardized test foot primarily for evaluation of flooring materials.

6. Apparatus

6.1 Slip tester capable of performing the required test.

6.2 A means of conditioning the test specimens and the standard reference materials against which the specimens are to be tested, prior to the test at $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ RH and of carrying out the test at $23 \pm 2^\circ\text{C}$.

6.3 A means of securely mounting the footwear, outsole, top lift, or slider.

6.4 A flat rigid horizontal surface mount of minimum width 150 mm and minimum length 450 mm, to which the test underfoot surface, hereafter termed the test surface, shall be securely mounted.

NOTE 1—A device may be used to entrap lubricant within the footwear/surface contact area to ensure that the required depth of lubricant is maintained.

6.5 A means of holding the footwear, sole unit, top lift, or slider clear of the test surface between test measurements without contact with any other surfaces.

6.6 A means of adjusting the angle between the footwear, sole unit, top lift, or slider and the test surface so that the required contact angle can be achieved, and a means of adjusting the contact point horizontally with respect to the line of action of the vertical force when required.

6.7 A rigid wedge of minimum dimensions 80 mm wide by 120 mm long shall be used to set the contact angle of $7.0 \pm 0.5^\circ$ between footwear, sole unit or slider and test surface when required. See Fig. 1.

6.8 A mechanism for lowering the footwear, sole unit, top lift, or slider onto the test surface and applying a steadily increasing downward force, including the weight of the test specimen and its mounting, at a rate that enables the required full force—either 400 ± 20 N or 500 ± 25 N (see Table 1) to be achieved within 0.2 s of reaching 50 N.



FIG. 1 Example of Footwear Mounted Using 7° Wedge to Set Proper Contact Angle

TABLE 1 Vertical Load to be Applied in Slip Test Run

Footwear Item	Full Load to be Applied (N)
Footwear and finished soles of size US size 7.5 men's and 8.5 women's, (Paris Points 40) (UK size 6.5) and above	500 ± 25
Footwear and finished soles of sizes below US size 7.5 men's and 8.5 women's (Paris Points 40) (UK size 6.5)	400 ± 20
Top-pieces and sole materials intended for men's footwear	500 ± 25
Top-pieces and sole materials intended for women's, children's and infant's footwear	400 ± 20

6.9 A means of sliding the test surface relative to the footwear, sole unit, top lift, or slider at a speed of 0.3 ± 0.03 m/s commencing within 0.2 s after a vertical load of 50 N is achieved. Sliding shall not start until full vertical force is achieved, see Fig. 2. The footwear test specimen may be constrained while the test floor is moved relative to it, or vice versa.

6.10 A means of measuring time with a resolution of 0.01 s (graph should have tick marks every 0.01 s) or better.

6.11 A means of measuring:

6.11.1 The continuous vertical force exerted on the test specimen, with an accuracy of 2 % or better.

6.11.2 The continuous horizontal frictional force, with an accuracy of 2 % or better, exerted on the test specimen measured in the plane of the surface of the test surface.

6.11.3 The displacement of the moving item, test surface or footwear, sole unit, top lift, or slider, to the nearest 1 mm.

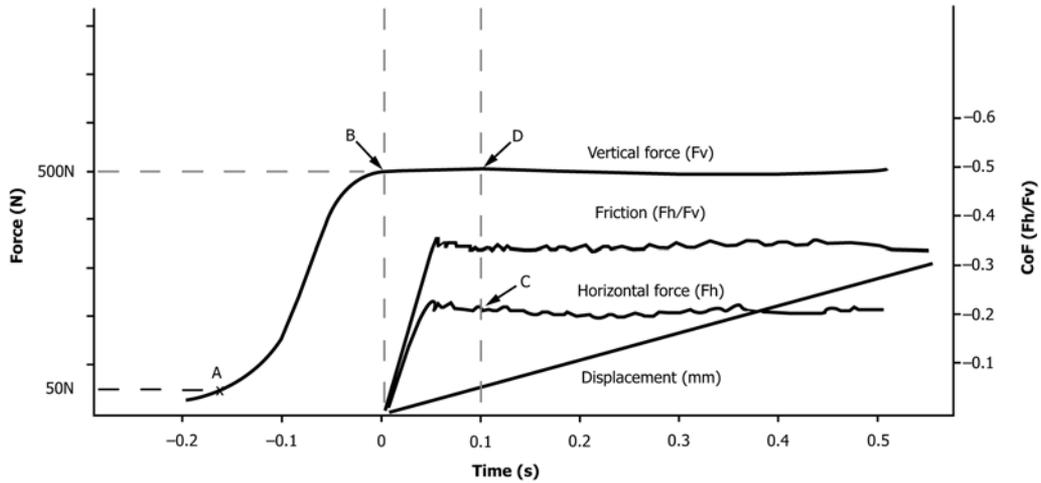
6.12 The apparatus comprising elements 6.2 – 6.10 shall be sufficiently rugged to prevent vibration.

7. Hazards

7.1 Care should be used when working with mechanical equipment. Attention to be given to preventing a pinch hazard while in operation.

8. Sampling and Test Specimens

8.1 For footwear items (footwear, sole units, top lifts, or sliders), see 10.9. It is suggested that circular sliders used to



- Key:
 A – 50 N reached
 B – Full force achieved and relative movement started within 0.2 s after 'A'
 C – Snapshot value of horizontal force taken at (0.1 ± 0.01) s after the start of sliding movement
 D – Snapshot value of vertical force taken at (0.1 ± 0.01) s after the start of sliding movement

FIG. 2 Test Chart Showing Sequence of Events in a Typical Test Run

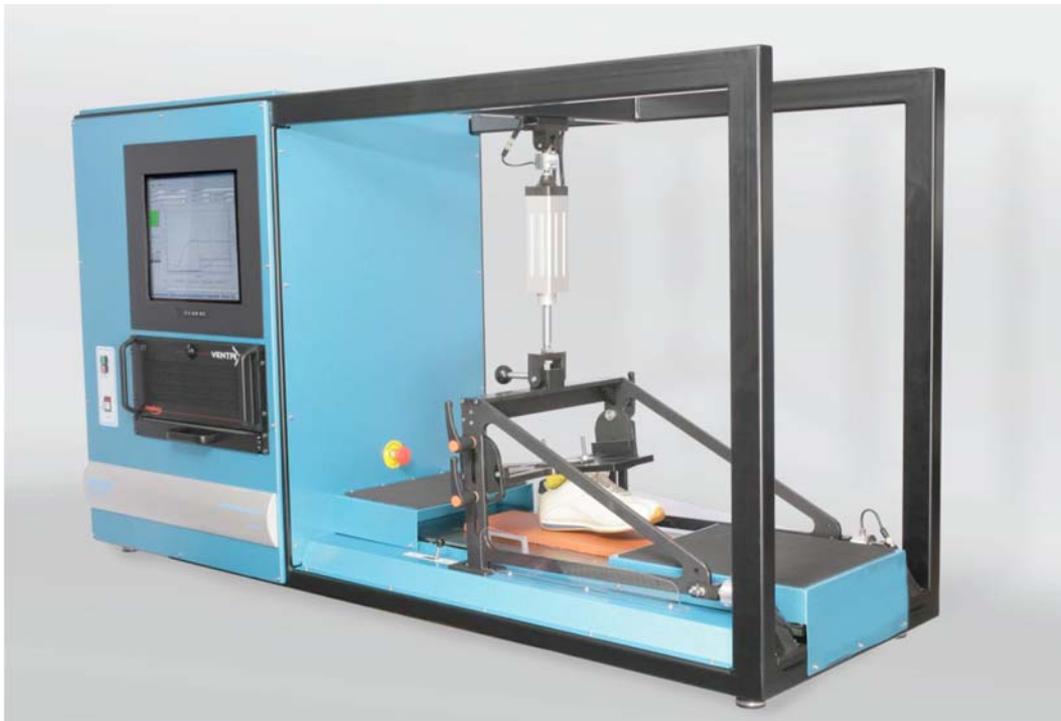


FIG. 3 Example of Test Apparatus

represent top lifts for everyday footwear should 76 ± 1 mm diameter and minimum thickness of 5 mm. A smaller diameter may be appropriate to represent the top lift of women's fashion footwear. The shape and size of slider used shall be documented within the test report (see 14.1.2.1).

NOTE 2—Sliders are generally samples of soling material cut to size from a larger sample.

8.2 For test surfaces, see 10.3; for contaminants/lubricants, see 10.4.

NOTE 3—Either the footwear item or the test surface may be the subject

of the test. Appropriate flooring items and footwear items respectively are selected as the reference materials against which the test item is to be tested.

9. Preparation of Apparatus, Test Specimens and Test Surfaces

9.1 Prepare and condition standard reference materials (test surfaces and/or test sliders) according to 10.6 and Section 11.

9.2 Prepare and condition footwear, sole unit, top lift, or slider according to 10.9.

9.3 Fit and secure the prepared test surface onto the rigid surface mount. If more than one test surface specimen is required to achieve a test track of at least 40 mm, position the joint(s) outside the area traversed during the test run.

9.4 Securely fit the prepared footwear, sole unit, top lift, or slider to an appropriate mounting.

9.5 Lower the footwear, sole unit, top lift, or slider into contact with the test surface under its own weight. Adjust the alignment and angle of the footwear, sole unit or slider to conform to one of the test modes defined in 12.6.1.

9.6 Fully tighten all mounting adjustments and lift the footwear, sole unit, top lift, or slider away from the test surface.

9.7 Apply contaminant if required (see 10.5).

9.8 Activate the data recording system.

9.9 Bring the footwear, sole unit, top lift, or slider into contact with the test surface and apply the required vertical force as specified in Table 1.

10. Calibration and Standardization—Test Surfaces (Floorings) and Lubricants

10.1 General Information:

10.1.1 Any type of test surface and lubricant may be used provided it can be mounted without interfering with the action of the test.

10.1.2 Test surfaces shall be of uniform mean thickness, allowing for any surface pattern, and have minimum dimensions of 220 by 120 mm.

10.1.3 When evaluating an extruded or rolled product, where possible, cut the surface material either:

- 10.1.3.1 Parallel to the process direction,
- 10.1.3.2 Perpendicular to the process direction, or
- 10.1.3.3 At 45° to the process direction.

NOTE 4—Where the process direction is not known, the directions should be referenced in relation to some other distinguishing feature on the flooring.

10.1.4 When evaluating worn surfaces it may be appropriate to evaluate these items in directions aligned with any patterns of wear in addition to the normal modes of testing.

10.1.5 When preparing the surfaces to be used as reference materials for testing footwear or footwear materials, the surfaces shall be calibrated in the direction in which they are to be evaluated.

10.1.5.1 Determination of standard COF test values against a Slider 96 slider in 10.5, or

10.1.5.2 Specification of surface roughness in 10.8.2.

10.1.6 Other floors used for comparing performance of footwear or footwear materials should be characterized by testing against Slider 96 rubber to establish the nominal performance level of the flooring for future reference.

10.1.7 Transient surfaces such as natural grass and ice should be characterized by other means as appropriate, describing in full detail in the report how the surface was made, prepared, and characterized. In general such surfaces will be damaged or changed by the action of the test so it may not be practicable to quantify their friction against a standard slider nor to perform multiple measurements on the same sample.

10.1.8 All test surfaces should be stored carefully: do not stack specimens on top of each other. When handling test surface samples, hold them by the edges and also do not touch the test surface of the tiles.

10.1.9 Cleaning procedures for test materials are given in 10.10.

10.2 Additional Apparatus:

10.2.1 For retaining friable, weak or loose surfaces such as natural grass or gravel, a walled tray that will locate on the horizontal surface of the friction test apparatus and is sufficiently large that no part of the footwear or footwear materials being tested will come into contact with the tray during the test. A flat rigid plate 5 mm less in length and in width than the tray that is used for consolidating friable, weak or loose surfaces such as natural grass or gravel.

10.2.1.1 A means of applying a vertical load to the center of the plate shall be laid on the surface, which should be evenly distributed in the tray, and a vertical load applied through the center of the plate. The area of the plate and the total load applied should be recorded.

10.3 Test Surface:

10.3.1 *Flat unglazed clay quarry tile*^{7,8} that is wider than the test specimen and long enough to allow a sliding distance of at least 75 mm without crossing a joint.

10.3.1.1 Sufficiently flat to allow it to be secured on the mounting table such that no movement occurs between the tile and mounting table during the test.

10.3.1.2 Has a ribbed profile or directional marking on the underside to identify the direction in which the tile should be aligned (with the ribs parallel to the sliding direction).

10.3.1.3 Conforms to the values specified in Table 2 when calibrated by the Slider 96 method (see 10.5).

10.3.1.4 Calibration of the tiles should be checked, after every 10 tests or prior to each day of testing whichever is the less frequent, to ensure that they are not being worn smooth or otherwise damaged. However, if experience shows that the friction properties of the test floor are not strongly influenced by repeated testing then calibration intervals may be extended.

10.3.2 *Ceramic Tile*, such as Eurotile 2 as defined in EN ISO 13287 or the reference surfaces defined in Practice F2508.

10.3.3 *Stainless Steel Plate*:

TABLE 2 Coefficient of Friction Range for Calibrated Quarry Tiles

	Dry COF	Wet COF
Minimum	0.57	0.43
Maximum	0.63	0.49

⁷ The sole source of supply of the tile (reference STM 603 Quarry Tile) known to the committee at this time is SATRA Technology Centre, Kettering, Northamptonshire, NN16 8SD, United Kingdom.

⁸ If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

10.3.3.1 Such as steel Number 1.4301, Type 2G (cold rolled, ground) conforming to EN 10088-2 or AISA Type 304.^{9,8}

10.3.3.2 That when calibrated by the roughness method which gives an overall mean value of R_z from all 10 locations of between 1.6 μm and 2.5 μm , as described in 10.8.

10.3.4 *Other Test Surfaces*, including such commonly found flooring materials as vinyl, wood, carpet, GRP (glass reinforced plastic), concrete, etc., shall consist of a flat sheet of material or set of tiles wider and longer than the test specimen and long enough to allow a sliding distance of at least 75 mm. The test surface may be calibrated or characterized as appropriate by the Slider 96 method (see 10.5), surface roughness where possible and then shall be checked at appropriate regular intervals. A full description of the surface should be given in the test report (14.1.2.2).

10.4 *Test Surface Condition:*

10.4.1 *Dry.*

10.4.2 *Wet*—Distilled or deionized water shall be applied to the flooring to thoroughly wet the test surface.

10.4.3 *Detergent*—solution, containing a mass fraction of 0.5 % sodium lauryl sulfate in distilled or deionized water. Shall be applied to the flooring to thoroughly wet the test surface.

10.4.4 *Oily*— 0.5 ± 0.02 g (approximately 20 drops) of vegetable oil. Type of vegetable oil must be detailed in the test report examples include corn, soy, canola etc. Shall be applied by smearing the vegetable oil over a 150 by 150 mm area of the flooring.

10.4.5 *Oily Wet*— 0.2 ± 0.02 g (approximately 8 drops) of vegetable oil with distilled or deionized water. Type of vegetable oil must be detailed in the test report examples include corn, soy, canola etc. Shall be applied by smearing the vegetable oil over a 150 by 150 mm area of the flooring and thoroughly wet the oily test surface with distilled or deionized water.

10.4.6 *Other Lubricants*, as might be found on pedestrian or workplace underfoot surfaces. A full description of the lubricant and application method shall be given in the test report (14.1.2.2).

10.5 *Calibration Procedure for Test Surfaces by Slider 96 Method—Materials and Apparatus:*

10.5.1 Material ‘Slider 96’ of calibrated hardness: 96 ± 2 IRHD measured value at $23 \pm 2^\circ\text{C}$ and specified resilience (Lupke BS903-A8:1990) of 24 ± 2 % at 23°C . Required specimen size: 25.4 mm wide, at least 50 mm long and greater than 5 mm thick. The walls shall be vertical and the edges square.

NOTE 5—Storage of Slider 96 rubber: storage temperature should be below 25°C and preferably below 15°C ; moist conditions should be avoided, and conditions should be such that condensation does not occur; protect from light, particularly direct sunlight and strong artificial light; protect from circulating air by wrapping or storing in air tight containers (paper and polythene are both suitable; however, plasticized PVC film

must not be used). It is recommended that Slider 96 sliders are discarded 12 months after issue.

10.5.1.1 Slider 96 rubber may be supplied pre-molded in a suitable size and form. However, if larger sheets of Slider 96 rubber are obtained then a means is required of cutting a rectangular test specimen such that it has vertical walls, square edges, is 25.4 ± 1.0 mm wide and at least 50 mm long. A means of trimming specimens parallel to the 25.4 mm edge while retaining a vertical wall and square edge may also be required.

10.5.2 A rigid, rectangular backing plate with dimensions at least as wide as the specimen cut with the device and at least 50 mm long.

10.5.3 A means of securely attaching a specimen of Slider 96 rubber to the backing plate. Suitable adhesives include: epoxy resins, cyanoacrylate or solvent based contact adhesive. The face to be bonded should be lightly abraded with abrasive paper then cleaned by blowing with clean air or by wiping with a suitable solvent such as methanol and allowing to dry in air before bonding.

NOTE 6—Double-side tape may be suitable for sliders approximately 75 mm or more in length.

10.5.4 A means of attaching the specimen backing plate to the test apparatus at the required contact angle.

NOTE 7—A rectangular metal box of dimensions 180 by 90 by 90 mm with the backing plate attached to it can be used to replace the shoemaking last.

10.5.5 400 grit silicon carbide abrasive paper mounted on a flat, rigid surface.

10.5.6 Dry, absorbent paper towel.

10.5.7 Floor surface as specified in 10.3.

10.6 *Preparation of Test Slider and Test Surface:*

10.6.1 If necessary, cut to size a specimen of Slider 96 rubber using the device and clean using distilled water then dry in air.

NOTE 8—If other contamination such as oil has occurred, use soap solution and distilled water to clean the specimen.

10.6.2 Attach the specimen of Slider 96 to the backing plate using adhesive.

10.6.3 Holding the specimen by the backing plate and applying a light, evenly distributed pressure abrade the surface of the rubber against the abrasive paper until a visually even level of abrasion is achieved and the surface is parallel with the backing plate. For this procedure alternately use a backward and forward linear movement in a direction parallel to the long side of the specimen, and a side to side movement in a perpendicular direction with the final direction of abrasion parallel to the long side.

10.6.4 Remove any debris from the test slider surface by lightly brushing with dry paper towel or soft brush.

10.6.5 Clean the test surface in accordance with 10.10.

10.6.6 Attach the plate with Slider 96 to the rectangular metal box. See Fig. 4.

NOTE 9—(1) The condition of the Slider 96 test slider must be restored at intervals as repeated use will cause edges to become rounded or a concave chamfer may develop across the tested edge. Either use the abrasion methods described above to restore the slider to the correct

⁹ The sole source of supply of the plate (reference STM 603S) known to the committee at this time is SATRA Technology Centre Ltd., Kettering, Northamptonshire, NN16 8SD, United Kingdom.

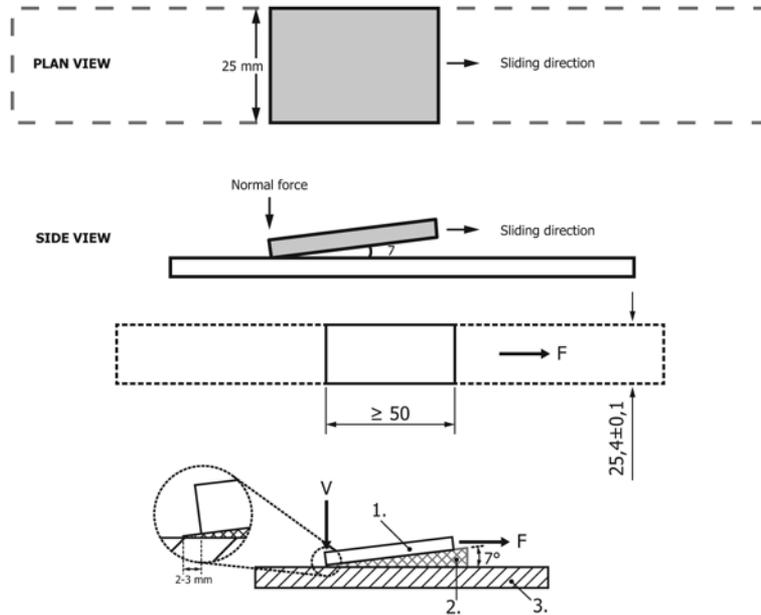


FIG. 4 Orientation and Setting of Contact Angle Using 7° Wedge for Slider 96

condition and/or cut away the affected end section of material, providing at least 50 mm length remains and the new cut edge is vertical and flat. (2) Both ends of the slider may be used provided that the end used is in the correct condition. (3) When the thickness of the slider has been reduced to 5 mm by repeated use, the slider shall be replaced.

10.7 Calibration Test Procedure:

10.7.1 Condition the quarry tiles, or other flooring and the test slider for at least 3 h at the test atmosphere.

10.7.2 Attach the test slider to the test machine so that the 25.4 mm edge is perpendicular to the direction of sliding movement and the line of action of the vertical force passes through the Slider 96 rubber–tile contact area.

10.7.3 Set the face of the test slider at a contact angle of $7 \pm 0.5^\circ$ to the test surface with 2 to 3 mm of the wedge protruding beyond the rearmost contact point of the Slider 96 with the face of the wedge (Fig. 4).

10.7.4 Mount the tile in accordance with 9.3.

10.7.5 Apply the test conditions specified in 6.8 for the forward heel slip mode, applying a 500 N normal force.

10.7.6 Carry out the test procedure defined in 12.7 and determine the coefficient of friction of the tile in a single test run. Repeat the test with water lubricant.

10.7.7 If the COF is outside the specified range (for example, see 10.3.1.3 for quarry tiles), reject the tile.

10.7.8 If the COF is within the specified range accept the tile and record the values obtained.

10.7.9 Clean and dry the Slider 96 slider before returning to storage.

10.8 Calibration Procedure for Surfaces by Roughness Method—Apparatus:

10.8.1 A suitable roughness meter^{10,8} that:

10.8.1.1 Has a stylus of radius 5 μm ,

¹⁰ The sole source of supply of the meter (STM 603F) known to the committee at this time is SATRA Technology Centre Ltd., Kettering, Northamptonshire, NN16 8SD, United Kingdom.

10.8.1.2 Capable of sampling over a 4 mm length of test surface divided into 5 cut-off lengths of 0.8 mm, and

10.8.1.3 Capable of measuring the maximum peak to valley height within each of the five cut-off lengths and reporting the average value, R_z , as specified in BS EN ISO 4287.

10.8.2 Calibration procedure for surfaces by roughness method.

10.8.2.1 Measure the surface roughness R_z according to BS EN ISO 4287 but with a sample length 0.8 mm in 10 locations in the area where slip measurements are made in the direction parallel to the sliding movement taking five sampling lengths per location (evaluation length 4.0 mm).

10.8.2.2 Calculate the overall mean value for R_z from all 10 locations.

10.8.2.3 If the value of R_z is within the specified range accept the surface and record the value obtained.

10.8.2.4 If the value of R_z is outside the specified range reject the surface.

NOTE 10—When the roughness parameter for the steel surface does not conform to this specification, the steel shall be prepared using silicon carbide abrasive paper or cloth for polishing in a succession of reducing grit sizes. The polishing direction of each operation shall be perpendicular to the preceding operation with the final direction being in the test direction. The preparation shall continue until the roughness parameter falls within the above specifications.

NOTE 11—Grit sizes 100 to 600 may be suitable.

10.9 Footwear Items—Specification and Calibration:

10.9.1 Footwear, Outsoles, Top Lifts, and Sliders:

10.9.1.1 Two specimens of the sample, footwear, outsoles, top lifts, or sliders, shall be tested. Each specimen shall be marked with a unique reference. When testing against a test surface in both dry and wet conditions, one specimen shall be tested first in the dry and then in the wet. The second specimen shall be tested first in the wet and then in the dry. In this way both dry and wet measurements will be made on footwear in

fresh condition as well as in slightly abraded condition from preceding measurements.

10.9.1.2 Worn footwear items may be tested. In addition to the normal modes of testing it may be appropriate to test these items at angles and orientations complementary to the wear pattern on the heel or sole directions in order to assess those particular locations.

10.9.1.3 Footwear, outsoles, top lifts, or sliders to be used as a standard or reference material for comparing the friction properties of different test surfaces shall be tested on dry and wet quarry tiles in order to characterize the footwear friction properties.

10.10 *Preparation of Footwear, Outsoles, Top Lifts, and Sliders—Materials and Equipment Required:*

10.10.1 *Materials Needed:*

10.10.1.1 A hand scrubbing brush, medium stiffness.

10.10.1.2 Detergent solution containing 5 % w/w sodium lauryl sulphate, general laboratory grade, in distilled or deionized water.

10.10.1.3 Propanone (acetone), general laboratory grade.

10.10.1.4 Silicon carbide paper, 400 grit size, mounted on a rigid block with a flat face (100 by 70 mm) and mass (1200 ± 120 g).

NOTE 12—This will be achieved using steel to make a block 22 mm thick.

10.10.1.5 Grease and lint free cotton wool.

10.10.1.6 A soft brush.

10.10.2 *Preparation:*

10.10.2.1 All new footwear test specimens shall be tested in the new condition so as to take account of the surface finish. Worn footwear may be tested in the condition in which they are received and the degree of wear must be reported.

10.10.2.2 All new test specimens (footwear, outsoles, top lifts, or sliders) other than those in 10.10.2.4, shall be cleaned and lightly abraded as per sections 10.10.2.3 and 10.10.2.5 prior to testing. All flooring materials shall be cleaned per 10.10.2.3.

NOTE 13—The intention is to test footwear in the condition in which it might be used, which may be in a new or worn condition. For new footwear however some initial washing (10.10.2.3) and preparatory abrasion (10.10.2.5) is necessary to bring all samples to a comparable starting condition with view to achieving consistent results and this is considered as the default preparation. However, both mold release agents used in manufacturing and painted or lacquer sole finishes applied for aesthetic reasons, may reduce slip resistance but are quickly worn away in wear, therefore it is appropriate in these instances to test in both the new condition and after removal of the mold releasing agent or paint/lacquer (10.10.2.4). Solvents should not be used for routine cleaning as on some types of footwear soling materials, such as thermoplastic rubber, and paint/lacquer finishes the solvent will attack and affect the nature of the surface.

10.10.2.3 Wash all test specimens, including flooring, by scrubbing with detergent solution (10.10.1.2). Rinse in clean running water and then dry completely by using an absorbent paper towel. It may not be appropriate to wash leather or textile soling materials.

10.10.2.4 Solings suspected of being contaminated with mold release agent (a greasy residue transferred to the sole from the inside of the metal mold; mainly polyurethane soles

which have been direct molded to the shoe upper) or any type of polymeric soling which has been spray painted shall be tested as follows:

(1) Test after initial washing (10.10.2.3) and before preparatory abrasion. They may then also be tested not less than 16 h after thoroughly wiping the surface with grease free cotton wool (10.10.1.5) wetted with solvent (10.10.1.3) to remove mold release agent and after preparatory abrasion (10.10.2.5). If mold release agent is suspected or a paint treatment is present and this procedure followed then it shall be called out in the test report.

10.10.2.5 For all new footwear and outsoles, prepare the sole (all parts that will be in contact with the surface during the test, including the heel and forepart) by lightly abrading it with silicon carbide paper wrapped around a rigid block (10.10.1.4). No significant additional pressure shall be applied other than by the weight of the block (see Fig. 5). Use linear or circular abrasion but with the final abrasion being linear and in the direction parallel to the direction of sliding movement in the test. Only superficial abrasion shall be applied that does not significantly change the tread pattern or the surface texture of the sole, and that produces a final visually uniform appearance. Any debris shall be removed using clean dry compressed air or a clean dry soft brush.

NOTE 14—It is preferable to mount the footwear on the shoemaking last (12.1.2) to be used for testing when undertaking the preparatory abrasion, but abrasion may be carried out without mounting the footwear on any device.

11. **Conditioning**

11.1 The specimens shall be cleaned prior to testing and conditioning but in all other respects they shall be tested in the condition as supplied unless otherwise specified.

11.2 All specimen samples shall be conditioned for at least 3 h prior to the test at 23 ± 2°C and 50 ± 5 % RH unless otherwise specified. The test shall be carried out at 23 ± 2°C within 30 min of removal from the conditioned atmosphere.

11.2.1 Samples tested on frozen surfaces such as rough ice should be condition for at least 3 h prior to testing at -5°C. Conditioned samples should be tested within 5 to 10 min from



FIG. 5 Sole Preparation per 10.10.2.5

removal of cold climate conditioning atmosphere and tested at normal room temperature conditions ($23 \pm 2^\circ\text{C}$).

12. Procedure—Mounting Footwear Items and Setting Up Test Modes

12.1 Apparatus and Materials:

12.1.1 For tests with complete footwear or outsoles with or without midsoles attached.

12.1.2 The specific shoemaking last on which the footwear was made, or for which the outsole was designed, or a comparable generic shoemaking last^{11,8} that will reasonably accommodate the size or sizes to be tested (see also 12.3.2 and 12.3.3).

12.1.3 A means of attaching the outsole securely to the shoemaking last such as double-sided tape or other adhesive or mechanical means such as screws, wire or cable ties as appropriate.

12.1.4 A steel rule or similar straight edge device of similar length to the largest last.

12.2 For Tests with Top Lifts or Sliders:

12.2.1 A flat rigid mounting plate of minimum dimensions 160 by 80 mm, with its length aligned with the axis of the test surface.

NOTE 15—A rectangular metal box of dimensions 180 by 90 by 90 mm with the mounting plate attached to it may be used to replace the shoemaking last.

12.2.2 A means of attaching the top lift or slider to the mounting plate such as double-sided tape or adhesive.

NOTE 16—In some circumstances adhesive tape may not hold the specimen firmly, for example, when the specimen is very small (problems may be expected when the area is less than 300 mm^2). Bonding the test specimen with an appropriate adhesive to a larger piece of thin stiff material, such as resin rubber, which in turn is fixed to the rigid mounting with double-sided adhesive tape is an alternative approach that generally is successful. When using this technique it is vital that contamination of the test surface with adhesive is avoided.

12.3 Mounting Procedures—Whole Footwear:

12.3.1 Remove any removable footbed from the footwear. (Contoured footbeds in particular may affect the fit of footwear on a generic last.) If the sole is molded with a concave heel seat, the concavity should be filled with a suitable material to present a flat surface against the bottom of the generic last used, or use the footwear specific last.

12.3.2 Select a shoemaking last (12.1.2) of a suitable size to fit inside the footwear test specimen. Use the largest size of last that will tightly fit inside the item of footwear without distorting it.

12.3.3 Fit whole footwear over the last. The upper may be cut or trimmed if necessary. It is important that the last should not move within the footwear test specimen during the test. If the last is a poor fit, then pieces of crumpled tissue paper may be used to fill any gaps at the toe or heel and so prevent movement. Whenever possible, secure the footwear fastening system.

12.4 Mounting Procedures—Outsoles:

12.4.1 Firmly attach outsole to the lower surface of the last using double-sided adhesive tape or other secure adhesive or mechanical means so that the specimen does not move relative to the last during the test—for example, units may be screwed to the last at points which will not interfere with contact with the test surface; wire or cable ties may be tied around the waist.

12.4.2 Locate the rear edge of the outsole on the rear edge of the heel area of the last.

12.4.3 Ensure that the center of the forepart of the footwear, outsole or other forepart specimen, coincides with the center of the forepart of the last so correct contact is achieved with the test surface.

NOTE 17—With oversized blocker sole units, it may be necessary to trim around the unit to ensure correct heel and forepart positioning.

12.5 Mounting Procedures—Top Lifts and Sliders:

12.5.1 Securely affix the top lift or slider to the flat mounting plate using double sided tape or adhesive.

12.5.2 Affix the plate with top lift or slider attached to the rectangular box.

12.6 Setting Footwear Test Modes:

12.6.1 Footwear may be tested in one or more of the following modes:

12.6.1.1 Forward heel slip at angled contact (see Fig. 6a).

12.6.1.2 Backward forepart slip (see Fig. 6b).

12.6.1.3 Forward flat slip (see Fig. 6c).

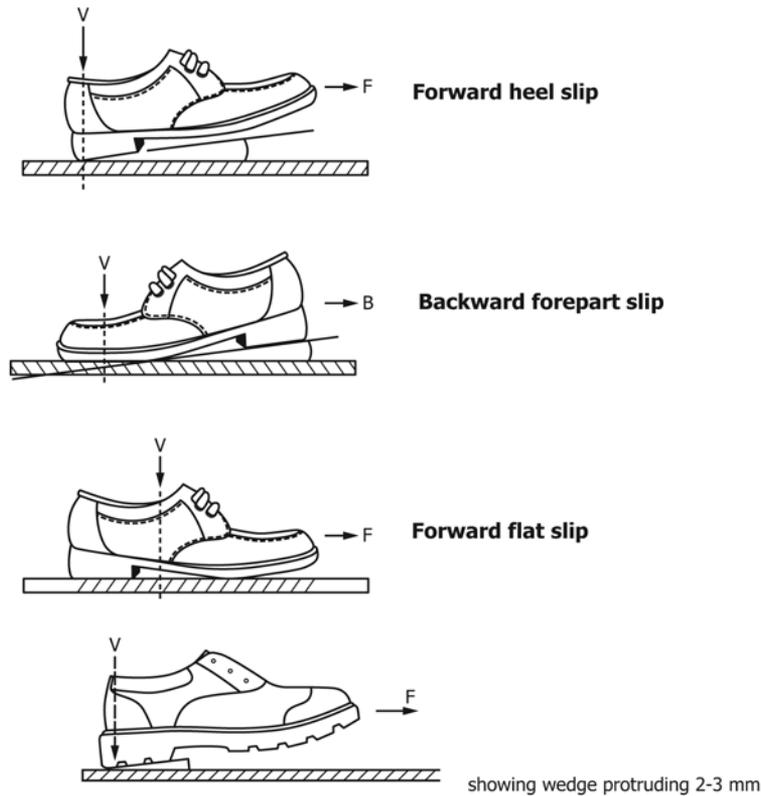
12.6.2 When testing footwear or outsoles in the above test modes align the inside tangent of the shoemaking last, as defined by a straight edge placed against the heel swell and joint swell on the inside or medial face of the last, parallel (within $\pm 2^\circ$) to the direction of movement.

12.6.3 When testing top lifts align the longitudinal centerline of the specimen at an angle of $10 \pm 2^\circ$ outwards relative to the direction of movement so that the contact is on the lateral edge of the top lift (see Fig. 4b).

12.6.4 *Forward Heel Slip at Angled Contact*—Set the footwear, sole unit, top lift, or slider so that the back edge of the heel, top lift, or slider contacts the test surface. Use a wedge (6.7) to set the wearing face of the heel to the required contact angle with respect to the test surface. While doing this ensure that the wedge is positioned to extend 2 to 3 mm beyond the back edge of the heel, top lift, or slider such that no part of the heel, top lift, or slider is in contact with the surface. The contact angle shall be $7.0 \pm 0.5^\circ$. If the rear of the heel is profiled, the 7° contact angle is relative to the main face of the heel, not to the profiled rear area. The center of the area of contact shall be vertically below the line of application of vertical force as judged visually.

12.6.5 *Backward Forepart Slip*—Bring the footwear or outsole into contact with the test surface (see Fig. 6b) at an appropriate angle with respect to the test surface and so that the joint or flexing area of the footwear forepart is in contact with the surface. Ensure that the heel remains clear of the surface when the full vertical force is applied (see Fig. 6b). The line of action of the normal force shall be aligned through the approximate center of the forepart-floor contact area as judged by eye.

¹¹ The sole source of supply of standard generic lasts known to the committee at this time is SATRA Technology Centre Ltd, Kettering, Northamptonshire, NN16 8SD, United Kingdom.



Key:
 V – Vertical force
 F – Forward movement of shoe relative to surface
 B – Backward movement of shoe relative to surface

FIG. 6 Three Test Modes Showing Line of Action of the Vertical Force with Respect to the Sole-Floor Contact Area

12.6.6 *Forward Flat Slip*—Align the footwear or outsole as for forward heel slip. Ensure that both the heel and forepart are in contact with the surface and that the line of application of vertical force passes through the midpoint between the centers of heel and forepart contact areas as judged by eye (see Fig. 6c).

12.7 *Activate Sliding Movement* as specified in 6.9.

12.7.1 Stop the test after a sliding distance of at least 40 mm and turn off the recording system.

12.7.2 Lift the footwear, sole unit, top lift, or test slider away from the test surface and support it so that it is not brought into contact with any other surface.

12.7.3 Reset the apparatus so that it is ready to take another measurement from the same contact point.

12.7.4 Restore the test surface to its specified condition if possible and note any marking or damage caused by testing. If testing in the dry condition, wipe the test surface with a clean dry paper towel to remove any visible loose deposits. If testing in a lubricated condition, remove any visible loose deposits and re-apply lubricant.

12.7.5 Repeat the procedure in 12.7.1 – 12.7.4 four times.

12.7.6 Examine the footwear and test surfaces and note any physical changes that have occurred (example: abrasion of the finish on leather).

12.7.7 For each test run determine the value at a time of 0.1 ± 0.01 s after the start of sliding movement of:

12.7.7.1 The vertical contact force between the two surfaces [Fv] in Newtons, and

12.7.7.2 The horizontal frictional force [Fh] in Newtons.

12.7.8 For each test run calculate the coefficient of friction to two decimal places as follows:

$$\text{Coefficient of friction (COF)} = \frac{\text{Horizontal force [Fh]}}{\text{Vertical force [Fv]}}$$

12.8 Repeat the procedure in Section 12 using other specified test conditions (for example, wet) the second footwear item, or second and third floor specimens, of the test sample and, if required, other test modes. See 10.9.1.1 for the test sequence of a pair of footwear specimens on a test surface in a dry and a wet condition.

13. Calculation or Interpretation of Results

13.1 Examine the test results.

13.1.1 If the five consecutive results of the measurements show a systematic increase or decrease of more than 10 % of the initial reading:

13.1.1.1 Carry out one or more further test runs until a sequence of five are obtained that do not show a systematic increase or decrease of greater than 10 %.

13.1.1.2 Where apparent, record the cause of variation, for example, abrasion of finish on leather or resin rubber soling, and record the COF value for the first run in the first sequence

of measurements, representing the initial surface condition of the material, and the value for the fifth run, of the last sequence, representing its changed condition after repeated testing.

13.1.2 Calculate the arithmetic mean COF of the last sequence of five results and report to 2 decimal places.

13.1.3 If a cause of variation cannot be identified the test specimens may be contaminated. In this case repeat the test using a fresh or re-cleaned test specimen.

13.1.4 In some circumstances the phenomenon of slip-stick may occur which manifests itself in a friction trace as excessive vibration or oscillation of the horizontal and vertical force curves, and COF curve if available. Where this occurs, the average value of COF between the maximum and minimum peaks on the trace in the measurement region (0.1 ± 0.01 s) should be recorded with a description of the shape of the trace.

13.1.5 Occasionally the friction trace may take the form of a steadily increasing or decreasing value which may reflect a genuine behavior of the particular test specimen. In these cases the result should be recorded but with a description of the shape of the trace.

14. Report

14.1 The test report shall include:

14.1.1 Reference to this test method ASTM F2913.

14.1.2 A full description of the test specimen (footwear or surface items), including any manufacturer's reference, and of the standard reference materials (flooring or footwear items respectively).

14.1.2.1 *Footwear Items:*

(1) A description of the footwear, outsole, top lift, or slider material including size, whether left or right and where applicable relevant details of bottom construction (example: heel height, whether a midsole is present and type if known) and in the case of footwear, the type (for example, sandal, boot).

(2) For sliders the shape, size, and thickness of the slider and the type(s) of material if known.

(3) For outsole and midsole (if applicable) materials used and the type(s) of material if known.

(4) A description of any surface pattern.

(5) Details of all pre-treatment such as cleaning, stating the cleaning agent used, or preparatory abrasion of the wearing surface before testing, or any previous wear and whether this is judged as light, moderate, or heavy.

(6) Details of any marking or damage caused by testing, either to footwear or test surface.

14.1.2.2 *Test Surface (Flooring) Items:*

(1) A description of the test surface.

(2) A description of any surface texture or profiling.

(3) The type(s) of material if known.

(4) Details of any surface polish or resin that has been applied, if known.

(5) Details of any non-standard pre-treatment such as cleaning or preparatory abrasion of the flooring before testing, or any previous wear and whether this is judged as light, moderate or heavy.

(6) A description of lubricant or other contaminant used.

(7) Details of any marking or damage caused by testing, either to footwear, outsole unit or top lift, or to the test surface.

14.1.3 The applied vertical force.

14.1.4 For each test specimen, the coefficient of friction for each mode of test and each test condition. The test condition shall be qualified if there was a preceding test condition on the same specimen. For example: Left foot–dry (result), Left foot–wet after dry (result), Right foot–wet (result), Right foot–dry after wet (result).

14.1.5 Where a systematic trend has been seen, the first and last values as specified in 13.1.1 and the number of test runs performed.

14.1.6 The atmosphere (temperature and humidity) under which the test specimens and reference materials were conditioned and tested.

14.1.7 Any deviations from the standard test method.

14.1.8 Any unusual slip trace shapes such as slip stick or significantly increasing or decreasing friction curve shall be described.

15. Precision and Bias¹²

15.1 The precision of this test method is based on an interlaboratory study of Test Method F2913 conducted in 2017. Ten laboratories tested two shoe parts (heel and forepart) on a quarry surface, under both wet and dry conditions. Each participant reported four test results, and every “test result” represents an individual determination which itself is the mean value of five successive slips. Practice E691 was followed for the design and analysis of the data.

15.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

15.1.1.1 Repeatability can be interpreted as maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

15.1.1.2 Repeatability limits are listed in Table 3 and Table 4.

15.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

15.1.2.1 Reproducibility can be interpreted as maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

15.1.2.2 Reproducibility limits are listed in Table 3 and Table 4.

¹² Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F13-1005. Contact ASTM Customer Service at service@astm.org.

TABLE 3 Quarry – Wet (Coefficient of Friction)

	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	\bar{x}	s_r	S_R	r	R
Heel	0.513	0.020	0.046	0.056	0.129
Forepart	0.519	0.022	0.029	0.061	0.082

TABLE 4 Quarry – Dry (Coefficient of Friction)

	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	\bar{x}	s_r	S_R	r	R
Heel	0.964	0.044	0.086	0.123	0.241
Forepart	0.972	0.046	0.081	0.128	0.228

15.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

15.1.4 Any judgment in accordance with statements 15.1.1 and 15.1.2 would have an approximate 95 % probability of being correct.

15.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

15.3 The precision statement was determined through statistical examination of 160 results, from 10 laboratories, on 2 shoe parts, under 2 surface/condition combinations.

15.4 To judge the equivalency of two test results, it is recommended to choose the material/surface combination closest in characteristics to the test conditions.

16. Keywords

16.1 flooring tester; footwear; heel; slip resistance; slip tester; sole; soling materials; whole shoe

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