Designation: F2412 – 11

Standard Test Methods for Foot Protection[1]

This standard is issued under the fixed designation F2412; 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.

INTRODUCTION

For more than sixty years, the predecessor to these test methods, ANSI Z41, established the performance criteria for a wide range of footwear to protect from the hazards that affect the personal safety of workers. The value of these standards was recognized early in the history of the Occupational Safety and Health Administration (OSHA) and incorporated as a reference standard in the Code of Federal Regulation (CFR) Section 1910.

These test methods contains test protocols developed in conjunction with ANSI Z41 as well as other ASTM standards that are used to evaluate the performance of footwear when exposed to a variety of hazards: *(1)* impact resistance (I) for the toe area of footwear; *(2)* compression resistance (C) for the toe area of footwear; *(3)* metatarsal impact protection (Mt) that reduces the chance of injury to the metatarsal bones at the top of the foot; *(4)* conductive properties (Cd) that reduce hazards that may result from static electricity buildup and reduce the possibility of ignition of explosives and volatile chemicals; *(5)* electric hazard resistant (EH) non-conductive; *(6)* static dissipative (SD) properties to reduce hazards due to excessively low footwear electrical resistance that may exist where SD footwear is required; and *(7)* puncture resistance (PR) of foot devices.

1. Scope

1.1 These test methods measure the resistance of footwear to a variety of hazards that can potentially result in injury.

1.2 These test methods may be used to test for compliance to minimum performance requirements in established safety standards.

1.2.1 By agreement between the purchaser and the supplier, or as required by established safety standards, these test methods can be used to determine any one, or all of the following: *(1)* impact resistance (I), *(2)* compression resistance (C), *(3)* metatarsal impact resistance (Mt), *(4)* resistance to electrical conductivity (Cd), *(5)* resistance to electric hazard (EH), *(6)* static dissipative performance (SD), and *(7)* puncture resistance (PR).

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are 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:*[2]

B117 Practice for Operating Salt Spray (Fog) Apparatus

2.2 *CSA Standard:*[3]

CAN/CSA Z195 Protective Footwear

3. Terminology

3.1 *Definitions:*

3.1.1 *insert/footbed/sockliner (all removable), n*—footbed normally made of a foam product with leather or fabric cover shaped to cover the entire insole which can be inserted between the foot and insole board.

3.1.2 *insole, n*—foundation of the shoe; the inner sole of the shoe which is next to the foot, under the sock liner or insert, onto which the upper is lasted.

[1] These test methods are under the jurisdiction of ASTM Committee F13 on Pedestrian/Walkway Safety and Footwearand are the direct responsibility of Subcommittee F13.30 on Footwear.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Canadian Standards Association (CSA), 178 Rexdale Blvd., Toronto, ON Canada M9W1R3.

3.1.3 *last, n*—solid hinged form, in the general shape of a foot, around which footwear is constructed.

3.1.4 *lasting, v*—building of footwear around a specific foot form.

3.1.5 *lining, n*—term used to describe all components that can be used to construct the interior of the upper portion of the footwear.

3.1.6 *outsole and heel, n*—exterior bottom platform of the footwear; the bottom surface.

3.1.7 *product category, n*—description for a type of footwear designed and manufactured for a specific hazard or hazards.

3.1.8 *product classification, n*—footwear manufactured to meet a minimum performance requirement for a specific hazard or hazards.

3.1.9 *protective footwear, n*—footwear that is designed, constructed, and classified to protect the wearer from a potential hazard or hazards.

3.1.10 *protective toe cap, n*—component designed to provide toe protection that is an integral and permanent part of the footwear.

3.1.11 *quarter, n*—entire back portion of the footwear upper.

3.1.12 *size, n*—length and breadth measurements of footwear determined by using a specific grading; the American system of footwear grading.

3.1.13 *socklining (non-removable), n*—fabric material placed over the insole, footbed, or insert that may be imprinted with a brand name or other designation.

3.1.14 *specimen, for protective footwear, n*—footwear units evaluated for various hazards.

3.1.14.1 *Discussion*—Footwear units may be a left foot, a right foot, or a matched pair. The exact number and type of footwear units is indicated by test method.

3.1.15 *upper, n*—parts of a shoe or boot that are above the sole.

4. Significance and Use

4.1 These test methods contain requirements to evaluate the performance of footwear for the following:

4.1.1 Impact resistance for the toe area of footwear (I/75),

4.1.2 Compression resistance for the toe area of footwear (C/75),

4.1.3 Metatarsal protection that reduces the chance of injury to the metatarsal bones at the top of the foot (Mt/75),

4.1.4 Conductive properties which reduce hazards that may result from static electricity buildup, and reduce the possibility of ignition of explosives and volatile chemicals (Cd),

4.1.5 Electric Hazard by stepping on live wire (EH),

4.1.6 Static dissipative (SD) properties to reduce hazards due to excessively low footwear electrical resistance that may exist where SD footwear is required, and

4.1.7 Puncture resistance footwear devices (PR).

4.2 Any changes to the original components of safety toe footwear such as replacing or adding after market footbeds/inserts could cause non compliance to any or all parts of this standard rendering the ASTM label invalid. Protective toe footwear specimens or samples shall be retested for any of the following changes.

4.2.1 Change in material used to make protective toe cap, change in protective cap manufacturer, change in the design of the toe cap.

4.2.2 Change in construction method used to make footwear or change in factory in which footwear is produced.

4.2.3 Change in the upper or insole material thickness greater than 25 %, change to the soling system or a change in the hardness of the outsole.

4.2.4 Change in shape of last used in the manufacturing of footwear.

4.2.5 Change in material or supplier of protective insole.

4.2.6 Change in material or supplier of met guard.

5. Protective Toe Impact Resistance (I)

5.1 *Summary of Method:*

5.1.1 Footwear shall be constructed and manufactured so that a protective toe cap is an integral and permanent part of the footwear.

5.1.2 Footwear with a protective toe cap is impacted with a specified force.

5.1.3 After impact, the height of the modeling clay cylinder is measured.

5.2 *Apparatus:*

5.2.1 The apparatus as shown in Fig. 1 consists of a frame structure that permits the impactor to be constrained to fall along a known and repeatable path.

5.2.1.1 The impactor consists of a steel weight having a mass of 22.7 ± 0.23 kg (50 ± 0.5 lb). The nose of the impactor is a steel cylinder having a diameter of 25.4 ± 0.8 mm (1 ± 0.03 in.) and length of 50.8 mm (2.0 in.). The impact side of the cylinder has a smooth spherical surface with a radius of 25.4 ± 0.127 mm (1.00 ± 0.005 in.). The longitudinal centerline of the cylinder is parallel and coincident with 3.175 mm (0.125 in.) to the symmetry of its vertical axis.

5.2.1.2 Apparatus incorporates a means of measuring the velocity at impact with a tolerance of ±2 %. The use of a velocity metering system allows for determining the time required for a 25.4-mm (1-in.) wide blade to pass completely through a beam of light prior to the impactor striking the specimen. The result, referred to as gate time, is measured in milliseconds (ms). The speed in in./s can be calculated using the following formula:

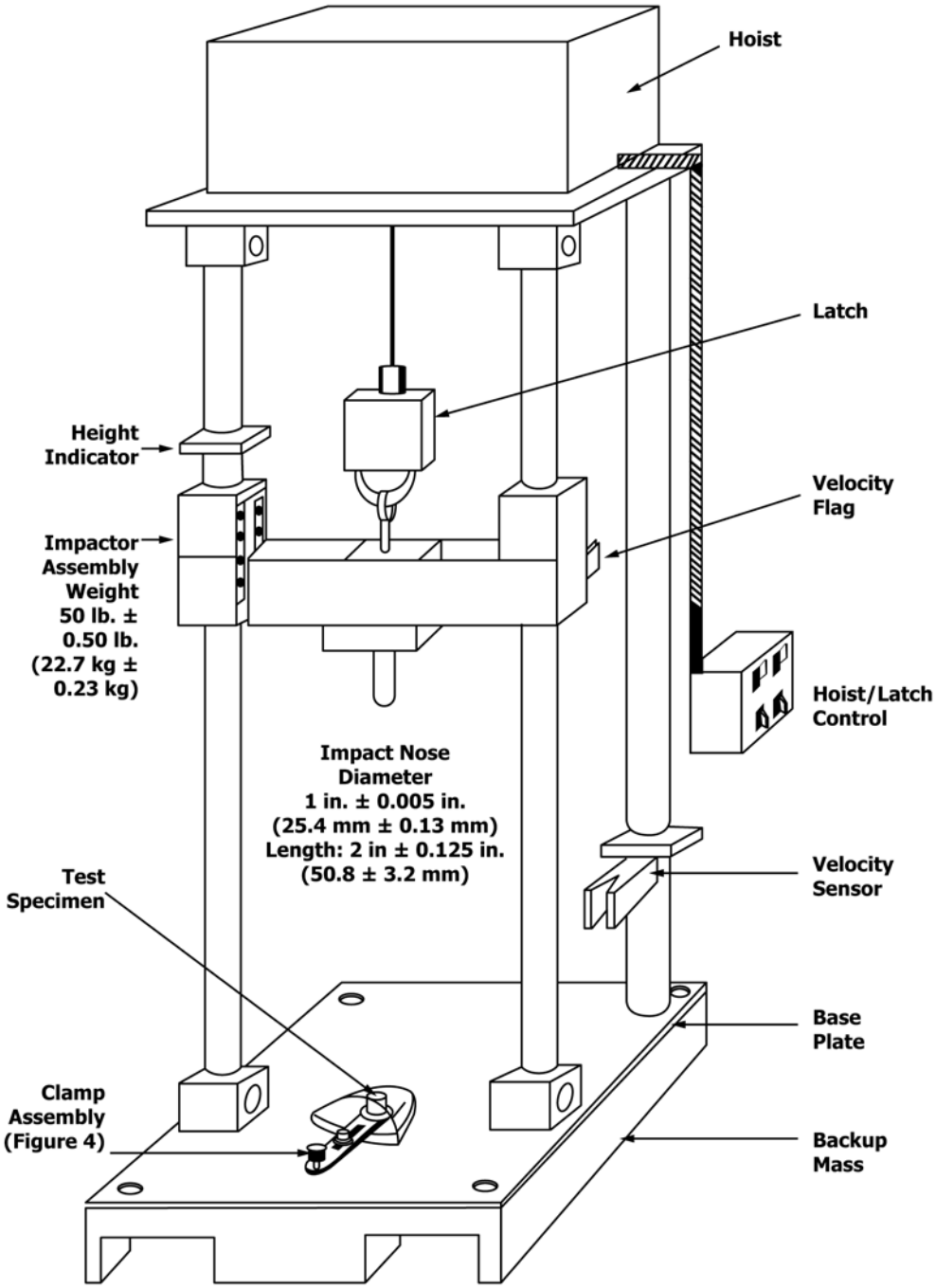
$$V = \frac{1000}{t_g} \tag{1}$$

where:

V = velocity in in./s, and
t_g = gate time in ms.

5.2.2 The base of the apparatus consists of a steel plate with a minimum area 0.3 m^2 (1 ft^2) and minimum thickness of 25.4 mm (1 in.). The base is anchored to a structure having a minimum mass of 909.1 kg (2000 lb) to provide sufficient stability to the apparatus before, during, and after testing.

5.3 *Sampling:*



NOTE 1—Dimensions are in inches (millimetres).

FIG. 1 Footwear Impact Test Apparatus

5.3.1 Randomly select three half-pair test specimens, including both left and right footwear, of each product category from unworn manufactured footwear.

5.3.1.1 Men's footwear specimens shall be obtained from size 9.

5.3.1.2 Women's footwear specimens shall be obtained from size 8.

5.3.2 The specimens shall be obtained by completely removing the toe portion of the footwear. This is done by cutting across the width of the footwear 25.4 ± 3.2 mm (1 ± 0.125 in.)

behind the back edge of the protective toe cap and cutting the upper material back to the edge of the protective toe cap as shown in Fig. 2.

5.4 Prior to impact testing, modeling clay, kept at room temperature and formed approximately as a vertical cylinder, shall be placed under the protective toe cap to back rear edge of the cap positioned inside the specimens directly under the point of impact (see Fig. 3).

5.4.1 Modeling clay for the test forms shall be tested in accordance with 5.4.2 – 5.4.9. Test frequency shall be no less than once every month. It is recommended that this quality test be conducted on a specimen just prior to its use during an impact test (see Fig. 4).

5.4.2 Weigh out a 50 ± 2 g sample of modeling clay.

5.4.3 Form material into a 35 ± 2 mm (1.375 ± 0.075 in.) cylinder and allow material to sit at room temperature for 24 h.

5.4.4 The modeling clay cylinder shall be placed horizontally on the base plate at the center point of the impact tester.

5.4.5 A block having dimensions of 75 by 75 by 44 mm (3 by 3 by 1.75 in.), with a hole drilled in the center of the block that is 25 mm (1 in.) in diameter and 25 mm (1 in.) deep, is slipped onto the impact nose.

5.4.6 The block/impactor assembly is carefully lowered until the wooden block makes contact with the modeling clay cylinder.

5.4.7 The impactor assembly is released allowing full weight to compress the cylinder for 10 s.

5.4.8 Immediately afterwards, the impactor assembly is raised and the modeling clay cylinder cut in half to measure.

5.4.9 A modeling clay cylinder having a compressed thickness of 15 ± 2 mm is acceptable to use in impact resistance.

5.5 *Specimen Mounting:*

5.5.1 Specimens are to be placed on the test apparatus base plate so that the sole is parallel with the base.

5.5.1.1 The specimen is positioned so that the longitudinal center of the nose of the impactor strikes the approximate center of the protective toe cap at a point that is 12.7 ± 1.6 mm (0.50 ± 0.0625 in.) toward the front as measured from the back edge of the protective toe cap (see Fig. 3).

5.5.2 The specimen is held in position during test by use of a clamping device as shown in Fig. 5.

5.5.2.1 The stabilizing fork clamp device rests on the insert and can be adjusted by means of a screw.

5.5.2.2 The adjustment secures the specimen parallel to the base plate and prevents movement when the impactor strikes the specimen.

5.5.2.3 Clamping screw shall be tightened using a force less than 28 Nm (25 in. lbs).

5.6 *Procedure:*

5.6.1 When in place, the modeling clay cylinder shall be shaped having a base diameter of approximately 25 mm (1 in.) nominal and positioned so that the cylinder simultaneously makes contact with the insert/sock liner/footbed of the footwear and the dome of the protective toe cap. (See Note 1.)

NOTE 1—A small piece of release paper such as wax paper or cellophane can be placed on either the bottom side or top side of the cylinder to prevent the modeling clay from adhering to either the insert/sock liner or dome.

5.6.2 To measure Impact 75 product footwear, the impactor is dropped from a height that results in an impact velocity of 2995 ± 61 mm/s (117.9 ± 2.4 in./s), creating an energy of 101.75 J (75 ft-lbf).

NOTE 2—In a vacuum, the distance would be 457 mm (18 in.). Due to friction and air resistance, the height used for the test is somewhat greater.

5.6.3 Release the impactor.

5.6.4 After impact raise and secure the impactor on test apparatus, carefully remove the clay cylinder from inside the specimen and measure the height of the modeling clay cylinder at its lowest point using a measuring device capable of measuring to the nearest 0.1 mm (0.004 in.).

5.6.5 This value is reported as the impact minimum interior height clearance for the specimen.

5.7 *Test Report*—Report the minimum height of the modeling clay cylinder, without rounding up, to the nearest 0.1 mm (0.004 in.) as the clearance result for the product category for all three specimens.

6. Protective Toe Compression Resistance (C)

6.1 *Summary of Method:*

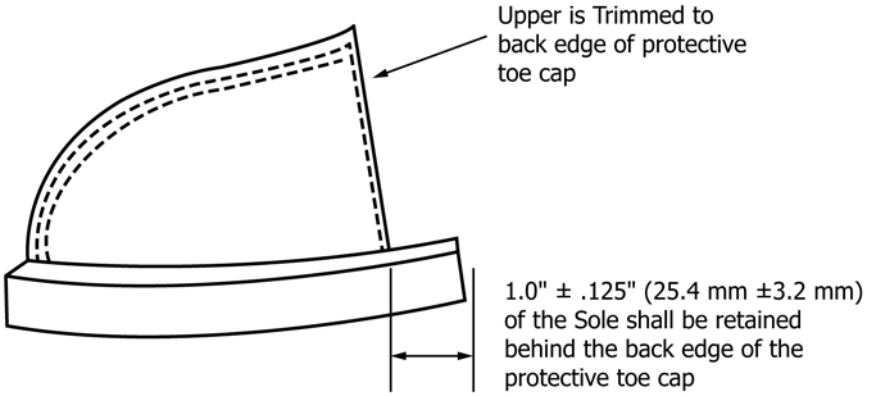


FIG. 2 Specimen Prepared for Impact and Compression Testing

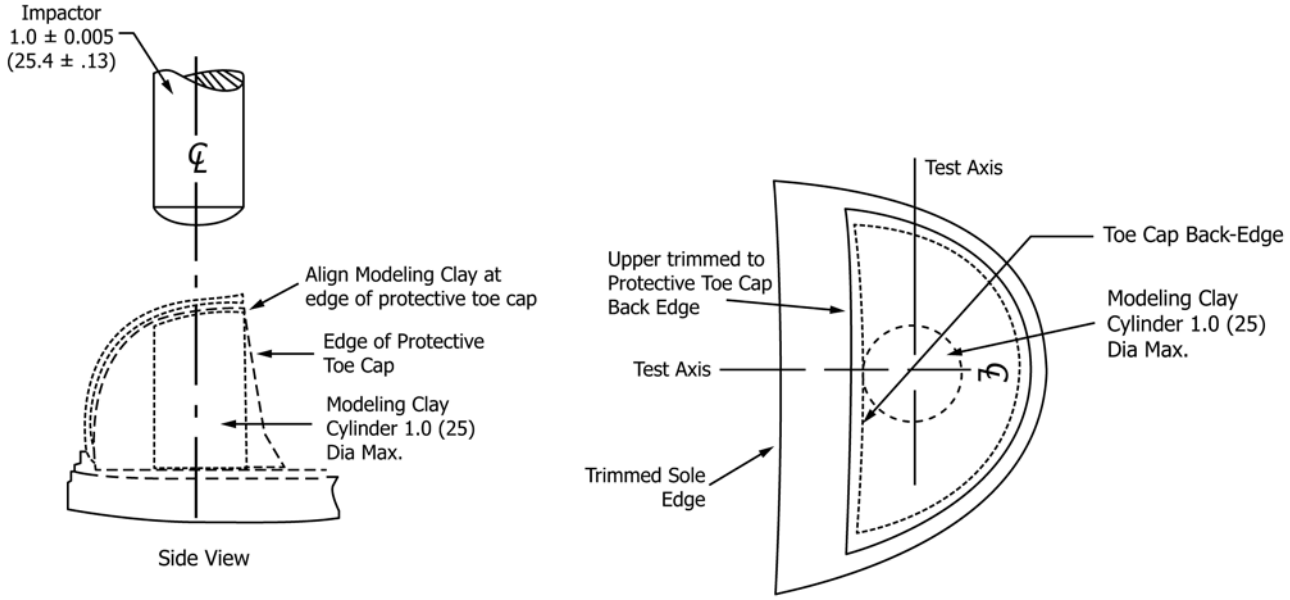


FIG. 3 Specimen Prepared for Impact and Compression Testing

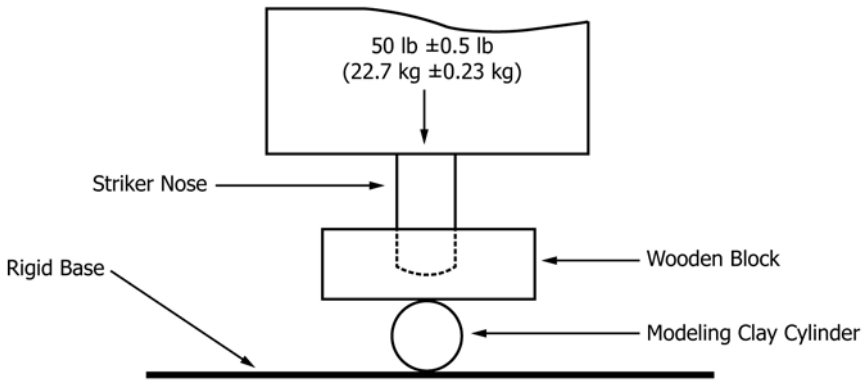


FIG. 4 Apparatus for Modeling Clay Quality Test

6.1.1 Footwear shall be constructed and manufactured so that a protective toe cap is an integral and permanent part of the footwear.

6.1.2 Footwear with a protective toe cap is exposed to a compressive force.

6.1.3 During application of the compressive force, the interior space of the toe cap is measured using a modeling clay cylinder.

6.2 *Apparatus:*

6.2.1 Compression testing equipment that is equipped with smooth steel compression test surfaces.

6.2.1.1 Test surfaces must remain parallel during application of force up to 44 482 N (10 000 lbf).

6.2.1.2 Pressure head has a minimum diameter of 76.2 mm (3 in.) and a bed plate with a minimum width of 152.4 mm (6 in.).

6.2.1.3 Equipment must be graduated in increments so as to measure compressive force between 222.4 N (50 lbf) to 44 482 N (10 000 lbf).

6.3 *Sampling:*

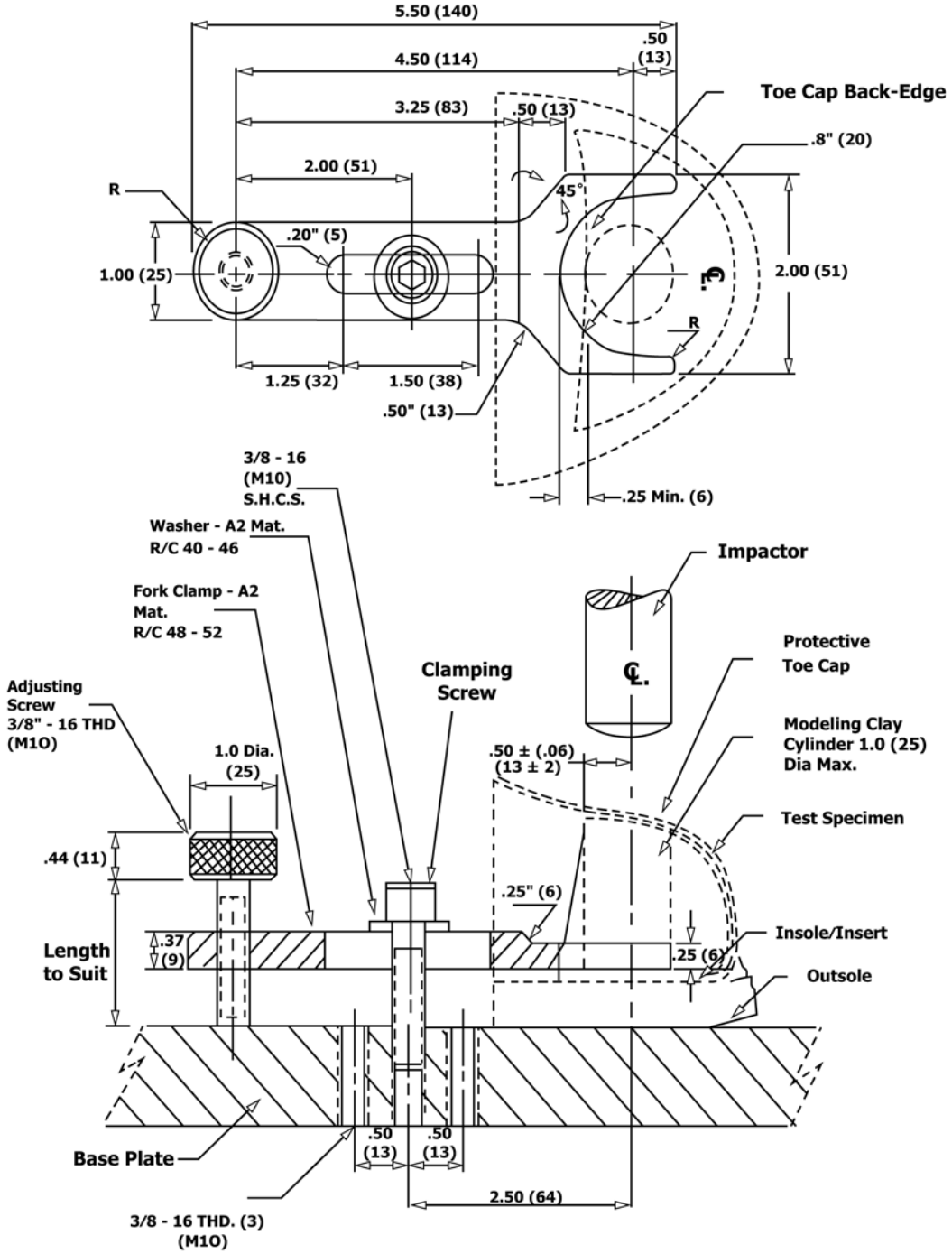
6.3.1 Randomly select three half-pair test specimens, including both left and right footwear, of each product category from unworn manufactured footwear.

6.3.1.1 Men's footwear specimens shall be obtained from size 9.

6.3.1.2 Women's footwear specimens shall be obtained from size 8.

6.3.2 The specimens shall be prepared by completely removing the toe portion of the footwear. This is done by cutting across the width of the footwear 25.4 ± 3.2 mm (1 ± 0.125 in.) behind the back edge of the protective toe cap and cutting the upper material back to the edge of the protective toe cap as shown in Fig. 2.

6.4 Prior to compression testing, modeling clay, kept at room temperature and formed approximately as a 1 in. diameter vertical cylinder, shall be placed under the protective toe cap positioned inside the specimens directly under the point of impact (see Fig. 3) with the edge of the clay cylinder aligned with the back edge of the toe cap.



NOTE 1—Dimensions are in inches (millimetres).

FIG. 5 Position/Clamping/Impact Arrangement

6.4.1 Modeling clay for the test forms shall be tested in accordance with 6.4.2 – 6.4.9. Test frequency shall be no less than once every 6 months. It is recommended that this quality test be conducted on a specimen just prior to its use during an impact test (see Fig. 4).

6.4.2 Weigh out a 50 ± 2 g sample of modeling clay.

6.4.3 Form material into a 35 ± 2 mm (1.375 ± 0.075 in.) cylinder and allow material to sit at room temperature for 24 h.

6.4.4 The modeling clay cylinder shall be placed horizontally on the base plate at the center point of the impact tester.

6.4.5 A block having dimensions of 75 by 75 by 44 mm (3 by 3 by 1.75 in.), with a hole drilled in the center of the block that is 25 mm (1 in.) in diameter and 25 mm (1 in.) deep, is slipped onto the impact nose.

6.4.6 The block/impactor assembly is carefully lowered until the block makes contact with the modeling clay cylinder.

6.4.7 The impactor assembly is released allowing full weight to compress the modeling clay cylinder for 10 s.

6.4.8 Immediately afterwards, the impactor assembly is raised and the modeling clay cylinder cut in half to measure.

6.4.9 A modeling clay cylinder having a compressed thickness of 15 ± 2 mm is acceptable to use in impact resistance.

6.5 *Specimen Mounting:*

6.5.1 The specimen is positioned on the bed plate of the test apparatus so that the highest point of the protective toe cap is perpendicular to the direction of force.

6.5.2 The stabilizing fork clamp device rests on the insert and can be adjusted by means of a screw (see Fig. 5).

6.5.2.1 This adjustment secures the specimen parallel to the bed plate and prevents movement.

6.5.2.2 Clamping screw shall be tightened using a force less than 28 Nm (25 in. lbs).

6.6 *Procedure:*

6.6.1 When in place, the modeling clay cylinder shall be shaped having a base diameter of approximately 25 mm (1 in.) nominal and positioned so that the cylinder simultaneously makes contact with the insert/sock liner/footbed of the footwear and the dome of the protective toe cap. (See Note 1 and Fig. 3.)

6.6.2 A compressive force is applied to the specimen at an approximate rate of 222.4 N/s (50 lbf/s) until it reaches 11 121 N (2500 lb) for Compression 75.

6.6.3 After compression testing, carefully remove the modeling clay cylinder from the specimen and, using a measuring device capable of measuring to the nearest 0.1 mm (0.004 in.) measure the height of the modeling clay cylinder at its lowest point, without rounding up.

6.7 *Test Report*—Report the minimum height of the modeling clay cylinder without rounding up to the nearest 0.1 mm (0.004 in.) the clearance result for the product category for all three specimens.

7. Metatarsal Impact Resistance (Mt)

7.1 *Summary of Method:*

7.1.1 Footwear shall be constructed and manufactured so that a metatarsal impact guard is positioned partially over the protective toe cap and extended to cover the metatarsal bone area. The metatarsal protection shall be an integral and permanent part of the footwear.

7.1.2 Footwear with a protective toe cap and metatarsal guard is impacted with the appropriate force.

7.1.3 After impact, carefully remove the wax form from inside the footwear and measure.

7.2 *Apparatus:*

7.2.1 The same apparatus as used in 5.2 (Fig. 1) for impact testing of protective footwear, with certain modifications, is used for metatarsal impact testing. The modifications to the apparatus are shown in Fig. 6 and Fig. 7.

7.2.1.1 The striking surface that impacts the metatarsal protection is a horizontal bar that is perpendicular to the vertical traverse of the test apparatus. The bar of polished steel has a diameter of 25.4 ± 0.5 mm (1 ± 0.02 in.) and a length of 152.4 ± 3.2 mm (6 ± 0.125 in.).

7.2.1.2 The striking bar is positioned so that the impact is perpendicular to the longitudinal plane of the heel/toe axis at the appropriate impact point for men's and women's footwear (see Fig. 8).

7.3 *Sampling:*

7.3.1 Randomly select three half-pair test specimens, including both left and right footwear, of each product category from unworn manufactured footwear.

7.3.1.1 Men's footwear specimens shall be obtained from size 9.

7.3.1.2 Women's footwear specimens shall be obtained from size 8.

7.4 *Specimen Mounting:*

7.4.1 Mount specimen in a device, as shown in Fig. 7, that retains footwear in place during testing.

7.4.2 Mount specimen so that outsole is resting on base of apparatus and positioned so that the point of contact for the striking bar is appropriate for the specimen as shown in Fig. 8.

7.4.2.1 Men's footwear requires that the point of contact for the striking bar is 89 mm (3.5 in.) when measured backwards from the front point of the toe toward the heel.

7.4.2.2 Women's footwear requires that the point of contact for the striking bar is 86 mm (3.375 in.) when measured backwards from the front part of the toe toward the heel.

7.5 *Procedure:*

7.5.1 Insert a wax form, as described in Annex A1, into the specimen. The insert/sock lining/footbed of the footwear shall remain in the footwear during testing.

7.5.1.1 The wax form shall completely fill the protective footwear cavity and extend toward the quarter of the footwear approximately 76.2 mm (3 in.) beyond the back edge of the protective toe cap. (See Fig. 8.)

7.5.1.2 The use of a heel block is used to secure the wax form in place and also to fill the cavity between the back edge of the wax form and the quarter.

7.5.2 To measure Metatarsal Impact 75 product footwear, the impactor is dropped from velocity of 2995 ± 61 mm/s (117.9 ± 2.4 in./s), creating an energy of 101.75 J (75 ft-lbf). a height that results in an impact see Note 3.

NOTE 3—In a vacuum, the distance would be 457 mm (18 in.). Due to friction and air resistance, the height used for the test is somewhat greater.

7.5.2.1 Release the impactor,

7.5.3 After impact raise and secure the impactor on test apparatus, and carefully remove the wax form from the specimen.

7.5.4 *Test Report*—Measure the distance from the lowest point of the impression made in the wax form to the bottom surface of the form as shown in Fig. 8 and report the results to the nearest 0.1 mm (0.004 in.) for all three test specimens without rounding up.

8. Conductive Protective Footwear (Cd)

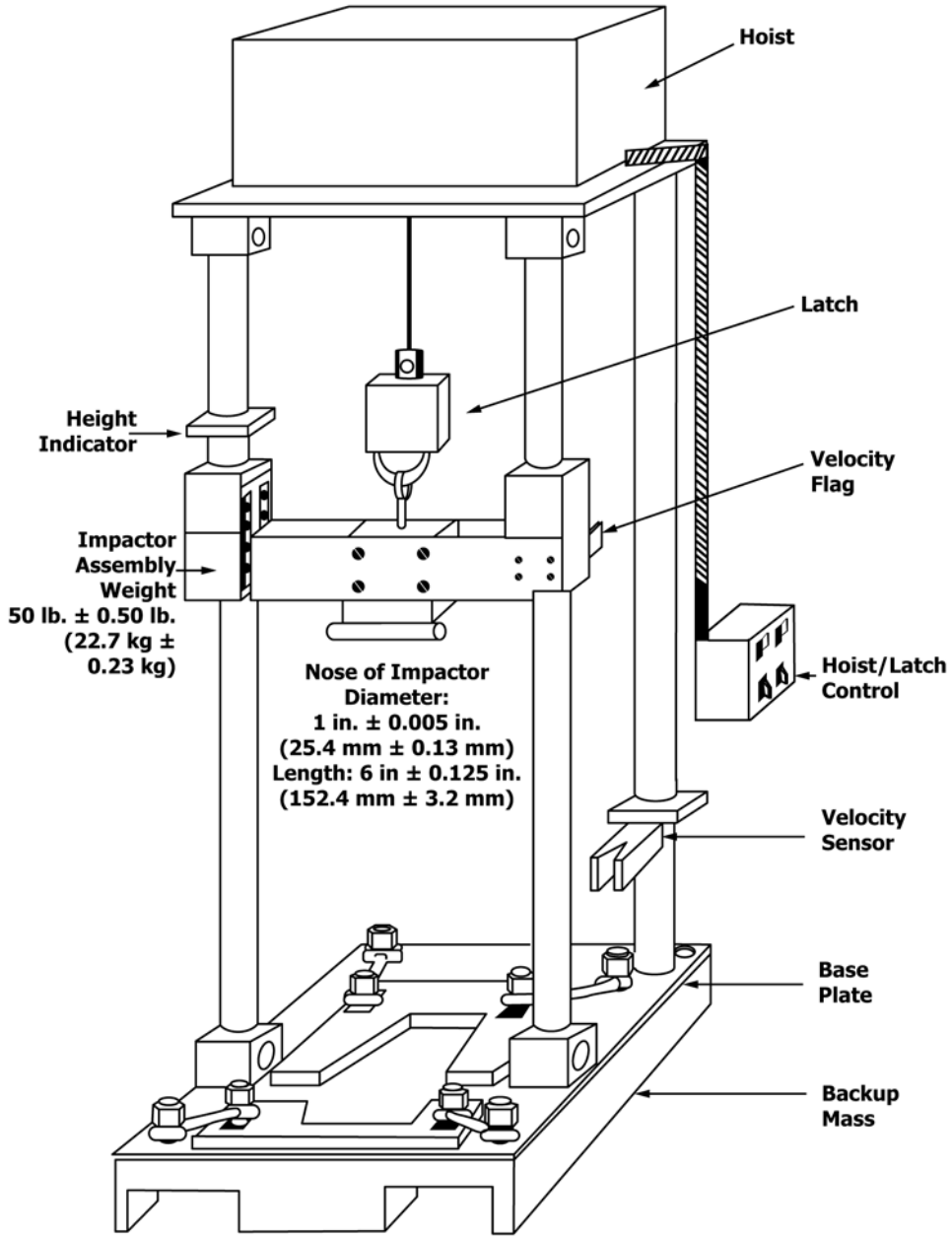
8.1 *Summary of Method:*

8.1.1 The footwear is placed on a base electrode plate and the second electrode is embedded in a layer of metal spheres which fill the inside of the footwear.

8.1.2 Electrical resistance is measured after applying the specified voltage for a prescribed time.

8.2 *Apparatus:*

8.2.1 The apparatus as shown in Fig. 9 requires that it be as follows:



NOTE 1—Dimensions are in inches (millimetres).

FIG. 6 Metatarsal Footwear Impact Test Apparatus

8.2.1.1 500 V regulated dc power supply with a current rating of 5 mA or greater.

8.2.1.2 100 000 Ω resistor with accuracy ±10 % rated at 2.5 W and 500 V or greater.

8.2.1.3 0 to 5 mA ammeter with accuracy of ±5 % in one or more ranges.

8.2.1.4 Voltmeter of 0 to 500 V with minimum accuracy of ±5 % in one or more ranges with a nominal internal resistance of 10 Megohm or greater.

8.2.1.5 A stainless steel base electrode plate 228.6 by 330.2 mm (9 by 13 in.) that can accommodate the complete outsole and heel of the footwear. The second electrode consists of 3 to 5 mm (0.117 to 0.197 in.) solid conductive metal spheres, which are placed inside the footwear to be tested so that the entire interior surface of the footwear is covered and reaches a depth of not less than 30 mm (1.18 in.).

8.2.1.6 Because the conductive metal spheres do degrade with repeated use and handling they most likely will oxidize or become dirty and should be replaced with new conductive metal spheres.

8.2.2 The electrical circuit connects power supply in series with the resistor, ammeter, electrodes, and test specimen. The volt meter is connected to the two electrodes to measure the voltage across the specimen.

8.2.2.1 Resistance is calculated using ohms law:

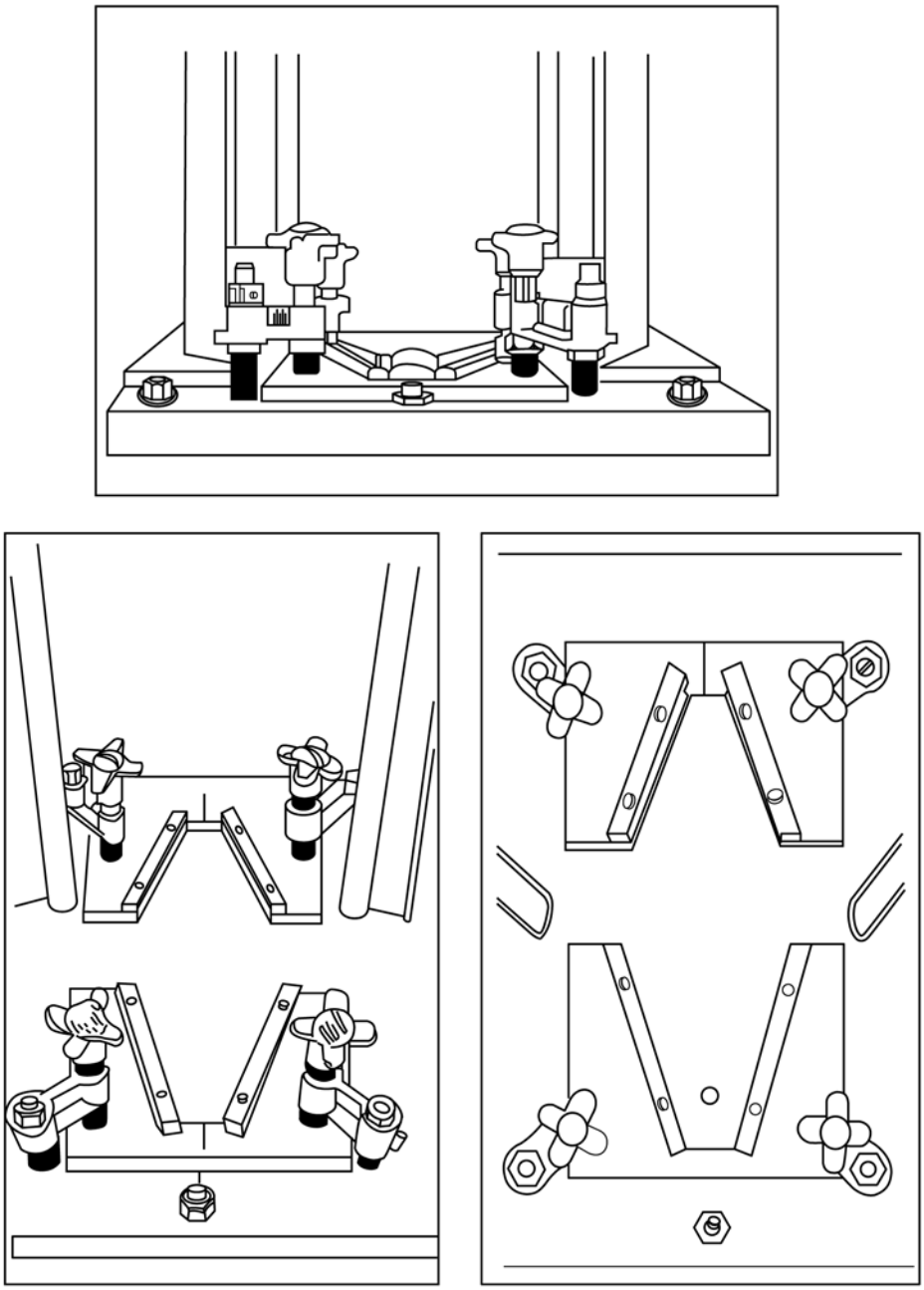


FIG. 7 Metatarsal Footwear Retaining Device

$$R = V/I \quad (2)$$

where:

R = resistance calculated in ohms,
V = voltage across the test sample in V, and
I = the current through the test sample in A.

8.3 *Sampling:*

8.3.1 Randomly select three half-pair test specimens, including both left and right footwear, of each product category from unworn manufactured footwear.

8.3.1.1 Men's footwear specimens shall be obtained from size 9.

8.3.1.2 Women's footwear specimens shall be obtained from size 8.

8.3.2 Specimens shall be conditioned in a controlled atmosphere for 24 h at 21.1 ± 1.1°C (70° ± 2°F) and 50 ± 2 % relative humidity and tested in those same conditions.

8.4 *Specimen Mounting*—Place the specimen that has been filled with metal spheres on the outer electrode plate of the apparatus so that outsole and heel are completely in contact with the steel plate base electrode.

8.5 *Procedure:*

8.5.1 Place specimen on steel plate base electrode.

8.5.2 Insert the second electrode so that it is positioned in the conductive metal spheres.

8.5.3 Apply the voltage and take the resistance measurements within a maximum time of 30 s.

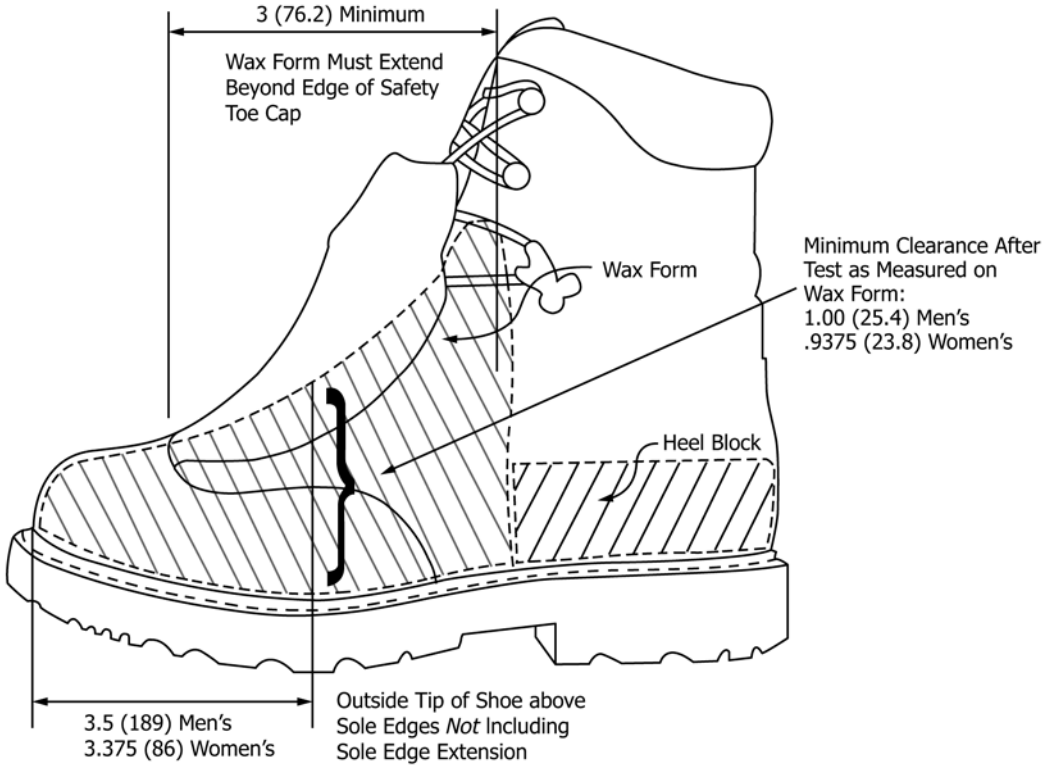


FIG. 8 Point of Impact, Wax Form Position, and After-Test Minimum Clearance

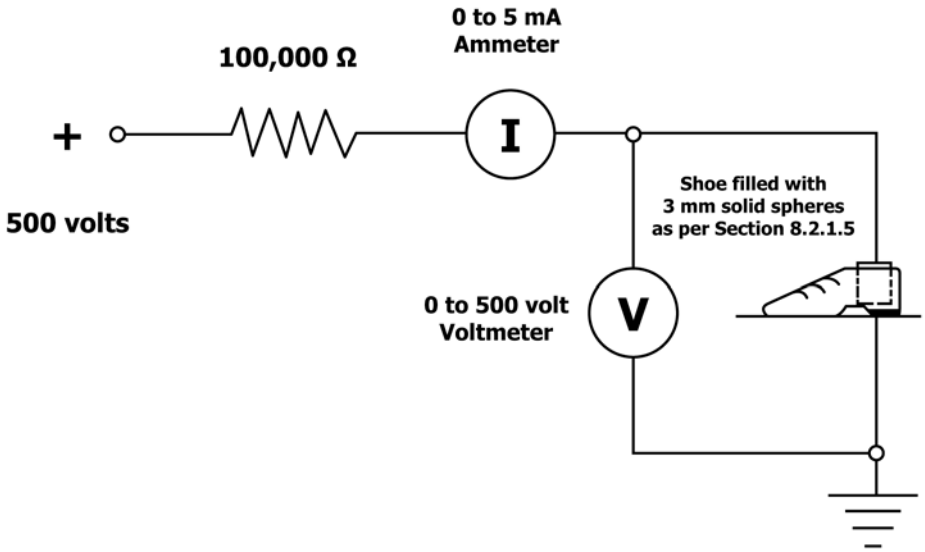


FIG. 9 Example of a Test Circuit

8.6 *Test Report*—Report the electrical resistance.

9. Electric Hazard Resistant Footwear (EH)

9.1 *Summary of Method:*

9.1.1 The footwear is placed on an outer metal mesh platform electrode; a second electrode is embedded in a layer of small metal spheres packing the inside of the footwear.

9.1.2 Voltage is applied to the footwear on the outer platform for a specified time.

9.1.3 AC resistance is determined by measuring current flow through the footwear.

9.2 *Apparatus:*

Warning—Extreme care must be used when operating this test apparatus. Human contact with any part of the circuit could be lethal. Only qualified operators trained in high voltage testing should use this apparatus. It is suggested that the equipment be operated enclosed in a cabinet with interlock protections on the door.

9.2.1 The apparatus shown in Fig. 10 is used to perform the test.

9.2.2 A 0.5 kVA (500 VA) transformer having a measurement system with an impedance value that does not exceed 280 000 ohms.

9.2.2.1 The outer electrode platform consists of a fine screen metal mesh that is spring mounted onto a frame using moderate tension. Mesh must be sufficient to support the weight of the footwear with the interior electrode.

9.2.2.2 The inner electrode consists of conductive metal spheres having a diameter of 3 to 5 mm (0.117 to 0.197 in.) placed inside the footwear to a depth of not less than 30 mm (1.18 in.).

9.2.2.3 Because the conductive metal spheres do degrade with repeated use and handling they most likely will oxidize or become dirty and should be replaced with new conductive metal spheres based on visual inspection as needed.

9.2.3 A voltmeter used in conjunction with a calibrated instrument potential transformer.

9.2.4 AC amp meter, or an equivalent non-inductive shunt and volt meter.

9.3 *Sampling:*

9.3.1 Randomly select three half-pair test specimens, including both left and right footwear, of each product category from unworn manufactured footwear.

9.3.1.1 Men's footwear specimens shall be obtained from size 9.

9.3.1.2 Women's footwear specimens shall be obtained from size 8.

9.3.2 Specimen shall be in a controlled atmosphere for 24 h at 21.1 ± 1.1°C (70 ± 2°F) and 50 ± 2 % relative humidity and tested in those same conditions.

9.4 *Specimen Mounting*—Place footwear that has been filled with conductive metal spheres onto outer electrode mesh platform, then insert the inner electrode into the conductive metal spheres.

9.5 *Procedure:*

9.5.1 Maintain inner electrode at ground potential.

9.5.2 Apply the test voltage to the outer electrode at a low level (near 0 V).

9.5.2.1 Raise voltage at a rate of 1 kV/s to 18 kV (root mean square (rms) value) at 60 Hz and maintain this voltage for 1 min.

9.5.2.2 Measure voltage using a voltmeter in conjunction with a calibrated instrument potential transformer connected directly across the high voltage circuit.

9.5.2.3 Measure the current with an AC amp meter or an equivalent non-inductive shunt and a voltmeter, connected in series with the specimen.

9.6 *Test Report*—Report the leakage current in mA for each specimen and any arc flashing.

10. Static Dissipative Footwear (SD)

10.1 *Reagent Section*—Ethanol or IPA (reagent grade).

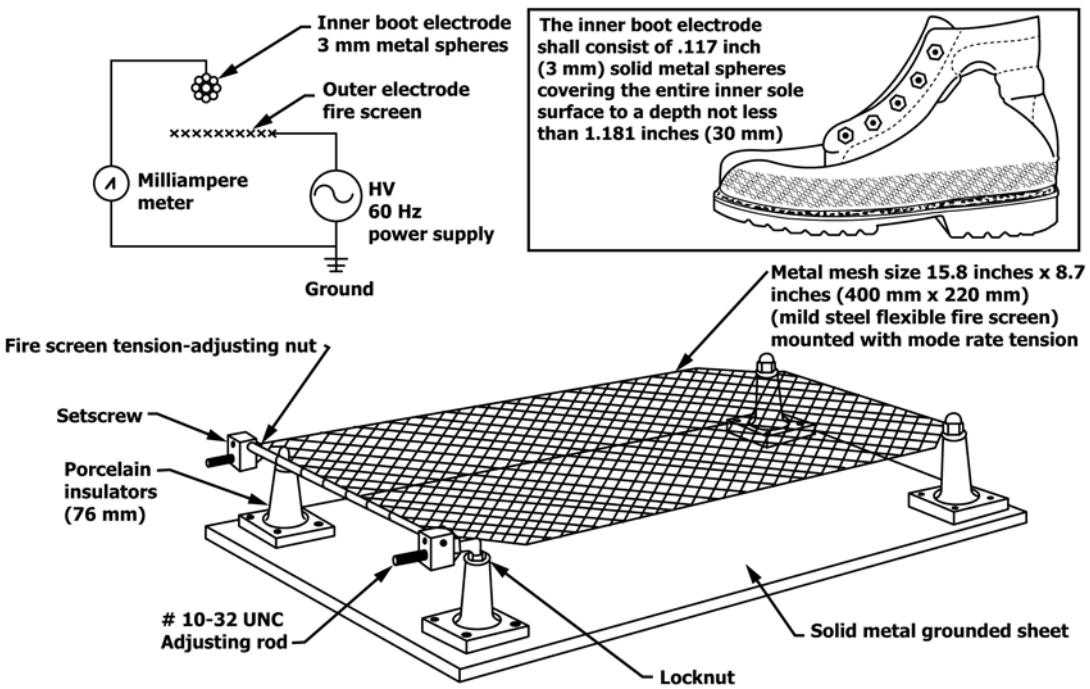
10.2 *Summary of Method:*

10.2.1 Static dissipative footwear is fitted onto the feet of a human test subject.

10.2.2 Resistance is measured by applying a specific voltage after a prescribed period of time.

10.3 *Apparatus:*

10.3.1 The apparatus, as shown in Fig. 11, requires having the following:



NOTE 1—**Warning—**Should be handled with extreme care.

FIG. 10 Typical Footwear Electrical Test Platform

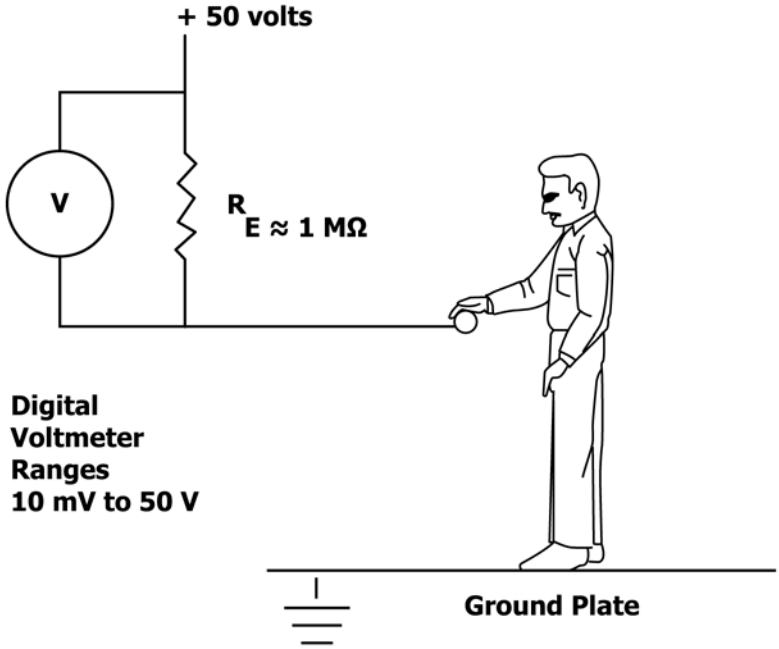


FIG. 11 Example of Test Circuit

10.3.1.1 A DC power supply at a fixed 50 V output that has current limited to 5 mA for shock protection of human test subjects.

10.3.1.2 Reference resistor greater than 1 megaohms. Voltmeter with a nominal internal resistance of 10 megaohms or greater and which measures to three or more significant digits.

10.3.1.3 A stainless steel ground plate of sufficient size to accommodate the outsole and heel of a specimen pair of footwear.

10.3.2 The electrical circuit connects the power supply in series with the resistor, electrodes, human test subject, and test specimen. The voltmeter is connected across the reference resistor to measure the voltage drop. The voltage applied across the human test subject and specimen footwear is less than 50 V.

10.3.2.1 Resistance is calculated using the following equation:

$$R = \frac{50\ \text{V} - V}{V} \cdot Rp \qquad (3)$$

where:

R = resistance in ohms,
V = voltage drop across the reference resistor Re, and
Rp = the combined parallel resistance of resistor Re and the internal resistance of voltmeter RV:

$$Rp = (Re \cdot Rv)/(Re + Rv)$$

10.4 *Sampling:*

10.4.1 Randomly select three pair test specimens of each product category from unworn manufactured footwear.

10.4.1.1 Men's footwear specimens shall be obtained from size 9.

10.4.1.2 Women's footwear specimens shall be obtained from size 8.

10.4.1.3 Specimens shall be in a controlled atmosphere for 24 h at 21.1 ± 1.1°C (70 ± 2°F) and 50 ± 2 % relative humidity and tested in those same conditions.

10.5 *Specimen Mounting:*

10.5.1 Human test subject mounts stainless steel ground plate in stocking feet.

10.5.1.1 Specimen is then fitted onto human test subject.

10.6 *Test Procedure:*

10.6.1 Human test subject in stocking feet makes hand contact to a conducting rod or clip that produces good body contact.

10.6.1.1 This contact shows a resistance path to ground of 100 000 Ω or less.

10.6.2 Test subject is fitted with specimens and wears them for 5 min. After 5 min the outsole shall be cleaned with a damp cloth with ethanol or IPA before standing on stainless steel ground plate.

10.6.2.1 Measure resistance of each specimen, left shoe, right shoe, and then measure resistance of both feet simultaneously.

10.7 *Test Report*—Report the electrical resistance for the right foot, left foot, and the pair of shoes tested.

11. Puncture Resistant Footwear (PR)

11.1 *Summary of Method*—The intent of this test method is to insure that all puncture resistant devices, metallic, and non-metallic provide the minimum level of protection.

11.1.1 Footwear shall be constructed and manufactured so that a puncture resistant device is positioned between the foot and outsole or used as the insole orientation of PR device per recommendation of manufacturer.

11.1.2 A puncture resistant device, a separate component outside of the footwear, is mounted on a stationary platform.

11.1.3 A test steel pin having a specific geometry is mounted on a movable block.

11.1.4 The puncture resistant device is visually examined to determine if puncture has occurred.

11.2 *Apparatus:*

11.2.1 A test steel pin apparatus having a movable block that permits travel either laterally or longitudinally.

11.2.1.1 A test apparatus having a stationary platform that holds the specimen to prevent movement either horizontally or vertically.

11.2.2 The apparatus will be of sufficient thickness to support forces required in the performance specification and is configured with an opening in the block having a diameter of 12.7 mm (0.50 in.) with the exit side having an approximate 45° bevel and pin viewing window. See Fig. 12.

11.2.2.1 The apparatus is configured with a pointed steel pin having a length of 50.8 ± 12.7 mm (2.0 ± 0.5 in.) and a diameter of 4.50 ± 0.05 mm (0.18 ± 0.002 in.), a conical truncated tip having a diameter of 1.00 ± 0.05 mm (0.04 ± 0.002 in.) and an angle of 30 ± 2° min at the tip. The steel pin shall have a Rockwell hardness C54 ± 2. See Fig. 13.

11.2.2.2 Confirm steel pin point is within tolerance prior to testing (see Fig. 13).

11.2.2.3 *Crosshead Travel Rate*—The rate of the crosshead travel shall be 10 ± 1 mm (0.393 ± 0.039 in.) per minute.

11.3 *Sampling:*

11.3.1 Select three test specimens of puncture resistant devices for testing for each of the three tests.

11.4 *Specimen Mounting:*

11.4.1 Mount specimen onto apparatus having a movable platform and secure specimen to prevent movement in any direction.

11.4.2 Confirm that alignment of block will permit test pin to penetrate the opening without any interference.

11.4.3 Confirm that puncture resistant device can be repositioned within the apparatus to permit multiple puncture tests anywhere on surface of device. Positions of puncture impact include any location that is at least 25.4 mm (1 in.) from outside edge of device and at least 25.4 mm (1 in.) from the last test.

11.5 *Test Procedure:*

11.5.1 Perform three puncture tests on each puncture resistant device by placing the steel pin in contact with the puncture resistant device and exerting a steady force. The rate of traverse of the steel pin is 10 ± 1 mm (0.393 ± 0.039 in.) per minute until you reach the minimum required force. Stop the travel and within 5 s, visually determine pass/fail in accordance with the performance specification.

11.5.1.1 Evaluate at a 90° angle to test pin.

11.6 *Test Report*—Report pass or fail each puncture test must meet the required minimum force. There is to be no penetration below the minimum requirement.

11.7 *Flex Resistance:*

11.7.1 Measure flex resistance of three puncture resistant specimens using CAN/CSA Z195.

11.7.1.1 Flex resistance device is shown in Fig. 14.

11.8 *Corrosion Resistance for Puncture Resistant Plates*—Measure the corrosive resistance of three puncture resistant specimens in accordance with Practice B117 using a 5 % salt solution for 24 h.

12. Precision and Bias

12.1 In case of a dispute arising from differences in reported test results, when using these test methods for acceptance testing of commercial shipments, the purchaser and the supplier should perform comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens from the same lot of product to be evaluated. These test specimens should then be randomly assigned in equal numbers to each laboratory for testing. If a bias is found, either its cause must be determined and corrected, or the purchaser and the supplier must agree to interpret future test results in light of the known bias.

13. Keywords

13.1 compression resistance (C); conductive footwear (Cd); electric hazard resistance (EH); ESD safety footwear; foot protection; impact resistance (I); metatarsal protection (Mt); protective footwear; puncture resistance (PR); soft toe protective footwear; static dissipative (SD)

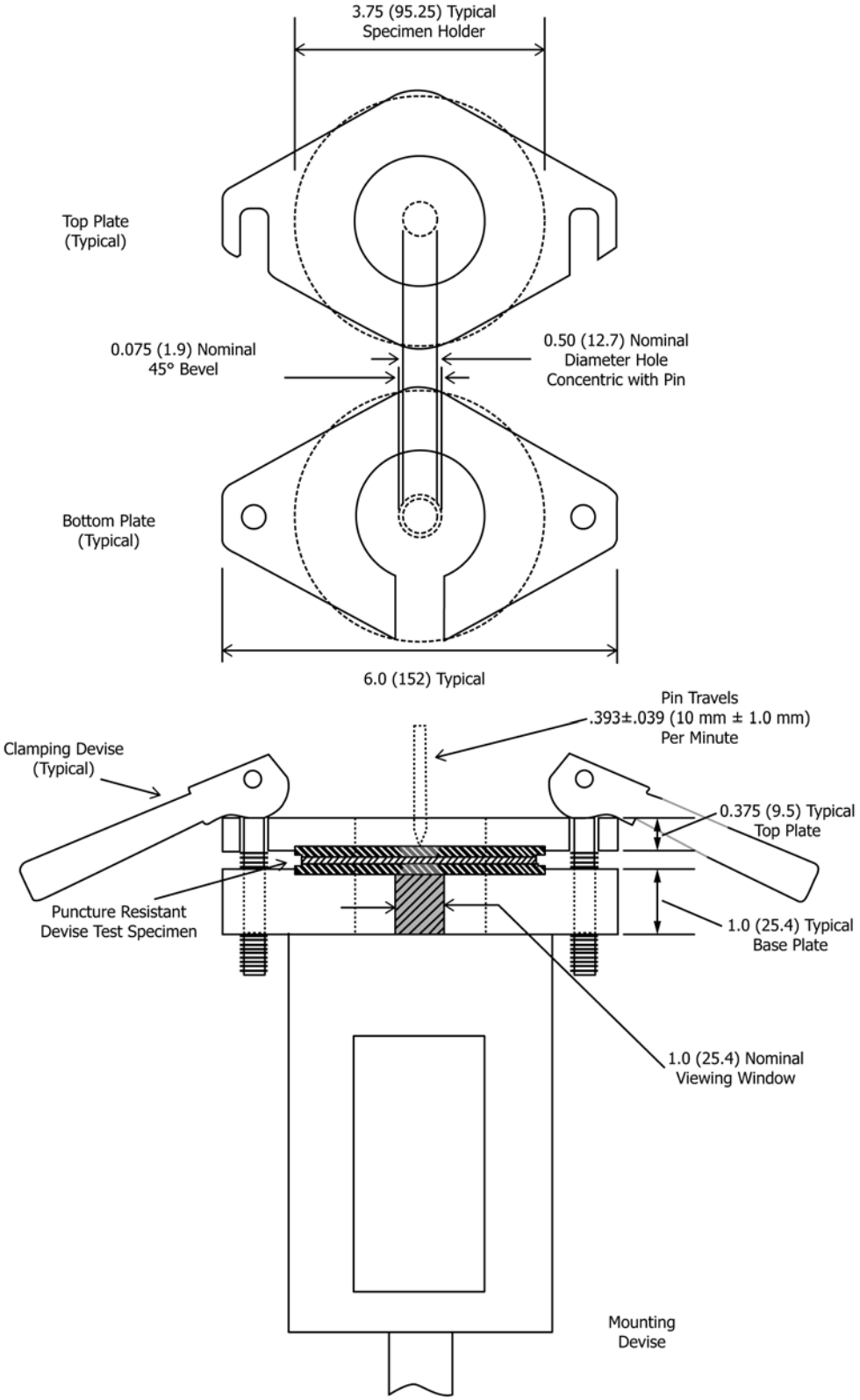
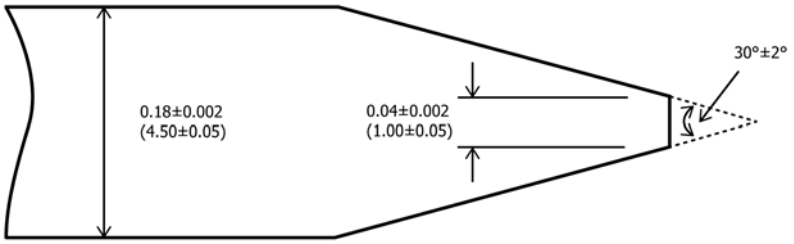
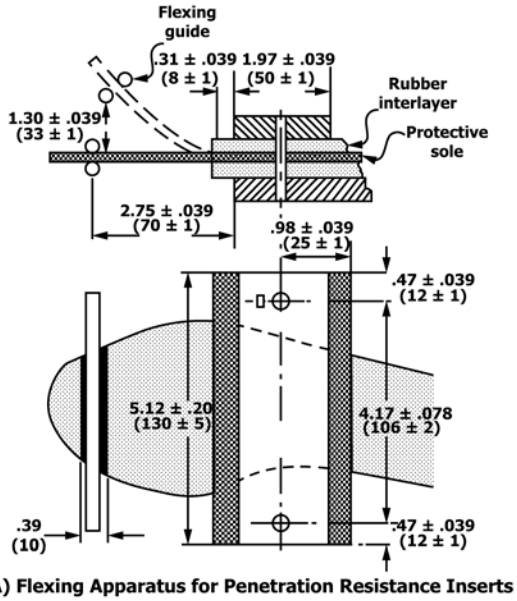


FIG. 12 Test Apparatus

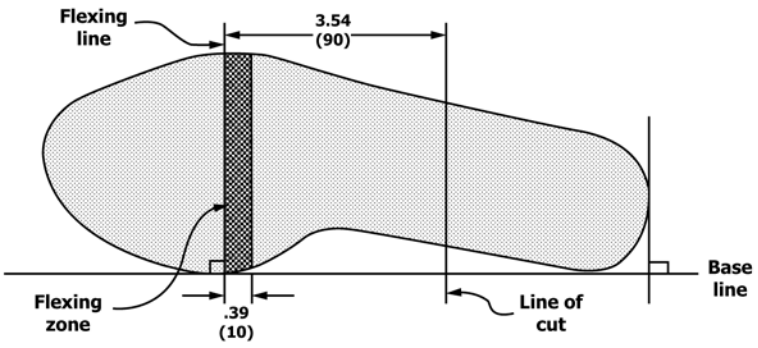


NOTE 1—Steel test pin 0.18 ± 0.002 in. (4.50 ± 0.05 mm) diameter with truncated tip 0.04 ± 0.002 in. (1.00 ± 0.05 mm) in diameter and with an angle of 30 ± 2° at the tip.

FIG. 13 Steel Test Pin



(A) Flexing Apparatus for Penetration Resistance Inserts



(B) Flexing Line for Inserts

NOTE 1—Dimensions are in inches (millimetres).

FIG. 14 Sole Puncture Resistance Protective Device Flexing Test

ANNEX

(Mandatory Information)

A1. PREPARATION OF WAX FORMS—METATARSAL IMPACT TESTING

A1.1 Apparatus

A1.1.1 The following equipment is needed to build wax forms to be used for metatarsal impact testing:

A1.1.1.1 Hot air circulating oven capable of maintaining temperatures up to 100°C (212°F),

A1.1.1.2 Scale,

A1.1.1.3 Mixer having a variable speed motor and a single agitator wire cage stirrer,

A1.1.1.4 Kettles for mixing liquid wax,

A1.1.1.5 Footwear test specimen(s),

A1.1.1.6 Refrigerator,

A1.1.1.7 Reinforced nylon strapping tape (used to remove wax from footwear after testing), and

A1.1.1.8 Thermometer.

A1.2 Ingredients

A1.2.1 A ratio of five parts paraffin wax and one part beeswax are needed to produce six wax forms:

Paraffin wax	2.25 kg (5 lb)
Beeswax	0.45 kg (1 lb)

A1.3 Procedure

A1.3.1 Combine the paraffin wax and the beeswax into a mixing kettle.

A1.3.2 Place kettle into hot air circulatory oven and heat to a temperature of 85°C (185°F) so that both ingredients are a liquid.

A1.3.3 Remove kettle from oven, insert thermometer in kettle, and stir at a low speed as the wax cools to a temperature of 60°C (140°F) and wax crystals start to form.

A1.3.3.1 Continue to stir while increasing agitation speed to medium rate of speed (approximately 440 rpm) until a light foam begins to form in wax.

A1.3.4 Create wax forms.

A1.3.4.1 Footwear test specimen(s) per Fig. A1.1.

(1) Cut away rear upper of Footwear test specimen.

(2) Line inside of footwear (footbed remains in place and footwear remains laced) with foil or equivalent material to prevent molten wax material from leaking out of footwear.

(3) Pour molted wax into footwear test specimen.

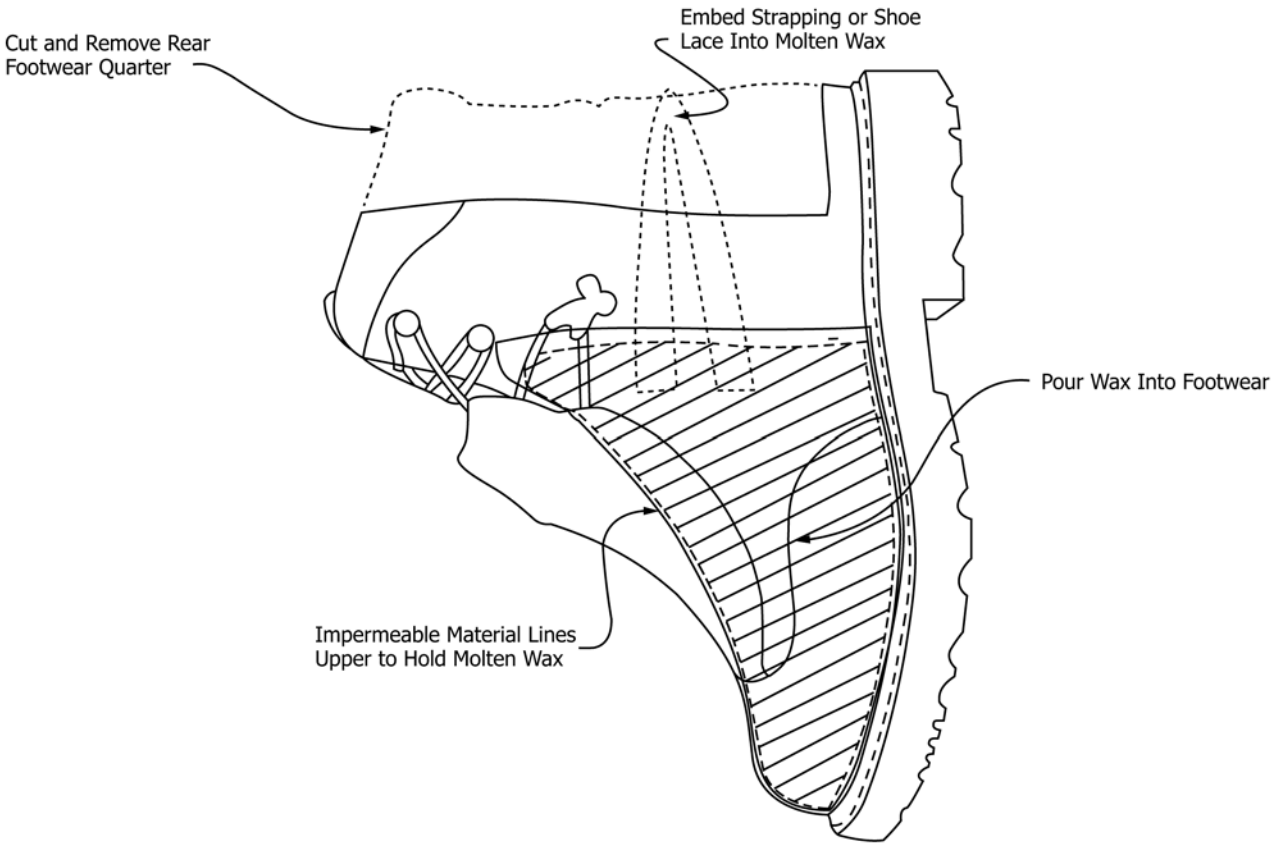


FIG. A1.1 Prepare Upper and Pour Wax into Footwear Test Specimen to Create Metatarsal Test Form

(4) Place a 226.8 mm (9 in.) length of reinforced strapping tape or equivalent inside the cavity of the footwear test specimen. Pressing the strapping tape against the sides of the footwear test specimen.

NOTE A1.1—Tape functions as a handle when removing wax form from test specimen.

A1.3.5 Place footwear test specimen(s) in refrigerator or allow to dry at room temperature 24 h until solid.

A1.3.6 Allow Footwear Test Specimen(s) to come to applicable room ambient/humidity conditions as defined in Test Methods F2412.