Designation: D3574 – 17

# Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams[1]

This standard is issued under the fixed designation D3574; 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.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope*

1.1 These test methods apply to slab, bonded, and molded flexible cellular products known as urethane foams. Urethane foam is generally defined as an expanded cellular product produced by the interaction of active hydrogen compounds, water, and isocyanates.

1.2 *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.*

1.3 The values stated in SI units are to be regarded as standard.

NOTE 1—There is no known ISO equivalent to this standard, however certain test methods in this standard have similar or equivalent ISO standards and are listed in the scope of the individual test method sections.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers

D737 Test Method for Air Permeability of Textile Fabrics

D3576 Test Method for Cell Size of Rigid Cellular Plastics

D3675 Test Method for Surface Flammability of Flexible Cellular Materials Using a Radiant Heat Energy Source

E162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source

E662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials

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

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bonded foam*—a product produced by the adhesion of small pieces of urethane foam to each other with a suitable bonding agent.

3.1.2 *core*—the internal portion of a molded part, free of skin.

3.1.3 *cored foam*—a flexible cellular material containing a multiplicity of holes (usually, but not necessarily, cylindrical in shape), molded or cut into the material in some pattern, normally perpendicular to the foam rise direction, and extending part or all the way through the piece.

3.1.4 *convoluted foam*—a flexible cellular material specially cut into sheets with "egg carton"-like dimples. The dimple peaks and bases can have varied shapes and dimensions.

3.1.5 *flexible cellular product*—a cellular organic polymeric material that will not rupture when a specimen 200 by 25 by 25 mm is bent around a 25-mm diameter mandrel at a uniform rate of one lap in 5 s at a temperature between 18 and 29°C.

3.1.6 *molded foam*—a cellular product having the shape of the enclosed chamber in which it is produced by foaming.

3.1.7 *skin*—the smooth surface layer of a molded foam product, formed by contact with the mold or surfaces.

3.1.8 *slab*—a section of foam that is cut from the internal portion of a large bun.

3.1.9 *urethane foam*—a flexible cellular product produced by the interaction of active hydrogen compounds, water, and isocyanates.

3.1.10 *viscoelastic foam*—a specially formulated urethane foam characterized by having slow recovery, low resilience, and high hysteresis loss.

3.1.11 *cell count*—a measurement used to characterize different types of foams based on the size of the individual cells in the foam matrix, typically expressed as either average cell diameter or as the number of cells per linear distance. For measuring cell counts, see Test Method D3576.

[1] These test methods are under the jurisdiction of ASTM Committee D20 on Plastics and are the direct responsibility of Subcommittee D20.22 on Cellular Materials - Plastics and Elastomers.

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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.

***A Summary of Changes section appears at the end of this standard**

3.1.12 *clickability*—the ability of a flexible cellular material to recover from the pinching effects of die cutting.

## 4. Summary of Test Methods

4.1 Unless otherwise specifically stated and agreed upon by the purchaser and the supplier, all tests shall be made in accordance with the methods specified in Sections 9 – 150, which include test procedures for the following:

| *Tests:* | | Sections |
|---|---|---|
| Test A | Density Test | 9 – 15 |
| Test $B_1$ | Indentation Force Deflection Test—Specified Deflection (IFD) | 16 – 22 |
| Test $B_2$ | Indentation Residual Gauge Length Test—Specified Force (IRGL) | 23 – 29 |
| Test C | Compression Force Deflection Test | 30 – 36 |
| Test D | Constant Deflection Compression Set Test | 37 – 44 |
| Test E | Tensile Test | 45 – 52 |
| Test F | Tear Resistance Test | 53 – 60 |
| Test G | Air Flow Test | 61 – 67 |
| Test H | Resilience (Ball Rebound) Test | 68 – 75 |
| Test $I_1$ | Static Force Loss Test at Constant Deflection | 77 – 85 |
| Test $I_2$ | Dynamic Fatigue Test by Roller Shear at Constant Force | 86 – 94 |
| Test $I_3$ | Dynamic Fatigue Test by Constant Force Pounding | 95 – 103 |
| Test $I_4$ | Dynamic Fatigue Test for Carpet Cushion | 104 – 112 |
| Test $I_5$ | Dynamic Fatigue Test by Constant Deflection Pounding | 113 – 121 |
| Aging Test J | Steam Autoclave Aging | 122 – 127 |
| Aging Test K | Dry Heat Aging | 128 – 133 |
| Aging Test L | Wet Heat Aging | 134 – 139 |
| Test M | Recovery Time | 140 – 145 |
| Test N | Hysteresis Loss | 146 – 150 |

*Appendixes:*

X1. Suggested Method for Specifying Flexible Urethane Foams
X2. Suggested Method of Construction for a Roller Shear Dynamic Flex Fatigue Apparatus
X3. Definitions of Terms Used to Describe the Force-Deflection Curve of Flexible Urethane Foam
X4. Suggested Tests for Determining Combustibility of Flexible Urethane Foam. (The combustion tests are given for informational purposes only and are not part of the standard.)
X5. Suggested Method for the Verification of an Inclined Oil Manometer

## 5. Significance and Use

5.1 The test procedures provide a standard method of obtaining data for research and development, quality control, acceptance and rejection under specifications, and special purposes.

5.2 The data obtained by these test methods are applicable to the material under conditions of the particular test and are not necessarily the same as obtained in other environments in use.

## 6. General Test Conditions

6.1 Tests shall be entirely conducted at 23 ± 2 °C and 50 ± 10 % relative humidity, unless otherwise specified in the individual test method. The product shall be conditioned, undeflected and undistorted, at 23 ± 2 °C and 50 ± 10 % relative humidity, for at least 12 h before being tested, unless otherwise specified in the individual test method.

6.2 It is recommended for referee purposes that all tests be performed seven days or more after the foam has been manufactured.

6.3 For mechanical tests, it is advisable to carefully select the proper load cell for each test. It is recommended that the expected load for any individual test falls within 10-90 % of the load cell capacity.

## 7. Sampling

7.1 When possible, the completed manufactured product shall be used for the test specified. Representative samples of the lot being examined shall be selected at random, as required.

7.2 When it is necessary or advisable to obtain specimens from the articles, as in those cases where the entire sample is not required or adaptable for testing, the method of cutting and the exact position from which specimens are to be taken shall be specified. The density and the state of cure can vary in different parts of the finished product, especially if the article is of complicated shape or of varying thickness, and these factors affect the physical properties of the specimens. Also, the density is affected by the number of cut surfaces on the specimen. If a test specimen is die cut, ensure that the sides are not concave and allow sufficient time for complete recovery of the thickness across the full width of the specimen before testing.

7.3 When the finished molded product does not lend itself to testing or to the taking of specimens because of complicated shape, small size, metal or fabric inserts, adhesion to metal, or other reasons, molded test slabs, as agreed upon between the purchaser and the supplier, shall be prepared.

7.4 When differences in test results arise due to the difficulty in obtaining suitable specimens from the finished parts, the purchaser and the supplier shall agree upon an acceptable location from which to take the specimen.

## 8. Measurement of Test Specimens

8.1 Measure the length and width with a scale, tape, or caliper gauge. Take care not to distort the foam.

8.2 Measure thickness up to and including 25 mm using a height or electronic display gauge with a minimum foot area of 650 $mm^2$. Hold the pressure of the gauge foot to a maximum of 800 Pa (see Note 2). Thicknesses over 25 mm shall be measured with a height or electronic display gauge, a sliding caliper gauge, or as specified in 8.1. When a sliding caliper gauge is employed, make the gauge setting with the gauge out of contact with the foam. Pass the specimen through the previously set gauge; the proper setting shall be the one when the measuring faces of the gauge contact the surfaces of the specimen without compressing it.

NOTE 2—For soft foams having compression force deflection values less than 1.65 kPa, the pressure on the gauge or compression foot shall not exceed 200 Pa.

8.3 The scale, tape, or gauge shall be graduated so as to permit measurements within ±1 % of the dimensions to be measured.

8.4 Unless otherwise specified, results shall be the mean of the measurements.

## TEST A—DENSITY TEST

### 9. Scope

9.1 This test method covers determination of the density of uncored foam by calculation from the mass and volume of the specimen. The density value thus obtained applies only to the immediate area from which the specimen has been taken. It does not necessarily relate to the bulk density of the entire molded pad.

NOTE 3—This standard is equivalent to ISO 845.

### 10. Test Specimen

10.1 *Core Density*—A representative specimen of regular shape, circular or square without skins or densification lines, not less than 10,000 $mm^3$ (~0.61 $in.^3$) in volume, shall be cut from a portion free of voids and defects and as near as possible to the section from which the tension and tear specimens were taken.

10.2 *Section Density*—A representative specimen with skins on the top and bottom surface measuring at least 0.1 $m^2$ in area by full-part thickness, shall be cut from an area free of voids and defects and as near as possible to the location from which the tension and tear specimens were taken. When these dimensions are not possible, the largest representative portion as agreed upon between the purchaser and the supplier, shall be used.

### 11. Number of Specimens

11.1 One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

### 12. Procedure

12.1 Determine the mass of the specimen to a precision of ±1 %.

12.2 Determine the dimensions of the specimen in accordance with Section 8, and calculate the volume.

### 13. Calculation

13.1 Calculate the density in kilograms per cubic metre as follows:

$$\text{Density} = M/V \times 10^6 \quad (1)$$

where:

$M$ = mass of specimen, g, and
$V$ = volume of specimen, $mm^3$.

### 14. Report

14.1 Report the following information:
14.1.1 Density to the nearest 0.1 $kg/m^3$, and
14.1.2 Type of specimen, core or section.

### 15. Precision and Bias

15.1 See Section 151 for Precision and Bias statements.

## TEST $B_1$ —INDENTATION FORCE DEFLECTION TEST—SPECIFIED DEFLECTION (IFD)

### 16. Scope

16.1 This will be known as the indentation force deflection test and the results as the IFD values. This test consists of measuring the force necessary to produce designated indentations in the foam product, for example, indentations at 25 and 65 % deflections. (See Appendix X3 for additional information).

NOTE 4—This standard and ISO 2439 address the same subject matter, but differ in technical content and results cannot be directly compared between the two methods.

### 17. Apparatus

17.1 An apparatus having a flat circular indenter foot 200 +3/–0 mm in diameter connected by means of a swivel joint capable of accommodating the angle of the sample to a force-measuring device and mounted in such a manner that the product or specimen can be deflected at a speed of 50 to 250 mm/min. The apparatus shall be arranged to support the specimen on a level horizontal plate which is perforated with approximately 6.5-mm holes on approximately 20-mm centers to allow for rapid escape of air during the test. Special supports for contoured molded pads shall be perforated in the same manner as the flat plate, unless otherwise agreed upon between the purchaser and the supplier. Pads longer than the base plate shall be supported from distortion at the 4.5-N contact force (see 20.3).

NOTE 5—Equipment design and test fixturing can affect the results of this test. As an example, load cells placed below the support plate can experience a bridging effect that likely does not occur in equipment which has the load cell mounted above the indenter foot.

### 18. Test Specimen

18.1 The test specimen shall consist of the entire product sample or a suitable portion of it, except that in no case shall the specimen have dimensions less than 380 by 380 by 100 mm. If specimens are less than (or different from) 100 mm in thickness, the thickness shall be noted on the test report.

18.2 The IFD values for molded products are dependent on the specimen dimensions. Higher values are generally obtained for specimens that retain all molded surfaces.

### 19. Number of Specimens

19.1 One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

### 20. Procedure

20.1 Place the test specimen in position on the supporting plate of the apparatus. If the product has one side cored or convoluted, this face shall rest on the perforated plate. The specimen position shall be such that, whenever practicable, the indentation will be made at the center of the specimen, except when another location is agreed upon by the purchaser and the supplier.

20.2 Preflex the test area twice to a deflection of 75 to 80 % of the full-part thickness, lowering and raising the indenter foot at a rate of 250 ± 25 mm/min, allowing the indenter to fully clear the top of the specimen after each preflex. For fatigue tests, or in case repeat testing proves necessary, mark the location of the test area by circumscribing the indenter foot with a pen. Allow the specimen to rest for 6 ± 1 min after the final preflex.

20.3 Bring the indenter foot into contact with the specimen at a rate of 50 ± 5 mm/min and determine the thickness while applying a contact force of 4.5 ± 0.5 N to the indenter foot. For super-soft foam, with a 25 % IFD less than 40 N, a reduction of pressure on the indenter foot shall be allowed. Sufficient contact force to make an accurate initial thickness measurement is required. Indent the specimen at a rate of 50 ± 5 mm/min 25 % of this thickness and observe the force in newtons after 60 ± 3 s. Without removing the specimen, increase the deflection to 65 % deflection, allowing the force to drift while maintaining the 65 % deflection, and again observe the force in newtons after 60 ± 3 s.

## 21. Report

21.1 Report the force in newtons required for 25 % and 65 % indentation or other indentations (see Note 6). These figures are known as the 25 % and 65 % IFD values, respectively. Report length, width, and thickness of the specimen, if non-standard, and the ratio of 65 % to 25 % IFD values (that is, support factor, see Appendix X3).

NOTE 6—Indentation deflection tests, other than 25 % and 65 %, as well as a 25 % return value (25 % RT), may be specified as agreed upon between the purchaser and the supplier. Alternative or additional deflections shall be performed as described in 20.3.

## 22. Precision and Bias

22.1 See Section 151 for Precision and Bias statements.

# TEST $B_2$—INDENTATION RESIDUAL GAUGE LENGTH TEST—SPECIFIED FORCE (IRGL)

## 23. Scope

23.1 Cellular foam products have traditionally been checked for indentation force deflection by determining the force required to effect a 25 % deflection. In seating, on the other hand, the interest is in determining how thick the padding is under the average person. Three measurements are called for to meet the requirements of this test method. The force deflection is determined by measuring the thickness of the pad under a fixed force of 4.5 N, 110 N, and 220 N, with a 200 + 3/– 0 mm circular indenter foot.

23.2 This determination shall be known as the Indentation Residual Gauge Length and the measurements as the IRGL values.

NOTE 7—This standard and ISO 2439 address the same subject matter, but differ in technical content; and results cannot be directly compared between the two methods.

## 24. Apparatus

24.1 An apparatus having a flat circular indenter foot 200 +3/–0 mm in diameter, connected with a swivel joint for applying forces of 4.5 N, 110 N, 220 N and 330 N, shall be mounted over a level horizontal platform that is perforated with approximately 6.5-mm holes on approximately 20-mm centers to allow for rapid escape of air during the test. The distance between the indenter foot and the platform shall be variable to indent the specimen at a speed of 50 to 250 mm/min for thickness measurements. The apparatus shall be equipped with a device for measuring the distance between plates.

24.2 Special supports for contoured molded pads shall be perforated and agreed upon between the purchaser and the supplier. Pads longer than the base plate shall be supported from distortion at the 4.5-N contact force (see 27.2).

## 25. Test Specimen

25.1 When possible, the finished manufactured product shall be used. In the case of tapered cushions, the location of the area for measurement is to be agreed upon between the purchaser and the supplier. In case a finished part is not feasible for test, 380 by 380-mm specimens of an average thickness are to be cut from the cushion.

25.2 The IRGL values for molded products are dependent on the specimen dimensions. Different values are generally obtained for specimens that retain all molded surfaces.

## 26. Number of Specimens

26.1 One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

## 27. Procedure

27.1 Test the whole test specimen or a minimum area of 380 by 380 mm. Position the specimen in the test apparatus with any cored or convoluted surfaces resting against the perforated bottom plate. Preflex the specimen twice with a 330 N force, raising and lowering the indenter foot at 200 ± 20 mm/min, allowing the indenter foot to fully clear the top of the specimen after each preflex. Allow the specimen to rest for 6 ± 1 min after the final preflex.

27.2 At a rate of 50 ± 5 mm/min, bring the indenter foot into contact with and determine the thickness of the specimen, in mm, with a 4.5 ± 0.5-N load on the indenter foot.

27.3 Apply the 110-N force at 50 ± 5 mm/min with the indenter foot until the force is carried by the specimen. Determine the thickness, in mm, at 110 N after maintaining the force for 60 ± 3 s.

27.4 Without removing the specimen, apply the 220-N force at 50 ± 5 mm/min with the indenter foot until the force is carried by the specimen. Determine the thickness, in mm, at 220 N after maintaining the force for 60 ± 3 s.

## 28. Report

28.1 Report the specimen thickness, in mm, at 4.5 N instantaneously and at 110 N and 220 N after 60 ± 3 s. These figures are known as the IRGL values, respectively. Report the length, width, and thickness of the specimen.

## 29. Precision and Bias

29.1 See Section 151 for Precision and Bias statements.

# TEST C—COMPRESSION FORCE DEFLECTION TEST

## 30. Scope

30.1 This test consists of measuring the force necessary to produce a 50 % compression over the entire top area of the foam specimen.

NOTE 8—This standard and ISO 3386 address the same subject matter, but differ in technical content; and results cannot be directly compared between the two methods.

NOTE 9—Compression force deflection tests other than at 50 % may be specified, as agreed upon between the purchaser and the supplier, following the procedure in Section 34.

## 31. Apparatus

31.1 An apparatus having a flat, fixed compression foot, larger than the specimen to be tested, connected to a force-measuring device and mounted in a manner such that the product or specimen can be deflected at a speed of 50 to 500 mm/min. The apparatus shall be arranged to support the specimen on a level horizontal plate that is perforated with approximately 6.5-mm holes on approximately 20-mm centers to allow for rapid escape of air during the test.

## 32. Test Specimens

32.1 The test specimens shall have parallel top and bottom surfaces and vertical sides. The thickness shall be no greater than 75 % of the minimum top dimension. The standard specimen shall be 50 mm by 50 mm by 25 mm in thickness. Larger specimens are preferable, where possible.

32.2 Specimens shall be a minimum of 2500 $mm^2$ in surface area and have a minimum thickness of 20 mm.

32.3 Unless otherwise agreed upon by purchaser and supplier, specimens from molded parts shall be cut from the core material at least 10 mm below the molded surface. Note in the report if the specimens contain one or more molded surfaces resulting from insufficient core material or contractual agreement.

## 33. Number of Specimens

33.1 Three specimens per sample shall be tested. The value reported shall be the mean value of those observed.

## 34. Procedure

34.1 Place the specimen, centered in the line of the axial load, on the supporting plate of the apparatus. If the product has one side cored or convoluted, rest this face on the perforated plates.

34.2 Preflex the specimen twice, to a deflection of 75 to 80 % of its original thickness, lowering and raising the compression foot at a rate of 250 ± 25 mm/min, allowing the compression foot to fully clear the specimen after each preflex. Allow the specimen to rest for a period of 6 ± 1 min after the final preflex.

34.3 Bring the compression foot into contact with the specimen at a rate of 50 ± 5 mm/min and determine the thickness after applying a contact load of 140 ± 14 Pa to the specimen area (see Note 2). Compress the specimen 50 % of this thickness at a rate of 50 ± 5 mm/min and determine the final force, in N, after 60 ± 3 s (see Note 8).

$$\textit{Compression Force Deflection, kPa} = [\textit{force, in N} \times 10^3]/\textit{specimen area, in mm}^2$$

## 35. Report

35.1 Report the thickness after contact force, the 50 % compression deflection value in kilopascals, and the dimensions of non-standard specimens. Indicate if the sample was cored or convoluted. Report if the specimens contained one or more molded surfaces.

## 36. Precision and Bias

36.1 See Section 151 for Precision and Bias statements.

# TEST D—CONSTANT DEFLECTION COMPRESSION SET TEST

## 37. Scope

37.1 This test method consists of deflecting the foam specimen to a specified deflection, exposing it to specified conditions of time and temperature and measuring the change in the thickness of the specimen after a specified recovery period.

NOTE 10—This standard and ISO 1856 address the same subject matter, but differ in technical content and results cannot be directly compared between the two methods.

## 38. Apparatus

38.1 *Compression Device,* consisting of two or more flat plates arranged so the plates are held parallel to each other by bolts or clamps and the space between the plates is adjustable to the required deflection thickness by means of spacers. The plates shall be metal in composition and have sufficient stiffness to ensure that they are not deflected under the force necessary to compress all of the specimens. Steel is the preferred plate material.

38.2 Mechanically convected air oven capable of maintaining the conditions of 70 ± 2 °C.

NOTE 11—While this method does not set limits on the surface area of the compression plates, the user should be aware that different thermal conditions can exist for specimens placed at different locations on the plate.

## 39. Test Specimens

39.1 The test specimens shall have parallel top and bottom surfaces and essentially perpendicular sides. It is recommended that the specimens be cut with a band knife or band saw. Die cut specimens have a greater tendency to exhibit edge sticking (pillowing) after being removed from the compression device. Specimens shall be cut at least 13 mm from any edge that has been exposed to light (see Note 13).

39.2 Specimens shall be 50 by 50 by 25 mm and core, unless otherwise specified. Specimens less than 25 mm in thickness shall be plied up, without the use of cement, to a 25-mm thickness.

39.3 Specimens from cored foams shall have a minimum top surface area of 100 $cm^2$. The thickness shall be no greater than 75 % of the minimum top dimension.

39.4 Specimens from uncored molded products 25 mm or less in thickness shall be 50 by 50 mm by full-part thickness and shall contain the top and bottom skin.

39.5 Specimens greater than 50 mm in thickness shall be cut to 25 mm thickness from the core (see Note 12).

NOTE 12—Specimens from molded products may be tested with one or both skins by agreement between the purchaser and the supplier.

NOTE 13—Care should be taken to minimize the exposure of compression set specimens to visible light. Studies have shown that light can have a deleterious effect on compression sets.[3] If the specimens are not to be tested within 24 hours of being cut from the part or block, they should be covered or be placed in an opaque container or bag.

## 40. Number of Specimens

40.1 Three specimens per sample shall be tested. The value reported shall be the mean of those observed.

## 41. Procedure

41.1 Conduct all measurements, conditioning, and recovery of the specimens at 23 ± 2 °C and in an atmosphere of 50 ± 10 % relative humidity, as specified in 6.1.

41.2 Measure the original thickness of the test specimens in accordance with the procedure described in Section 8.

41.3 Place the test specimens in the compression device and deflect them to 50 ± 1 %, 75 ± 1 %, or 90 ± 1 % of their original thickness, or to any other deflection agreed upon between the purchaser and the supplier. Space the specimens in the compression device in such a manner that there is at least 6 mm of separation between specimens in all directions.

41.4 Within 15 min, place the compression device containing deflected specimens into the mechanically convected air oven for a period of 22 h.

41.5 After the 22 h period, remove compression device from the oven. Immediately remove the specimens from the compression device and measure the final thickness in accordance with the procedure described in Section 8 after allowing them to recover 30 to 40 min at the temperature and humidity conditions specified in 41.1.

NOTE 14—Recovery periods greater than 30 to 40 min may be agreed upon by the purchaser and the supplier.

## 42. Calculation

42.1 Calculate the compression set value by one of the following formulas:

NOTE 15—The $C_t$ calculation is preferred and shall be the calculation used when neither $C_t$ nor $C_d$ are specified.

42.1.1 Calculate the constant deflection compression set, expressed as a percentage of the original thickness, as follows:

$$C_t = [(t_o - t_f)/t_o] \times 100 \quad (2)$$

where:

$C_t$ = compression set expressed as a percentage of the original thickness,
$t_o$ = original thickness of test specimen, and
$t_f$ = final thickness of test specimen.

42.1.2 Calculate the constant deflection compression set, expressed as a percentage of the original deflection, as follows:

$$C_d = [(t_o - t_f)/(t_o - t_s)] \times 100 \quad (3)$$

where:

$C_d$ = compression set expressed as a percent of the original deflection,
$t_o$ = original thickness of test specimen,
$t_s$ = thickness of spacer bar used, and
$t_f$ = final thickness of test specimen.

NOTE 16—Approximate conversion of $C_t$ to $C_d$ can be calculated by multiplying the 50 % $C_t$ by 2, the 75 % $C_t$ by 1.33, and the 90 % $C_t$ by 1.11.

## 43. Report

43.1 Report compression set as $C_t$ or $C_d$, and report deflection used. Also report any non-standard recovery periods or sample sizes and whether the sample was cored, uncored and/or molded.

## 44. Precision and Bias

44.1 See Section 151 for Precision and Bias statements.

[3] Blair, G.R., Dawe, B., McEvoy, J., Pask, R., Rusan de Priamus, M., Wright, C. "The Effect of Visible Light on the Variability of Flexible Foam Compression Sets" Center for the Polyurethanes Industry of the American Chemistry Council 2007 Conference Proceedings.

## TEST E—TENSILE TEST

### 45. Scope

45.1 This test method determines the effect of the application of a tensile force to foam. Measurements are made for tensile stress at a predetermined, specified elongation (optional), tensile strength, and ultimate elongation.

NOTE 17—This standard and ISO 1798 address the same subject matter, but differ in technical content and results cannot be directly compared between the two methods.

### 46. Apparatus

46.1 *Specimens*—The specimen for tensile tests shall be stamped out with a die of the shape (dumbbell) and dimensions shown in Fig. 2 (D3574 die), or Fig. 3 (Die A of Test Method D412). The die shall be sharp and free of nicks in order to prevent leaving ragged edges on the specimen. The ASTM D412 Die A, shown in Fig. 3, is the preferred die.

46.2 *Bench Marker*—The marker shall have two parallel marking edges 1 to 3 mm in thickness and spaced 20 or 25 mm apart on centers.

46.3 *Measurements*—The dimensions of the test specimen shall be determined with a suitable gauge in accordance with Section 8.

46.4 *Machine*—Tensile tests shall be conducted on a power-driven machine complying with the following requirements:

46.4.1 The machine shall be equipped with a load cell or force measuring device to measure the maximum applied force. The test speed shall be 500 ± 50 mm/min, and shall be uniform at all times.

46.4.2 Elongation shall be determined by either a device graduated to 2.5 mm for measuring the elongation, by the use of a non-contact extensometer, or by crosshead travel (also referred to as grip separation). Extensometers that clip on to the specimen generally are unsuitable for flexible foam. For testing dumbbell specimens, the machine shall have either screw-type flat plate grips or a type of grip that tightens automatically and exerts a uniform pressure across the gripping surfaces, increasing as the tension increases to prevent slipping.

### 47. Test Specimens

47.1 The test specimens shall be cut from flat sheet material. Test specimens shall be from 3 - 14 mm in thickness. The foam rise shall be in the thickness direction, unless otherwise agreed upon by purchaser and supplier. The top and bottom surfaces shall be parallel and free of skin. The cut edges shall be perpendicular to the top surface and be free of ragged edges. The length of the tabs can be adjusted to fit machine conditions provided that all other requirements remain constant.

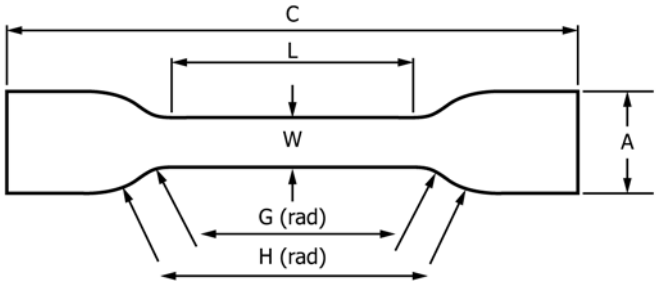


FIG. 1 Tensile Dumbbell Specimen Dimension Key

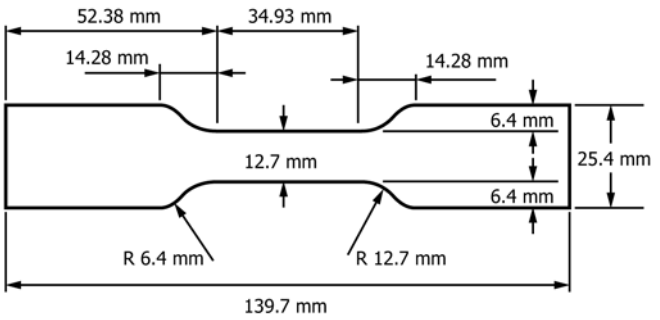


FIG. 2 Die for Stamping Tensile Dumbbell Specimens—D3574 Die

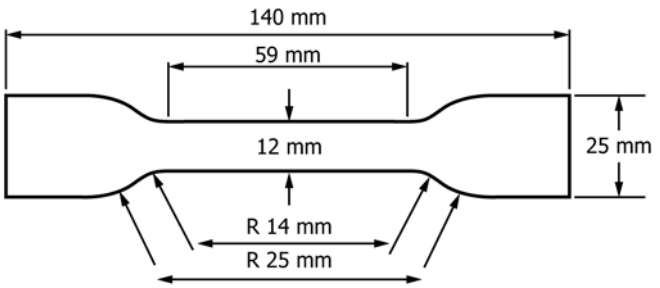


FIG. 3 Die for Stamping Tensile Dumbbell Specimens—D412A Die

### 48. Number of Specimens

48.1 Three specimens per sample shall be tested. The value reported shall be the mean value of those observed.

### 49. Procedure

49.1 Set the grip separation at a minimum of 62.5 mm for the D3574 die and at a minimum of 75 mm for D412 Die A. Place the dumbbell tabs in the grips of the testing machine, using care to adjust them symmetrically, so that the tension will be distributed uniformly over the cross section. The test shall

TABLE 1 Dimension Tolerances of Tensile Dies

| Dimension | Units | Tolerance | D3574 Die | D412 Die A |
|---|---|---|---|---|
| A | mm | ±1 | 25.4 | 25 |
| C | mm | min | 139.7 | 140 |
| G | mm | ±1 | 12.7 | 14 |
| H | mm | ±2 | 6.4 | 25 |
| L | mm | ±2 | 34.93 | 59 |
| W | mm | +0.05, –0.00 | 12.7 | 12 |

be run at a speed of 500 ± 50 mm/min, unless otherwise specified by agreement between purchaser and supplier.

49.2 Start the machine and, if measuring elongation by bench mark, note continuously the distance between the two bench marks.

49.3 If tensile stress at a predetermined elongation was specified, record the stress at the specified percent elongation (it is also acceptable to note the stress at a predetermined elongation automatically by means of a recording device, or by machine software).

49.4 At rupture, measure or record elongation to the nearest 10 %.

## 50. Calculation

50.1 Calculate the tensile strength by dividing the maximum breaking force by the original cross-sectional area of the specimen.

50.2 Calculate the tensile stress by dividing the force at predetermined percent elongation by the original cross-sectional area of the specimen.

50.3 Calculate the ultimate elongation, *A*, by subtracting the original distance between the bench marks from the total distance between the bench marks at the time of rupture and expressing the difference as a percentage of the original distance, as follows, or use the grip separations in a similar calculation.

$$A, \% = [(d_f - d_o)/d_o] \times 100 \quad (4)$$

where:

$d_o$ = original distance between bench marks, and
$d_f$ = distance between bench marks at the break point.

50.4 The value reported shall be the mean value of all specimens tested.

## 51. Report

51.1 Report the following information:

51.1.1 Tensile strength in kilopascals.

51.1.2 Tensile stress in kilopascals at predetermined elongation.

51.1.3 Ultimate elongation, in percent, and whether bench marks, grip separation or extensometers were used to measure elongation.

51.1.4 Crosshead speed, if other than 500 mm/min.

## 52. Precision and Bias

52.1 See Section 151 for Precision and Bias statements.

# TEST F—TEAR RESISTANCE TEST

## 53. Scope

53.1 This test method covers determination of the tear propagation resistance of foam. The block method, as described, measures the tear resistance under the conditions of this particular test.

NOTE 18—This standard and ISO 8067 address the same subject matter, but differ in technical content and results cannot be directly compared between the two methods.

## 54. Apparatus

54.1 Tear resistance shall be measured on a power-driven machine, which will indicate the maximum force, by mechanical or electronic means, at which rupture of the specimen takes place.

## 55. Test Specimens

55.1 The test specimens shall be a block shape free of skin, voids, and densification lines, as shown in Fig. 4. They shall be cut on a saw from sheet material ensuring that the sides are parallel and perpendicular to each other. A nominal 40-mm cut shall be placed in one side as shown in Fig. 4. Dimension *A-B* can be reduced to the pad thickness. The thickness shall be determined in accordance with Section 8.

## 56. Number of Specimens

56.1 Three specimens per sample shall be tested. The values reported shall be the mean of those tested.

## 57. Procedure

57.1 Clamp the test specimen in the jaws of the testing machine, taking care that the jaws grip the specimen properly. Spread the block so that each tab is held in the jaw to pull across the specimen. The test speed shall be 500 ± 50 mm/min, unless otherwise specified by agreement between the purchaser and the supplier. Aid the cut in the specimen with a razor blade or knife, so as to keep it in the center of the block (Note 19). After the rupture of the specimen, or after at least a 50-mm length is torn, record the maximum force in newtons and note also the thickness of the specimen (direction *A-B*).

NOTE 19—For foams that will not tear by this method, side by side tear strength comparisons can be made by testing in accordance with Test Method D624, using Type C die. It shall be noted that the D624 Type C tear test is a tear initiating measurement, as opposed to a tear propagating measurement, as in this block tear test.

## 58. Calculation

58.1 Calculate the tear strength from the maximum force registered on the testing machine and the average thickness of the specimen (direction *A-B*), as follows:

$$\text{Tear strength, N/m} = F/T \times 10^3 \quad (5)$$

where:

$F$ = force, N, and
$T$ = thickness, mm.

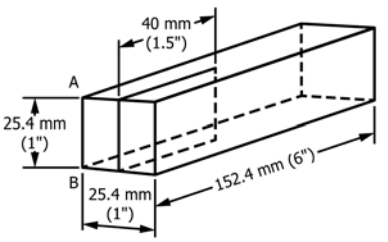


**FIG. 4 Tear Resistance Test Specimens**

## 59. Report

59.1 Report the following information:
59.1.1 Tear strength in newtons per metre.
59.1.2 Orientation of specimen.
59.1.3 Crosshead speed, if other than 500 mm/min.

## 60. Precision and Bias

60.1 See Section 151 for Precision and Bias statements.

## TEST G—AIR FLOW TEST

## 61. Scope

61.1 The air flow test measures the ease with which air passes through a cellular structure. Air flow values can be used as an indirect measurement of certain cell structure characteristics. The test consists of placing a flexible foam core specimen in a cavity over a chamber and creating a specified constant air pressure differential. The rate of flow of air required to maintain this pressure differential is the air flow value. This test is normally for slab foam products or for the core materials of molded products. Alternative methods can be used to measure air flow through molded skins or extremely high air flow products (see Note 21).

NOTE 20—This standard is identical to ISO 7231.

NOTE 21—For measuring air flow of products, such as very tight viscoelastic foams or very high air flow foams, which can have air flows beyond the range of this method, very good success has been achieved by using the equipment specified in Test Method D737. Direct correlations between Test Method D737 and this method have been established, although some modification of the D737 equipment could be necessary.[4] Test Method D3574 air flow times 36 will give an approximate value for Test Method D737 air flow.

## 62. Terminology

62.1 *Definitions of Terms Specific to This Standard:*

62.1.1 *air flow value*—the volume of air per second at standard temperature and atmospheric pressure required to maintain a constant pressure differential of 125 Pa across a flexible foam specimen approximately 50 by 50 by 25 mm.

62.1.2 *air flow parallel to foam rise*—the air flow value obtained when the air enters and leaves the mounted specimen parallel to foam rise.

## 63. Apparatus

63.1 A schematic drawing of the apparatus, including the specimen mounting chamber, manometer, air flow meters, blow meters, blower, and voltage control, is shown in Fig. 5.

63.2 *Chamber,* consisting of a pot approximately 130 mm in diameter and 150 mm high, with provision for mounting the foam specimen and fittings for the manometer and air exhaust.

[4] Gummaraju, R.V., Pask, R.F., Koller, H.J., Wujcik, S.E., and Reimann, K.A., "Evaluation, Modification and Adaptation of an Airflow Test Method for Polyurethane Foams," *Journal of Cellular Plastics* , May/June 2001.

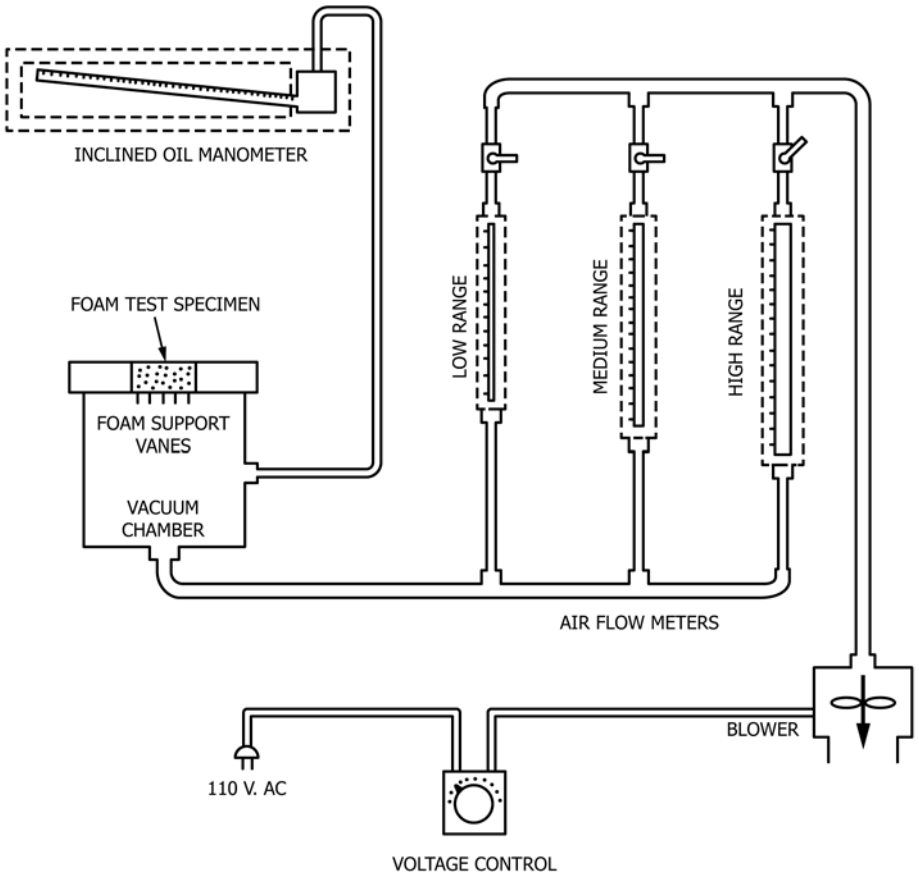


**FIG. 5 Air Flow Apparatus Schematic Diagram**

The specimen mount cavity shall be 50.0 ± 0.5 by 50.0 ± 0.5 by 25.0 ± 0.5 mm in size. Four foam support vanes approximately 1 mm thick and 12.5 mm high shall be placed under the opening to prevent the foam from being pulled into the vacuum chamber. The vanes shall be spaced 12.5 mm on center from each other and also centered relative to the bottom of the cavity opening. The manometer fitting shall enter a 1-mm hole midway along the side of the chamber. A 25-mm pipe fitting shall be used as the exhaust outlet from the center of the bottom of the chamber.

63.3 *Manometer,* calibrated from 0 to 250 Pa and having an accuracy of ±2 %, is required. An inclined oil manometer with graduations of 2 Pa is recommended. A level mounted on the manometer shall be used to ensure that the proper degree of inclination from the horizontal is maintained. Traps shall be provided to prevent indicating fluid from being accidentally drawn into the chamber. Appendix X5 describes a suggested method for the verification of the inclined oil manometer. The manometer can alternatively be replaced with a 0-250 Pa magnehelic gauge with graduations of 5 Pa.

63.4 *Flow Meters and Blower*—Low-pressure-drop air flow meters accurate to ±2 % shall be used for air-flow measurements. A given flow meter shall not be used for values less than 10 % of full scale. Air flow meters with at least 250-mm scales are recommended. Since the flow meter calibration is temperature-and pressure-dependent, the use of the apparatus under ambient conditions can result in erroneous readings. In cases of dispute, the apparatus shall be used under standard conditions of 23°C and 100 kPa (1 atm pressure), or else a suitable calibration correction applied. Flow meters that range from 0 to 0.01 $m^3$ /s will cover a wide range of foam cell structures, but a lesser range can be used. Actual flow is adjusted by a combination of valve restriction and blower speed. The two-way valves shall be mounted on the output side of the flow meter to maintain the pressure drop across the flow meter constant at any given flow level. A vacuum cleaner type unit shall be used for an exhaust blower.

63.5 *Leak Test*—To check the apparatus for leaks, the specimen mount cavity shall be sealed with masking tape. With all valves closed, turn on the exhaust blower to approximately ⅓ power and observe any movement of the manometer. The manometer reading, if any, shall not exceed 1 Pa after a 30-s waiting period. Next, open the valve very slightly for the lowest range flow meter reading. The flow shall be essentially zero, as evidenced by a less than 3-mm movement of the air flow meter float from its static position. For the equipment to perform satisfactorily over its entire range, the requirements for both parts of the leak test must be met.

## 64. Test Specimens

64.1 The test specimens shall be parallelepiped cut to fit the mount cavity of the apparatus. A cavity 50 by 50 mm requires a specimen 51.0 ± 0.3 by 51.0 ± 0.3 by 25.0 ± 0.5 mm in size. A band saw with a movable table and a double-bevel knife-edge blade is recommended for cutting the specimens.

64.2 Three specimens per sample shall be cut parallel to the foam rise. See 62.1.2. The values reported shall be the mean of those observed for each location and orientation.

## 65. Procedure

65.1 Measure each specimen in accordance with the procedure described in Section 8 to verify the specimen size.

65.2 Insert the specimen into the test cavity. Make sure that a good air seal is obtained along all edges. The top of the specimen shall be flush with the top of the test chamber.

65.3 With all valves closed, adjust the voltage control of the apparatus to 30 %.

65.4 Open one flow-control valve slowly until a pressure differential of 100 to 150 Pa is obtained. Adjust the voltage control carefully to obtain a pressure differential of 125 ± 1 Pa.

65.5 After this pressure differential has been maintained for at least 10 s, read the scale of the flow meter.

65.6 If this reading is off-scale or less than 10 % of full scale, close that flow-control valve and open a more appropriate one. Repeat this process until the proper manometer reading and air flow is achieved.

65.7 The air flow value shall be obtained from the flow meter scale directly, estimated from a calibration chart, or calculated with a factor depending on the calibration system.

## 66. Report

66.1 Report the following information:

66.1.1 Mean air flow value in cubic metres per minute for each location and orientation.

66.1.2 Dimensions of the specimens.

66.1.3 Dimension of the mount cavity of the apparatus.

## 67. Precision and Bias

67.1 See Section 151 for Precision and Bias statements.

# TEST H—RESILIENCE (BALL REBOUND) TEST

## 68. Scope

68.1 This test consists of dropping a steel ball on a foam specimen and noting the height of rebound.

NOTE 22—This standard is identical to ISO 8307.

## 69. Apparatus

69.1 The ball rebound tester shall consist of a 40 ± 4-mm inside diameter vertical clear plastic (such as acrylic) tube, into which a 16.0 ± 0.2-mm diameter steel ball, weighing 16.3 ± 0.2 g, is released by a magnet or other device. The steel ball must be released so that it falls without rotation. Centering of the ball is assured by a recess at the base of the magnet. The height of drop shall be 500 mm. Since it is most convenient to note the position of the top of the ball on rebound, the top of the ball shall be 516 mm above the surface of the foam. Thus, "zero" rebound shall be 16.0 ± 0.2 mm (diameter of ball) above the specimen surface. The scale on the tube shall be scribed directly in percent as follows. Every 5 %, a complete circle shall be scribed and every 1 %, a 120° arc shall be scribed. The complete circles are an essential part of the apparatus, since they are used to eliminate parallax error.

### 70. Test Specimens

70.1 The test specimens shall have parallel top and bottom surfaces.

70.2 The test specimens shall consist of the entire product sample or a suitable portion of it, except that in no case shall the thickness be less than 30 mm. The standard specimen size shall be 100 mm by 100 mm by 50 mm. For molded products, the top skin shall be removed.

### 71. Number of Specimens

71.1 Three specimens per sample shall be tested. The three specimens can be obtained by using separate specimens or different locations on a given specimen.

### 72. Procedure

72.1 Center the specimen at the base of the tube and adjust the height of the tube so that zero rebound is 16.0 ± 0.2 mm above the surface of the foam specimen.

72.2 Mount the steel ball on the release mechanism, then drop it and note the maximum rebound height (top of ball). If the ball strikes the tube on the drop or rebound, the value obtained is invalid. This condition is usually due to the tube not being vertical or irregularities on the specimen surface. In order to minimize parallax error, the circles on the tube in the region where the percent rebound is read must appear as lines.

72.3 Make an additional two drops on the same specimen in the same location, noting the maximum rebound height, unless otherwise agreed upon by the purchaser and the supplier.

### 73. Calculation

73.1 Calculate the mean of the three rebound values.

### 74. Report

74.1 Report the mean of the three specimens' mean values as the ball rebound resilience value in percent.

74.2 Report if measurements were obtained from different locations on a single specimen or on separate specimens.

### 75. Precision and Bias

75.1 See Section 151 for Precision and Bias statements.

## TEST I—DURABILITY TESTS

### 76. Scope

76.1 The durability tests consist of five methods:

76.1.1 Static Force Loss Test at Constant Deflection,

76.1.2 Dynamic Fatigue by Roller Shear at Constant Force,

76.1.3 Dynamic Fatigue Test by Constant Force Pounding,

76.1.4 Dynamic Fatigue Test for Carpet Cushion, and

76.1.5 Dynamic Fatigue Test by Constant Deflection Pounding.

## TEST $I_1$—STATIC FORCE LOSS TEST AT CONSTANT DEFLECTION

### 77. Scope

77.1 The purpose of this static force loss test is to determine: (*1*) loss in IFD values, (*2*) loss in thickness, and (*3*) structural breakdown as assessed by visual examination.

77.2 This procedure tests the specimen at a 75 % constant deflection.

NOTE 23—There is no known ISO equivalent to this standard.

### 78. Apparatus

78.1 The apparatus shall consist of two parallel plates (wood or metal) that will produce a uniform, constant deflection of the specimen. The plates shall be 500 by 500 mm square, and spacer bars or other appropriate means shall be employed to maintain a constant 75 % deflection throughout the test.

### 79. Test Specimen

79.1 The test specimen shall be 380 by 380 mm by the desired thickness. One specimen shall be tested.

### 80. Initial Measurements

80.1 Measure the 25 and 65 % IFD of the test specimen in accordance with Sections 16 to 22. Measure the original thickness with 4.5 ± 0.5 N contact force after preflexing.

### 81. Procedure

81.1 Place the specimen between the plates with the spacer bars to provide a 75 % deflection. Clamp the plates and hold at 75 % deflection for 22 h.

### 82. Final Measurements

82.1 Measure the final IFD values 60 ± 5 min after the fatigue test is completed in accordance with 80.1, using the original thickness to determine the deflection for the final IFD values.

82.2 If the loss in thickness is above 10 %, the IFD losses shall not be calculated and only the thickness loss shall be reported.

82.3 For a measurement of more permanent fatigue, repeat 82.1, except allow 24 ± 1 h of recovery time rather than 60 ± 5 min.

### 83. Calculation and Inspection

83.1 Check the specimen for physical breakdown of the cellular structure by visual examination and comparison with unflexed specimens.

83.2 Calculate the percent loss in thickness, as follows:

$$F_t = \frac{(t_o - t_f)}{(t_o)} \times 100 \quad (6)$$

where:

$F_t$ = loss in thickness, %,

$t_o$ = original specimen thickness, and
$t_f$ = final specimen thickness.

83.3 Calculate the percent loss of IFD, as follows:

$$F_L = \frac{(L_o - L_f)}{(L_o)} \times 100 \quad (7)$$

where:

$F_L$ = loss of indentation force deflection, %,
$L_o$ = original indentation force deflection value, and
$L_f$ = final indentation force deflection value.

## 84. Report

84.1 Report the following information:

84.1.1 Percent loss in thickness, and the percent loss of 25 and 65 % IFD if the thickness loss is less than 10 %.

84.1.2 Results of visual examination.

84.1.3 Recovery time, whether 60 ± 5 min or 24 ± 1 h.

## 85. Precision and Bias

85.1 See Section 151 for Precision and Bias statements.

# TEST $I_2$ —DYNAMIC FATIGUE TEST BY ROLLER SHEAR AT CONSTANT FORCE

## 86. Scope

86.1 This procedure fatigues the specimen dynamically at a constant force, deflecting the material both vertically and laterally. The purpose of this dynamic fatigue test is to determine (*1*) loss in IRGL values, (*2*) loss in thickness, and (*3*) structural breakdown as assessed by visual examination.

86.2 The fatigue test shall be conducted by either Procedure A or Procedure B. Both test procedures are the same and differ only in the number of cycles used. Procedure A shall use 8,000 cycles (approximately 5 h) and Procedure B shall use 20,000 cycles (approximately 12 h). It shall be noted that a single cycle is actually two passes over the foam sample, that is, a complete forward and reverse stroke.

NOTE 24—There is no known ISO equivalent to this standard.

NOTE 25—The mass of the roller and the number of cycles can be changed as agreed upon between the purchaser and the supplier.

## 87. Apparatus (Appendix X2)

87.1 *Perforated-Base Platen,* approximately 500 by 500 by 10 mm with a finished ground-top surface and with perforation of approximately 6.5-mm centers covering the center 360 by 360-mm portion.

87.2 *Roller,* 450-mm minimum length and 76.0 ± 1.3 mm-diameter made from stainless steel or chrome-plated metal having a minimum surface finish of 1 µm. The roller shall be mounted in an offset position (15 ± 3°) with suitable means of adjustment for a specified loading of the test specimen. The force imparted by the roller assembly shall not exceed 110 N.

87.3 The test is conducted at a frequency of 0.50 ± 0.05 Hz. A cycle is a complete forward and reverse stroke. The length of the stroke shall be 300 ± 10 mm.

87.4 Any suitable method for holding the test specimen securely on the roller base platen is acceptable, as long as the test specimen remains stationary during the rolling flex cycles. An acceptable method for retaining the specimen on the base platen is described as follows: four pieces of cotton sheeting or paper masking tape 50 to 75 mm wide and at least 50 mm longer than each side of the test specimen shall be required. Bond the cotton strips or the masking tape along the edges of the base surface of the test specimen with a solvent or water-emulsion-type of adhesive. Allow 25 to 50 mm of each strip to extend beyond the edges of the test specimen so that the test specimen can be securely clamped to the base platen through the use of suitable metal retainer straps.

## 88. Test Specimen

88.1 A specimen 380 mm long by 300 mm wide by 50 mm thick is used. The thickness of specimens tested shall be at least 25 mm and no greater than 125 mm. Normally, full-part thickness is used where the top and bottom surfaces are essentially parallel and fall within the thickness limits. Where part thickness exceeds 125 mm or the bottom surface is contoured so that the surfaces are not essentially parallel, the bottom surface shall be sliced to provide a flat surface essentially parallel to the top surfaces (see Section 7).

88.2 The length and width dimensions shall be held to a tolerance of ±6.5 mm and shall be saw cut or die cut.

88.3 One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

## 89. Initial Measurements

89.1 Bond suitable hold-down cloth or masking tape to the bottom edges of the specimen so the specimen can be secured to the perforated base platen of the fatigue tester.

89.2 Determine the IRGL in accordance with Sections 23 – 29.

## 90. Procedure

90.1 Adjust the roller to obtain a constant force of 130 ± 2 N on the foam specimen (Note 25). This critical measurement can be made by fashioning a lightweight fabric sling around the roller at its center and measuring the downward force while holding the force scale vertically over the roller and maintaining the roller axis in a horizontal plane with the pivot axis.

90.2 Set the vertical adjustment of the roller or the mounting base by placing the specimen in position and lowering the roller so it is supported by the specimen. Observe the pivot axis and roller axis relationship and adjust the vertical height so that the axes lie in an essentially horizontal plane at the start of the test.

90.3 Mount the test specimen on the base platen with the long dimension parallel to the stroke of the dynamic fatigue machine and secure by means of the aforementioned cotton/cloth strips or tape glued previously to specimen bottom and metal retainer straps (see 87.4). When mounting cored pieces, coring is to be against the platen. Set the counter to zero, start the machine, and fatigue test the sample for either 8,000 cycles

(Procedure A) or 20,000 cycles (Procedure B) or an alternate number of cycles, if specified by the purchaser.

## 91. Final Measurements

91.1 Within 60 ± 5 min after the fatigue test is completed, measure the final IRGL in accordance with 89.2.

91.2 For a measurement of more permanent fatigue, repeat 91.1, except allow 24 ± 1 h of recovery rather than 60 ± 5 min.

## 92. Calculation and Inspection

92.1 Check the specimen for physical breakdown of cellular structure by visual examination and comparison with unflexed similar specimens.

92.2 Calculate and report the percent loss in thickness, as follows:

$$\text{Thickness loss, \%} = \frac{[100(A - B)]}{(A)} \quad (8)$$

where:

$A$ = original thickness under compression forces of 4.5 N, 110 N, and 220 N, and
$B$ = final thickness under the same indentation forces.

92.3 If requested by the purchaser, calculate the total loss number, as follows:

$$\text{Total Loss Number} = \text{Sum of \% Losses at each Force} \quad (9)$$

*Sample Calculation:*
Percent thickness loss at 4.5 N = 2.0
Percent thickness loss at 110 N = 18.0
Percent thickness loss at 220 N = 27.0
Total Loss Number = 47.0

## 93. Report

93.1 Report the following information:
93.1.1 Percent loss in thickness and IRGL values.
93.1.2 The number of cycles.
93.1.3 Total loss number, if requested.
93.1.4 Results of visual examination.
93.1.5 Recovery time, whether 60 ± 5 min or 24 ± 1 h.

## 94. Precision and Bias

94.1 See Section 151 for Precision and Bias statements.

# TEST $I_3$ —DYNAMIC FATIGUE TEST BY CONSTANT FORCE POUNDING

## 95. Scope

95.1 The purpose of this fatigue test is to determine: (*1*) loss of force support at 40 % IFD (indentation force deflection), (*2*) loss in thickness, and (*3*) structural breakdown as assessed by visual inspection. Deflections other than 40 % can be used, as agreed upon between the purchaser and the supplier.

95.2 This procedure describes tests that evaluate the specimen by repeatedly deflecting the material with a flat-horizontal fixed indenter exerting a vertical force of 750 ± 20 N on the test specimen.

95.3 This fatigue test shall be conducted by Procedure A, Procedure B, or Procedure C. Procedures A and B differ only in the number of cycles used. Procedure A shall use 8,000 cycles (approximately 2 h) and Procedure B shall use 80,000 cycles (approximately 19 h). Procedure C calls for 12,000 cycles at a slower cycling rate (approximately 20 h). See 96.3.

NOTE 26—This standard is equivalent to ISO 3385.

## 96. Apparatus

96.1 *Perforated Base Platen,* approximately 500 by 500 by 10 mm, with finished ground-top surface and with perforation of approximately 6.5-mm diameter holes on 20-mm centers, over a minimum central area of 350 by 350 mm.

96.2 A flat circular fixed indenter that exerts a force of 750 ± 20 N on the test specimen at maximum indentation. The indenter shall have an overall diameter of 250 ± 1 mm with a 25 ± 1-mm radius at the lower edge, to prevent cutting hard foam. The indenter mechanism is usually comprised of either A) a weighted system, or B) a system using a platen and force measuring device (for example, load cell) to ensure the specified constant force. If a weighted system is used, the indenter shall be fashioned to be completely supported by only the specimen at the end of its stroke (that is, at the end of its stroke, zero force exerted by the machine, all force due to the machine-unsupported indenter weight only), in order to prevent overloading of the specimen. Specimen softening will necessitate stroke distance adjustments, in order to maintain constant force.

96.3 By means of a crank or other suitable mechanism, (for example, actuator), the machine shall be capable of oscillating either the platen carrying the test specimen or the indenter support mounting towards each other in a vertical direction at a frequency of 70 ± 5 cycles per minute for Procedures A and B. For Procedure C, the frequency shall be 10 ± 1 cycles per minute.

## 97. Test Specimen

97.1 The test specimen shall be 380 by 380 by 50 mm. One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

## 98. Initial Measurement

98.1 Measure the 40 % IFD of the test specimen in accordance with Sections 16 – 22. Measure the original thickness with 4.5 ± 0.5 N contact force after preflexing.

## 99. Procedure

99.1 Mount the specimen on the base platen. Set the counter to zero, start the machine, and fatigue the test specimen for 8,000 cycles (Procedure A), 80,000 cycles (Procedure B), or 12,000 cycles (Procedure C), in accordance with 96.3. Procedure C shall be used for slow recovery (viscoelastic) foams where the cycle speed is slow enough to allow enough time between cycles for the foam to recover its height.

## 100. Final Measurement

100.1 Within 60 ± 5 min after the fatigue test is completed, repeat 98.1 using the original thickness to determine the deflection for the final force reading.

100.2 For a measurement of more permanent fatigue, repeat 100.1, except allow 24 ± 1 h of recovery rather than 60 ± 5 min.

100.3 If the loss in thickness is above 10 %, final IFD shall not be measured and only the thickness loss shall be reported.

## 101. Calculation and Inspection

101.1 Check the specimen for physical breakdown of the cellular structure by visual examination and comparison with unflexed specimens.

101.2 Calculate the percent loss in thickness, as follows:

$$F_t = \frac{(t_o - t_f)}{(t_o)} \times 100 \quad (10)$$

where:

$F_t$ = loss in thickness, %,
$t_o$ = original specimen thickness, and
$t_f$ = final specimen thickness.

101.3 Calculate the percent loss of force deflection, as follows:

$$F_L = \frac{(F_o - F_f)}{F_o} \times 100 \quad (11)$$

where:

$F_L$ = loss of 40 % indentation force deflection, %,
$F_o$ = original 40 % indentation force deflection value, and
$F_f$ = final 40 % indentation force deflection value.

## 102. Report

102.1 Report the following information:

102.1.1 Percent change in thickness, and the percent change in 40 % IFD, if the thickness change is less than 10 %, and

102.1.2 Results of visual examination.

102.1.3 Recovery time, whether 60 ± 5 min or 24 ± 1 h.

## 103. Precision and Bias

103.1 See Section 151 for Precision and Bias statements. A round robin for Procedure C is being planned and the data will be available by the end of 2018.

## TEST $I_4$—DYNAMIC FATIGUE TEST FOR CARPET CUSHION

## 104. Scope

104.1 The purpose of this test is to determine: (*1*) retention of load bearing (65 % IFD), (*2*) loss in thickness, and (*3*) structural breakdown as assessed by visual inspection.

104.2 This procedure describes tests that evaluate the specimen by repeatedly deflecting the carpet cushion by a 152 mm diameter and 152 mm wide rubber covered roller exerting a force of 266 ± 5 N on the test specimens.

104.3 This fatigue test shall be conducted by either Procedure A or Procedure B. The test procedures differ only in the number of cycles used. Procedure A shall use 8,000 cycles (approximately 5 h) and Procedure B shall use 40,000 cycles (approximately 24 h). It shall be noted that a single cycle is actually two passes over the foam sample, that is, a complete forward and reverse stroke.

NOTE 27—There is no known ISO equivalent to this standard.

## 105. Apparatus (Appendix X2)

105.1 The apparatus is identical to that described in Section 87 with the following changes: the roller described in 104.2 replaces the longer roller and is attached perpendicularly. The base platen is replaced or covered with a 19 mm thick plywood

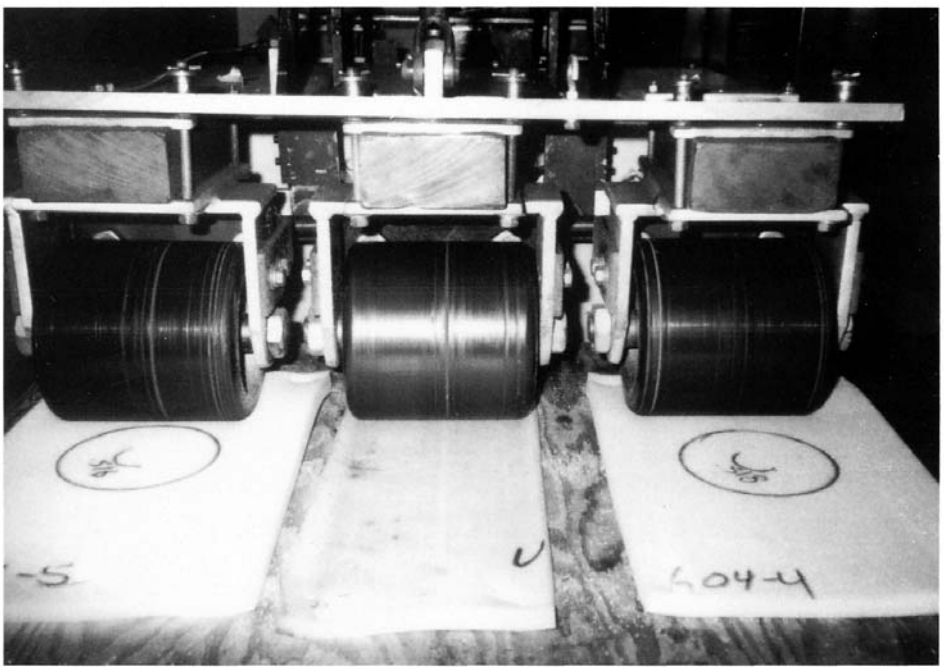

FIG. 6 Three-station Carpet Cushion Fatigue Tester

for mounting the sample. The sample is secured with floor tacks or staples. (See Fig. 6 for test apparatus.)

### 106. Test Specimen

106.1 The specimen is 380 mm long and 230 mm wide and 13 ± 1 mm thick, unless otherwise agreed upon by the purchaser and the supplier.

### 107. Initial Measurements

107.1 Preflex the specimen two times to 75 % of the nominal thickness. After a 6 ± 1 min rest, measure the original thickness, $t_o$, in accordance with Section 8, and determine the original 65 % IFD, $F_o$, in accordance with Sections 16 – 22 using a 102 + 2/– 0 mm diameter flat circular indenter foot.

### 108. Procedure

108.1 Secure the sample to the plywood base using staples or tape, making sure that the roller will not roll over the stapled areas. Set the counter to zero, start the machine, and fatigue the sample for 8,000 or 40,000 cycles.

### 109. Final Measurements

109.1 Within 60 ± 5 min after the fatigue test is completed measure the final thickness, $t_f$, in accordance with Section 8, and the final 65 % IFD, $F_f$, in accordance with 107.1, using the original thickness, $t_o$, to determine the 65 % IFD deflection.

109.2 For a measurement of more permanent fatigue, repeat 109.1, except allow 24 ± 1 h of recovery rather than 60 ± 5 min.

### 110. Calculation and Inspection

110.1 Check the specimen for physical breakdown by visual examination.

110.2 Calculate and report the percent loss in thickness, as follows:

$$F_t = \frac{(t_o - t_f)}{(t_o)} \times 100 \quad (12)$$

where:

$F_t$ = loss in thickness, %,
$t_o$ = original specimen thickness, and
$t_f$ = final specimen thickness.

110.3 Calculate the percent IFD retention, as follows:

$$R = 100 - \frac{(F_o - F_f \times 100)}{(F_o)} \quad (13)$$

where:

$R$ = IFD retention, %,
$F_o$ = original IFD force, and
$F_f$ = final IFD force.

### 111. Report

111.1 Report the following information:

111.1.1 Percent loss in thickness, and percent retention of 65 % indentation force deflection.

111.1.2 Recovery time, whether 60 ± 5 min or 24 ± 1 h.

### 112. Precision and Bias

112.1 Round robin testing to determine the precision of this method is being planned and the data will be available by the end of 2018.

## TEST $I_5$—DYNAMIC FATIGUE TEST BY CONSTANT DEFLECTION POUNDING

### 113. Scope

113.1 The purpose of this fatigue test is to determine: (*1*) % loss in thickness, (*2*) % loss of 25 % IFD, and (*3*) structural breakdown as assessed by visual inspection. IFD testing at deflections other than 25 % (for example, at 40 % IFD or 50 % IFD) can be used, as agreed upon between the purchaser and the supplier.

113.2 This procedure evaluates the specimen for durability by repeatedly deflecting the entire sample by 75 % of its original height with a moving platen that is larger than the test piece, that is, a standard 50 mm thick specimen shall be deflected to a height of 12.5 mm. Deflections other than 75 % of the original height can be used as agreed upon between the purchaser and the supplier.

113.3 This fatigue test shall be conducted by Procedure A, Procedure B, or Procedure C. Procedures A and B differ only in the number of cycles used. Procedure A shall use 8,000 cycles (approximately 2 h) and Procedure B shall use 80,000 cycles (approximately 19 h) at 70 ± 5 cycles/min. Procedure C calls for 12,000 cycles at a slower cycling rate of 10 ± 1 cycles/min (approximately 20 h). Procedure C shall be used for slow recovery (viscoelastic) foams where the cycle speed is slow enough to allow enough time between cycles for the foam to recover its height.

113.4 This test was originally in ASTM D1564 Fatigue Test (Suffix H) Procedure C. This version changes the thickness of the test specimen from 100 mm to 50 mm to standardize it with the constant force pounding and static fatigue methods within this standard.

NOTE 28—There is no known ISO equivalent to this standard.

### 114. Apparatus

114.1 *Perforated Base Platen,* approximately 500 by 500 by 10 mm, with finished ground-top surface and with perforation of approximately 6.5-mm diameter holes on 20-mm centers, over a minimum central area of 350 by 350 mm.

114.2 A flat upper platen that is larger than the sample being tested shall be used.

114.3 By means of a crank or other suitable mechanism, the machine shall be capable of oscillating either the upper or lower platen towards the other in a vertical direction at a frequency of 70 ± 5 cycles per minute.

### 115. Test Specimen

115.1 The standard test specimen shall be 380 by 380 by 50 mm and is the default size unless otherwise agreed upon by the purchaser and the supplier. One specimen shall be tested, unless otherwise agreed upon.

### 116. Initial Measurements

116.1 Measure the 25 % IFD of the test specimen in accordance with Sections 16 – 22. Measure the original thickness with 4.5 ± 0.5 N contact force after preflexing.

### 117. Procedure

117.1 Mount the specimen on the base platen. Set the counter to zero, start the machine, and fatigue the test specimen for 8,000 cycles (Procedure A), 80,000 cycles (Procedure B) or 12,000 cycles (Procedure C) in accordance with 113.3.

### 118. Final Measurements

118.1 Within 60 ± 5 min after the fatigue test is completed, repeat 116.1 using the original thickness to determine the deflection for the final force reading.

118.2 For a measurement of more permanent fatigue, repeat 118.1, except allow 24 ± 1 h of recovery rather than 60 ± 5 min.

118.3 If the loss in thickness is above 10 %, the final IFD shall not be measured and only the thickness loss shall be reported.

### 119. Calculation and Inspection

119.1 Check the specimen for physical breakdown of the cellular structure by visual examination and comparison with unflexed specimens.

119.2 Calculate the percent loss in thickness, as follows:

$$F_t = \frac{(t_o - t_f)}{(t_o)} \times 100 \quad (14)$$

where:

$F_t$ = loss in thickness, %,
$t_o$ = original specimen thickness, and
$t_f$ = final specimen thickness.

119.3 Calculate the percent loss of IFD, as follows:

$$FL = \frac{(F_o - F_f)}{(F_o)} \times 100) \quad (15)$$

where:

$FL$ = loss of 25 % IFD, %
$F_o$ = original 25 % IFD force, and
$F_f$ = final 25 % IFD.

### 120. Report

120.1 Report the following information:

120.1.1 Percent change in thickness and the percent change in 25 % IFD if the thickness change is less than 10 %.

120.1.2 Results of visual examination.

120.1.3 Recovery time, whether 60 ± 5 min or 24 ± 1.

120.1.4 Specimen size prior to fatigue test—length, width and thickness.

120.1.5 Percent deflection (75 % or deflection specified by the purchaser and the supplier).

### 121. Precision and Bias

121.1 See Section 151 for Precision and Bias statements.

## AGING TEST J—STEAM AUTOCLAVE AGING

### 122. Scope

122.1 This test consists of exposing the foam specimens in a low-pressure steam autoclave and observing the effects on the properties of the foam. Use either of the following procedures, $J_1$ or $J_2$:

122.1.1 Procedure $J_1$, 3 h at 105 ± 3 °C.

122.1.2 Procedure $J_2$, 5 h at 120 ± 5 °C.

NOTE 29—This standard and ISO 2440 address the same subject matter, but differ in technical content and results cannot be directly compared between the two methods.

### 123. Apparatus

123.1 *Steam Autoclave,* or similar vessel, that is thermostatically controlled to ±2 °C and capable of withstanding gauge pressures of up to 140 kPa.

### 124. Procedure

124.1 Fill the autoclave with distilled or deionized water to a level 50 mm above the bottom of the autoclave. Set the thermostat control to the desired test temperature, which is either 105 ± 3 °C or 120 ± 5 °C. Allow the autoclave to heat until the water boils. Place the specimens on edge on a rack in the inside container and ensure that one specimen does not touch another or any metal except at the supporting surface. Place the container inside the autoclave and close and tighten the top. Leave the safety valve open until all the air is out of the autoclave. This is apparent when steam begins blowing out of the ports on the safety valve. Close the valve 2 min after the appearance of steam, and begin the zero time of the heat at this point.

124.2 After the exposure period, turn off the heat, release the steam pressure, and remove the specimens without delay. Dry the specimens for 3 h for each 25 mm of thickness at 100 ± 5 °C in a mechanically convected dry air oven. Condition specimens for at least 2 h at 23 ± 2 °C and 50 ± 10 % relative humidity.

124.3 Test each specimen for the prescribed property in accordance with the appropriate test method.

NOTE 30—A drying temperature of 70 °C shall be used where 100 °C adversely affects the final properties upon agreement by the purchaser and the supplier.

### 125. Calculation

125.1 Calculate the percent change in physical property, as follows:

$$\text{Physical property change, \%} = \frac{(P_o - P_f)}{(P_o)} \times 100 \quad (16)$$

where:

$P_o$ = mean property of the unexposed specimen, and
$P_f$ = mean property of the exposed specimen.

### 126. Report

126.1 Report the following information:

126.1.1 Percent change in physical property.

126.1.2 Test procedure $J_1$ or $J_2$.

## 127. Precision and Bias

127.1 The precision of this method is dependent on the material property that is being measured.

## AGING TEST K—DRY HEAT AGING

## 128. Scope

128.1 This test consists of exposing foam specimens in an air-circulating oven and observing the effects on the properties of the foam.

NOTE 31—This standard and ISO 2439 address the same subject matter, but differ in technical content and results cannot be directly compared between the two methods.

## 129. Apparatus

129.1 *Air-Circulating Oven,* capable of maintaining 140 ± 2 °C for exposing the specimens. A device for sensing and recording the temperature of the oven at least every 2 h shall be attached.

## 130. Procedure

130.1 Expose the specimens for 22 h at 140 ± 2 °C. Obtain and record the oven temperature near the specimen at least every 2 h.

130.2 Condition specimens for not less than 2 h at 23 ± 2 °C and 50 ± 10 % relative humidity.

## 131. Calculation

131.1 Calculate the percent change in physical property, as follows:

$$\text{Physical property change, \%} = \frac{((P_o - P_f))}{(P_o)} \times 100 \qquad (17)$$

where:

$P_o$ = mean property of the unexposed specimen, and
$P_f$ = mean property of the exposed specimen.

## 132. Report

132.1 Report the following information:
132.1.1 Percent change in physical property.

## 133. Precision and Bias

133.1 The precision of this method is dependent on the material property that is being measured.

## AGING TEST L—WET HEAT AGING

## 134. Scope

134.1 This test consists of exposing foam specimens in an environmental chamber and observing the effects on the properties of the foam.

NOTE 32—There is no known ISO equivalent to this standard.

## 135. Apparatus

135.1 *Environmental Chamber,* capable of maintaining 50 ± 2 °C and 95 ± 5 % RH for exposing the specimens. A device for sensing and recording the temperature of the oven at least every 2 h shall be attached.

NOTE 33—Other temperature and humidity conditions can be used as agreed upon by the purchaser and the supplier.

## 136. Procedure

136.1 Place the specimens into the environmental chamber set to the temperature and humidity conditions specified in 135.1, making sure they do not touch each other. For wet compression sets, the specimens shall be clamped into the test fixture before putting them into the chamber. Expose the specimens for 22 h ± 5 min, or as agreed upon by the purchaser and the supplier.

136.2 After the exposure period, remove the specimens from the chamber and from any fixturing and then condition them for not less than 2 h at 23 ± 2 °C and 50 ± 10 % relative humidity. For wet compression sets, after removing the specimens from the fixtures, allow the specimens to recover as specified in 41.5.

136.3 Perform any measurements and calculations specified in the test method being evaluated.

## 137. Calculation

137.1 Calculate the percent change in physical property, as follows:

$$\text{Physical property change, \%} = \frac{[(P_o - P_f)]}{(P_o)} \times 100 \qquad (18)$$

where

$P_o$ = mean property of the unexposed specimen, and
$P_f$ = mean property of the exposed specimen.

## 138. Report

138.1 Report the following information:
138.1.1 Percent change in physical property.

## 139. Precision and Bias

139.1 The precision of this method is dependent on the material property that is being measured.

## TEST M—RECOVERY TIME

## 140. Scope

140.1 This method is used to determine the recovery time of slow recovery (viscoelastic) foams.

NOTE 34—There is no known ISO equivalent to this standard.

## 141. Apparatus

141.1 Use the standard IFD apparatus, as described in 17.1.

## 142. Test Specimen

142.1 Use the standard IFD specimen, as described in 18.1. One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

## 143. Procedure

143.1 Place the test specimen on the perforated supporting plate. Bring the indenter foot into contact with the specimen at

a rate of 50 ± 5 mm/min, while applying a contact force of 4.5 ± 0.5 N to determine the specimen's initial thickness. Immediately indent the specimen 75 % of its initial thickness at a rate of 1000 ± 100 mm/min. After a 60 ± 3 s dwell time, return the indenter to a 5 % deflection at 1000 ± 100 mm/min, starting a stopwatch immediately upon initiating the upward movement of the indenter. Stop the watch as soon as the foam recovers to a 4.5 ± 0.5 N preload on the indenter. If there is no separation between the foam and the indenter foot during the upward movement of the indenter foot, the recovery time is indeterminate by this method.

### 144. Report

144.1 Report the recovery time in seconds.

### 145. Precision and Bias

145.1 See Section 151 for Precision and Bias statements.

## TEST N—HYSTERESIS LOSS

### 146. Scope

146.1 Hysteresis Loss, for the purpose of this method for cellular foam products, is defined as the difference between the loading energy and the unloading energy, expressed as a percentage of the loading energy. This measures the loss of ability of flexible foam to return to its original support characteristics after compression.

$$\textit{Hysteresis Loss} = [\textit{Loading Energy} - \textit{Unloading Energy}] \times 100/[\textit{Loading Energy}]$$

where:

146.1.1 Energy is defined as the area under the force/deflection curve.

146.1.2 Loading Energy is the energy required to indent or compress a flexible specimen to a preset deflection (compression cycle).

146.1.3 Unloading Energy is the energy recovered when the indentation or compression platen is retracted from the preset deflection and completely unloaded. (decompression cycle).

### 147. Apparatus

147.1 Use the standard IFD apparatus, as described in 17.1 for Procedure A—Hysteresis Loss—IFD.

147.2 Use the standard CFD apparatus as described in 31.1 for Procedure B—Hysteresis Loss—CFD.

### 148. Test Specimen

148.1 For Procedure A—Hysteresis Loss—IFD, use the standard IFD specimen, as described in 18.1. One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

148.2 For Procedure B—Hysteresis Loss—CFD, use the standard CFD specimen, as described in 32.1–32.3. One specimen shall be tested, unless otherwise agreed upon by the purchaser and the supplier.

### 149. Procedure

149.1 *Procedure A—Hysteresis Loss—IFD:*

149.1.1 Preflex specimen as described in 20.2. Allow the specimen to rest for 6 ± 1 min after the final preflex.

149.1.2 Bring the indenter foot into contact with the specimen at a rate of 50 ± 5 mm/min, while applying a contact force of 4.5 ± 0.5 N to determine the specimen's initial thickness. Immediately indent the specimen 75 % of its initial thickness at a rate of 50 ± 5 mm/min.

149.1.3 Immediately remove the compression force at 50 ± 5 mm/min until the platen fully returns. Calculate the hysteresis loss as defined in 146.1.

149.2 *Procedure B—Hysteresis Loss—CFD:*

149.2.1 Preflex sample as described in 34.1. Allow the specimen to rest for 6 ± 1 min after the final preflex.

149.2.2 Bring the compression foot into contact with the specimen at a rate of 50 ± 5 mm/min and determine the thickness after applying a contact load of 140 ± 14 Pa to the specimen area (see Note 2). Immediately compress the specimen 75 % of its initial thickness at a rate of 50 ± 5 mm/min.

149.2.3 Immediately remove the compression force at 50 ± 5 mm/min until the platen fully returns. Calculate the hysteresis loss as defined in 146.1.

NOTE 35—Different wait times, test speeds, and deflections may be agreed upon by the purchaser and the supplier.

NOTE 36—It is extremely important that the Universal Testing Machine's (UTM) crosshead reverses direction with minimal hesitation at the maximum compression point, otherwise false readings will be obtained.

### 150. Report

150.1 Report hysteresis loss as a %.

150.2 Report the foam as core or with skin.

150.3 Report whether the IFD or CFD procedure was followed.

150.4 Report any variances to the procedure, such as those listed in Note 35.

### 151. Precision and Bias

151.1 Precision and bias for test methods in this standard are based on round robin studies conducted by the Polyurethane Foam Association from 1998 to 2006 in accordance with Practice E691. The Test $B_2$, $I_1$, and $I_2$ data were generated by the molded foam industry between 2004 and 2007. Test $I_5$ data was generated in 2010. For each study, three or more materials were carefully selected to cover the range of properties expected in commercially available products. The number of labs varied from 6 to 10. The samples were distributed by one lab, but individual specimens were prepared at the labs performing the tests. Each laboratory obtained six test results for each material. Precision, characterized by repeatability ($S_r$ and r) and reproducibility ($S_R$ and R) have been determined as shown in the individual tables.

151.2 *Bias*—There are no recognized standards by which to estimate bias for these test methods. (**Warning—**The explanation of r and R are only intended to present a meaningful way of considering the approximate precision of these test methods. The data in the tables shall not be applied to acceptance or rejection of materials, as these data apply only to the materials tested in the round robins and are unlikely to be rigorously

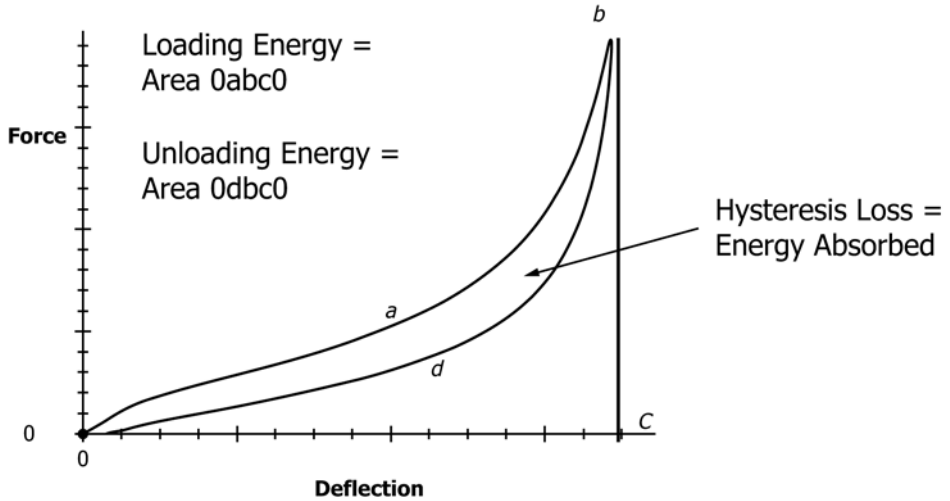


**FIG. 7 Hysteresis Loss**

representative of other lots, formulations, conditions, materials, or laboratories. Users of these test methods shall apply the principles outlined in Practice E691 to generate data specific to their materials and laboratory.)

NOTE 37—The precision data presented in the tables were obtained using the test conditions defined in the test methods. If a material specification defines other test conditions, these precision data shall be assumed to not apply.

**TABLE 2 Density Test A, kg/m³**

| | (8 Laboratories) | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$ [A] | $S_R$ [B] | r [C] | R [D] |
| 1 | 27.21 | 0.23 | 0.31 | 0.64 | 0.88 |
| 2 | 43.44 | 0.28 | 0.34 | 0.78 | 0.94 |
| 3 | 35.07 | 0.51 | 0.61 | 1.43 | 1.70 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 3 IFD Test $B_1$, Thickness, mm**

| | (8 Laboratories) | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$ [A] | $S_R$ [B] | r [C] | R [D] |
| 1 | 104.1 | 0.20 | 0.31 | 0.53 | 1.50 |
| 2 | 102.3 | 0.28 | 0.34 | 0.53 | 1.52 |
| 3 | 99.1 | 0.45 | 0.61 | 0.74 | 2.08 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

## 152. Keywords

152.1 bonded; flexible cellular; molded; slab; urethane

**TABLE 4 IFD Test $B_1$, 25 % IFD, N**

| | (8 Laboratories) | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$ [A] | $S_R$ [B] | r [C] | R [D] |
| 1 | 73.48 | 0.93 | 2.09 | 2.62 | 5.85 |
| 2 | 136.35 | 1.10 | 4.31 | 3.07 | 12.06 |
| 3 | 249.11 | 3.16 | 8.73 | 8.85 | 24.44 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 5 IFD Test $B_1$, 65 % IFD, N**

| | (8 Laboratories) | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$ [A] | $S_R$ [B] | r [C] | R [D] |
| 1 | 147.91 | 2.99 | 5.68 | 8.37 | 15.92 |
| 2 | 253.33 | 2.34 | 8.49 | 6.56 | 23.77 |
| 3 | 491.16 | 7.18 | 20.64 | 20.16 | 57.81 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 6 IFD Test $B_1$, 25 % RT IFD, N**

| (8 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 58.23 | 0.83 | 1.26 | 2.33 | 3.54 |
| 2 | 99.83 | 0.94 | 2.14 | 2.64 | 5.99 |
| 3 | 145.14 | 2.53 | 2.53 | 4.62 | 11.12 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 7 IRGL Test $B_2$, 4.5 N Height, mm**

| (8 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 99.84 | 0.38 | 0.73 | 1.06 | 2.04 |
| 2 | 100.69 | 1.04 | 1.04 | 2.91 | 2.91 |
| 3 | 101.51 | 0.90 | 1.00 | 2.51 | 2.79 |
| 4 | 100.59 | 0.61 | 1.06 | 1.71 | 2.97 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 8 IRGL Test $B_2$, 110 N Height, mm**

| (8 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 87.05 | 2.25 | 5.03 | 6.31 | 14.07 |
| 2 | 99.07 | 1.00 | 1.00 | 2.79 | 2.79 |
| 3 | 99.79 | 0.88 | 1.01 | 2.47 | 2.83 |
| 4 | 99.49 | 0.63 | 1.06 | 1.76 | 2.96 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 9 IRGL Test $B_2$, 220 N Height, mm**

| (8 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 41.06 | 2.82 | 5.20 | 7.88 | 14.55 |
| 2 | 93.76 | 0.98 | 3.54 | 2.74 | 9.92 |
| 3 | 98.37 | 0.92 | 1.26 | 2.57 | 3.53 |
| 4 | 98.66 | 0.58 | 1.06 | 1.62 | 2.98 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 10 CFD Test C, 50 % CFD, kPa**

| (9 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 2.06 | 0.05 | 0.29 | 0.14 | 0.81 |
| 2 | 3.04 | 0.07 | 0.58 | 0.18 | 1.62 |
| 3 | 9.36 | 0.14 | 0.38 | 0.40 | 1.07 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 11 Compression Set Test D, 90 % $C_t$, %**

| (9 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 3.36 | 0.62 | 0.83 | 1.73 | 2.34 |
| 2 | 5.78 | 0.82 | 0.97 | 2.30 | 2.71 |
| 3 | 8.23 | 0.83 | 1.61 | 2.34 | 4.51 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 12 Compression Set Test D, 90 % $C_d$, %**

| (9 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 3.72 | 0.68 | 0.92 | 1.91 | 2.58 |
| 2 | 6.45 | 0.79 | 1.11 | 2.22 | 3.11 |
| 3 | 9.07 | 0.92 | 1.78 | 2.59 | 5.00 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 13 Tensile Test E, D3574 Die, kPa**

| (10 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 45.84 | 1.54 | 2.82 | 4.33 | 7.90 |
| 2 | 74.96 | 3.02 | 4.56 | 8.47 | 12.78 |
| 3 | 91.62 | 4.02 | 5.11 | 11.24 | 14.32 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 14 Tensile Test E, D412A Die, kPa**

| (10 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 46.06 | 2.67 | 4.00 | 7.48 | 11.19 |
| 2 | 78.20 | 3.88 | 4.81 | 10.85 | 13.47 |
| 3 | 89.99 | 3.26 | 3.42 | 9.12 | 9.56 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 15 Tensile Test E, Elongation by Crosshead Travel, D412A Die, %**

| (10 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 218.4 | 16.2 | 24.2 | 45.5 | 67.6 |
| 2 | 231.8 | 15.4 | 24.9 | 43.0 | 69.6 |
| 3 | 154.5 | 14.1 | 27.5 | 39.4 | 77.1 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 16 Tensile Test E, Elongation by Crosshead Travel, D3574 Die, %**

| (10 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 205.3 | 13.2 | 23.6 | 36.9 | 66.0 |
| 2 | 219.2 | 15.2 | 24.0 | 42.6 | 67.2 |
| 3 | 146.4 | 14.2 | 26.3 | 39.7 | 73.6 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 17 Tensile Test E, Elongation by Bench Marking, D3574 Die, %**

| (10 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 217.9 | 12.1 | 30.2 | 33.9 | 84.5 |
| 2 | 236.6 | 14.6 | 30.3 | 40.7 | 84.9 |
| 3 | 158.9 | 16.9 | 31.9 | 47.3 | 89.2 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 18 Tear Test F, N/m**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 599.4 | 41.6 | 52.1 | 116.5 | 145.8 |
| 2 | 244.0 | 18.0 | 35.3 | 50.4 | 98.9 |
| 3 | 215.2 | 17.6 | 28.3 | 49.2 | 79.1 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 19 Air Flow Test G, $m^3$/min**

| (7 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 0.056 | 0.002 | 0.006 | 0.006 | 0.017 |
| 2 | 0.109 | 0.004 | 0.013 | 0.011 | 0.038 |
| 3 | 0.160 | 0.009 | 0.024 | 0.027 | 0.068 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 20 Resilience Test H, %**

| (8 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 46.1 | 0.82 | 2.86 | 2.31 | 8.00 |
| 2 | 70.8 | 1.00 | 3.15 | 2.79 | 8.82 |
| 3 | 69.2 | 0.99 | 2.89 | 2.76 | 8.09 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 21 Static Fatigue Test $I_1$, Thickness Loss, %**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 1.19 | 0.31 | 0.43 | 0.88 | 1.20 |
| 2 | 2.69 | 0.31 | 0.75 | 0.87 | 2.11 |
| 3 | 1.74 | 0.45 | 0.79 | 1.25 | 2.21 |
| 4 | 1.48 | 0.23 | 0.32 | 0.67 | 0.89 |

[A]$S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B]$S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C]r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D]R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 22 Static Fatigue Test $I_1$, 25 % IFD Loss, %**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 19.82 | 3.15 | 3.39 | 8.82 | 9.50 |
| 2 | 25.29 | 1.39 | 2.80 | 3.88 | 7.83 |
| 3 | 21.43 | 0.79 | 1.95 | 2.21 | 5.46 |
| 4 | 22.18 | 0.79 | 1.24 | 2.22 | 3.48 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 23 Static Fatigue Test $I_1$, 65 % IFD Loss, %**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 20.26 | 2.22 | 4.02 | 6.21 | 11.24 |
| 2 | 21.52 | 1.52 | 6.43 | 4.26 | 18.00 |
| 3 | 21.43 | 0.83 | 3.57 | 2.33 | 9.99 |
| 4 | 20.23 | 0.76 | 5.83 | 2.11 | 16.31 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 24 Roller Shear Fatigue Test $I_2$, 1 h, 4.5 N Thickness Loss, % (20 Kcycles)**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 4.76 | 0.59 | 3.59 | 1.63 | 10.06 |
| 2 | 1.12 | 1.28 | 1.56 | 3.59 | 4.36 |
| 3 | 1.91 | 0.18 | 1.54 | 0.51 | 4.33 |
| 4 | 0.57 | 0.41 | 0.46 | 1.14 | 1.27 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 25 Roller Shear Fatigue Test $I_2$, 24 h, 4.5 N Thickness Loss, % (20 Kcycles)**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 4.61 | 1.55 | 3.91 | 4.33 | 10.94 |
| 2 | 0.91 | 0.94 | 1.25 | 2.64 | 3.48 |
| 3 | 1.45 | 0.43 | 1.50 | 1.21 | 4.21 |
| 4 | 0.45 | 0.22 | 0.36 | 0.61 | 1.02 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 26 Roller Shear Fatigue Test $I_2$, 1 h, 110 N Thickness Loss, % (20 Kcycles)**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 46.97 | 3.51 | 9.33 | 9.84 | 26.11 |
| 2 | 4.29 | 0.78 | 2.89 | 2.18 | 8.10 |
| 3 | 40.47 | 5.98 | 10.83 | 16.75 | 30.32 |
| 4 | 3.50 | 1.28 | 2.01 | 3.59 | 5.64 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 27 Roller Shear Fatigue Test $I_2$, 24 h, 110 N Thickness Loss, % (20 Kcycles)**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 46.05 | 3.96 | 8.86 | 11.08 | 24.81 |
| 2 | 2.22 | 1.07 | 1.53 | 3.00 | 4.28 |
| 3 | 32.84 | 5.91 | 12.76 | 16.54 | 35.73 |
| 4 | 2.71 | 0.81 | 1.77 | 2.27 | 4.96 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 28 Roller Shear Fatigue Test $I_2$, 1 h, 220 N Thickness Loss, % (20 Kcycles)**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 29.87 | 1.78 | 8.60 | 4.99 | 24.07 |
| 2 | 21.02 | 1.97 | 8.43 | 5.51 | 23.61 |
| 3 | 38.38 | 2.21 | 6.61 | 6.18 | 18.51 |
| 4 | 32.96 | 4.68 | 14.74 | 13.10 | 41.27 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 29 Roller Shear Fatigue Test $I_2$, 24 h, 220 N Thickness Loss, % (20 Kcycles)**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 30.29 | 9.06 | 10.06 | 25.36 | 28.17 |
| 2 | 18.31 | 1.68 | 6.62 | 4.70 | 18.54 |
| 3 | 36.07 | 3.48 | 8.29 | 9.73 | 23.21 |
| 4 | 29.95 | 4.50 | 13.47 | 12.59 | 37.70 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] $r$ = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] $R$ = between-laboratories critical interval between two results = $2.8 \times S_R$.

**TABLE 30 Pounding Fatigue Test $I_3$ 1 h Thickness Loss, % (80 Kcycles)**

| (7 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 1.69 | 0.76 | 0.87 | 2.14 | 2.43 |
| 2 | 1.46 | 0.39 | 0.42 | 1.08 | 1.17 |
| 3 | 2.50 | 0.24 | 0.61 | 0.68 | 1.70 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 31 Pounding Fatigue Test $I_3$ 24 h Thickness Loss, % (80 Kcycles)**

| (7 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 1.47 | 0.70 | 0.97 | 1.96 | 2.70 |
| 2 | 1.11 | 0.32 | 0.39 | 0.89 | 1.10 |
| 3 | 1.81 | 0.24 | 0.52 | 0.68 | 1.47 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 32 Pounding Fatigue Test $I_3$ 1 h 40 % IFD Loss, % (80 Kcycles)**

| (7 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 29.9 | 1.34 | 2.93 | 3.75 | 8.22 |
| 2 | 20.6 | 2.11 | 2.49 | 5.92 | 6.96 |
| 3 | 34.1 | 1.56 | 2.86 | 4.36 | 8.01 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 33 Pounding Fatigue Test $I_3$ 24 h 40 % IFD Loss, %(80 Kcycles)**

| (7 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 24.3 | 2.46 | 3.26 | 6.88 | 9.14 |
| 2 | 17.2 | 2.09 | 2.53 | 5.86 | 7.09 |
| 3 | 27.0 | 1.95 | 3.56 | 5.46 | 9.96 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 34 Constant Deflection Pounding Test $I_5$ 1 h Thickness Loss, % (80 Kcycles)**

| (4 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 4.33 | 1.02 | 1.04 | 2.84 | 2.91 |
| 2 | 3.66 | 0.20 | 0.59 | 0.57 | 1.64 |
| 3 | 5.94 | 0.77 | 0.82 | 2.15 | 2.29 |
| 4 | 3.74 | 0.23 | 0.73 | 0.64 | 2.03 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 35 Constant Deflection Pounding Test $I_5$ 24 h Thickness Loss, % (80 Kcycles)**

| (4 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 2.72 | 0.50 | 0.51 | 1.39 | 1.43 |
| 2 | 2.15 | 0.12 | 0.43 | 0.32 | 1.20 |
| 3 | 3.30 | 0.29 | 0.75 | 0.81 | 2.11 |
| 4 | 2.47 | 0.18 | 0.73 | 0.51 | 2.04 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 36 Constant Deflection Pounding Test $I_5$ 1 h 25 % IFD Loss, % (80 Kcycles)**

| (4 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 44.2 | 3.5 | 6.3 | 9.9 | 17.5 |
| 2 | 44.0 | 1.1 | 4.0 | 3.2 | 11.2 |
| 3 | 53.1 | 2.4 | 4.3 | 6.8 | 12.1 |
| 4 | 47.8 | 0.6 | 1.8 | 1.8 | 4.9 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 37 Constant Deflection Pounding Test $I_5$ 24 h 25 % IFD Loss, % (80 Kcycles)**

| (4 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 34.4 | 1.5 | 3.6 | 4.3 | 10.1 |
| 2 | 34.1 | 1.6 | 3.1 | 4.4 | 8.7 |
| 3 | 39.6 | 1.5 | 4.9 | 4.2 | 4.2 |
| 4 | 40.0 | 0.9 | 0.9 | 2.5 | 2.5 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = 2.8 × $S_r$.
[D] R = between-laboratories critical interval between two results = 2.8 × $S_R$.

**TABLE 38 Recovery Time Test M, s**

| (6 Laboratories) | | | | | |
|---|---|---|---|---|---|
| Material | Avg. | $S_r$[A] | $S_R$[B] | r[C] | R[D] |
| 1 | 30 | 6 | 22 | 16 | 61 |
| 2 | 17 | 4 | 5 | 10 | 14 |
| 3 | 32 | 24 | 31 | 66 | 88 |
| 4 | 9 | 2 | 3 | 4 | 8 |
| 5 | 65 | 31 | 56 | 86 | 159 |
| 6 | 12 | 2 | 3 | 7 | 8 |

[A] $S_r$ = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] $S_R$ = between-laboratory reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two results = $2.8 \times S_r$.
[D] R = between-laboratories critical interval between two results = $2.8 \times S_R$.

# APPENDIXES

**(Nonmandatory Information)**

## X1. SUGGESTED METHOD FOR SPECIFYING FLEXIBLE URETHANE FOAMS

X1.1 For simplification in specifying foams, a line call out system can be used. The line call out could be used on engineering drawings for parts. The properties correspond to the sections of this test method. The call out format shall be as follows:

ASTM D3574 Type [Slab, Molded, Bonded or other, as specified]
Coring [Cored or Uncored]
Urethane Chemistry [Polyether, Polyester, HR, Conventional]
A Density [kg/m$^3$] maximum, minimum or range
$B_1$ IFD [N] [for 25 % and 65 % deflections, 100 mm thick sample] max, min, or range
$B_2$ IRGL [mm] [at 4.5, 110 and 220 N, 100 mm thick sample] max, min, or range
C CFD [kPa] [50 % deflection] max, min, or range
D Compression set [%] [method—$C_d$ or $C_t$] max
E Tensile [kPa] min
F Tear [N/m] min
G Air Flow [cfm] min
H Ball Rebound [%] min
$I_1$ Static Fatigue [percent thickness loss and 25 % and 65 % IFD loss] max
$I_2$ Roller Shear [percent loss of thickness and IRGL values] max
$I_3$ Constant Force Pounding [percent change in thickness and percent change in 40 % IFD] max
$I_4$ Dynamic Fatigue Test for Carpet Cushion [percent loss of thickness and percent retention of 65 % IFD value] maximum value and minimum value, respectively
$I_5$ Constant Deflection Pounding [percent change in thickness and percent change in 25 % IFD] max
$J_1$ Steam Autoclave [physical properties to be tested as (tests A through I or M as specified, units as above] maximum or minimum values based on test specified
$J_2$ Steam Autoclave [physical properties to be tested as (tests A through I or M as specified, units as above] maximum or minimum values based on test specified
K Dry Heat Aging [physical properties to be tested as (tests A through I or M as specified, units as above] maximum or minimum values based on test specified
L Wet Heat Aging [physical properties to be tested as (tests A through I or M as specified, units as above] maximum or minimum values based on test specified
M Recovery Time [seconds] max, min, or range
N Hysteresis Loss [%] [for 75 % deflection] max, min, or range
X Other tests as specified (Individual tests listed with subscripts)

X1.2 Example:

D3574 Type [Slab]
Coring [Uncored]
Urethane Chemistry [Polyether]
A Density [15.5 kg/m$^3$] min
$B_1$ IFD [13 mm thick specimen 80-140 N ] range
C CFD [3.0-4.0 kPa at 50 % deflection] range
D Compression Set [10 % $C_t$] maximum
E Tensile [80 kPa] min
F Tear [0.25 kN/m] min
$J_1$ Steam Autoclave [15 % change in CFD] max
K Dry Heat Aging [15 % change in CFD] max
$X_1$ Flammability—MVSS 302 [102 mm/min] max
$X_2$ Odor—SAE J 1351 [3] max
$X_3$ Stain Resistance—ASTM D925 Test A [no staining]
$X_4$ Low Temperature Flexibility—DCX MSAY 349 [no rupturing]
$X_5$ No auxiliary blowing agents shall be used to manufacture product

## X2. SUGGESTED METHOD OF CONSTRUCTION FOR A ROLLER SHEAR DYNAMIC FLEX FATIGUE APPARATUS

X2.1 The following requirements are established to define the equipment and relationship of parts for a constant-load roller shear machine. See Fig. X2.1 and Fig. X2.2 for reference to part numbers.

X2.2 *Roller*, 1:

X2.2.1 *Dimensions*—457-mm minimum length, and 76.20 ± 1.27-mm diameter.

X2.2.2 *Material*—Corrosion and wear-resistant metal, either (*1*) chrome-plated material, or (*2*) stainless steel.

X2.2.3 *Surface Finish*—Finish surface on roller is to be ground and equivalent to at least 0.001 mm.

X2.2.4 The mass of the roller shall not exceed 11.340 kg.

X2.3 *Roller Mounting Bracket Assembly* 2, 3, 4, 11—The assembly consists of metal members designed to attach the roller to a pivot point, to provide bearing surfaces for minimum friction for turning, and to serve as a platform to add required mass to the roller.

X2.3.1 *Bearings* , 2 and 4—The proper bearings are required on each end or roller axis (*A-A*) and also on the pivot axis (*B-B*). The bearing should be equivalent to the following example:
Bearing No. 4—Nice No. 1635, DC Ball Bearing 19 by 32 by 13 mm.
Bearing No. 2—Nice No. 6906, flange mounted radial bearing.

NOTE X2.1—Roller axis bearings can be mounted in the bracket with the axle attached to the roller or, if the roller is a hollow cylinder, the bearing can be press fitted into the cylinder end with the bracket furnishing the axle.

X2.3.2 *Pivot Arm* , 11—The distance between the pivot axis and the roller axis shall be 203.20 ± 6.35 mm.

X2.3.3 *Roller Bracket Connector,* 3, connects the right and left bearing brackets across the top of the roller. The connection must also provide a flat horizontal surface with means (pin) to attach the weights. The weights must be centered directly above the axis of the roller.

X2.3.4 *Axis Relationship*—The roller axis (*A-A*) and pivot axis (*B-B*) must be parallel and lie in the same horizontal plane parallel to the specimen mounting base.

X2.3.5 *Alignment and Clearance*—Brackets and axles must be aligned so that no binding occurs to obstruct free turning on either axis. Brackets and other support members (5) must give free clearance so that specimen is not touched during test other than by roller surface.

X2.3.6 *Weight*, 6—The total vertical force exerted by the assembly plus the roller shall not exceed 111 N as measured at a point directly above or below the roller axis when both roller and pivot axes are in the same horizontal plane (X2.3.4). Additional weights to be added as shown.

X2.3.7 *Vertical Adjustment*, 7—If the roller is not driven to provide stroke movement, provision shall be made so that attachment of the pivot axis to the support can be raised or lowered at least 75 mm [3 in.]. This adjustment must be able to be made in not less than 12.5-mm increments.

X2.4 *Specimen Mounting Base*, 8:

X2.4.1 *Dimensions*—500-mm minimum length. 500-mm minimum width, and 9.5-mm minimum thickness.

X2.4.2 *Material*—Structural-grade carbon steel.

X2.4.3 *Perforation*—6-mm diameter holes on 20-mm centers, over a minimum area covering 350 mm in length by 350 mm in width.

X2.4.4 *Surface Finish*—Top surface shall be a finish grind.

X2.4.5 *Hold-Down Plates*, 9—Provision to attach metal or wood hold-down plates for clamping cotton sheeting retaining strips to base. Four plates are required to cover perimeter of specimen size.

X2.4.6 *Vertical Adjustment and Level*, 10—If mounting base is not driven to provide stroke movement, provision shall be made for vertical adjustment of at least 75 mm. This adjustment must be able to provide vertical movement in not less than 12.5-mm increments and maintain a horizontal level condition of the mounting base.

X2.5 *Mechanical Requirements*:

X2.5.1 *Stroke Length*—The length of stroke shall be 330 ± 12 mm.

X2.5.2 *Stroke Speed, Stroke Drive*—The rate of stroke speed shall produce 0.47 ± 0.03 Hz. A cycle is a complete forward and reverse stroke. Either the roller or the mounting base shall be driven to produce stroke travel. In either case, the drive mechanism must produce travel in a horizontal plane.

X2.5.3 *Angular Offset*—The axis of the roller shall be level and mounted at a 15 ± 3° offset from perpendicular to the direction of the stroke.

X2.5.4 *Mounting Base Location*—The length of the mounting base shall be parallel to the direction of the stroke and centered under the midpoint of the stroke and the center of the roller. The distance of the base surface from the roller axis (X2.3.4) shall be 45 mm when vertical adjustment provides a minimum clearance.

X2.5.5 *Cycle Counter*—Means to record the number of cycles shall be provided.

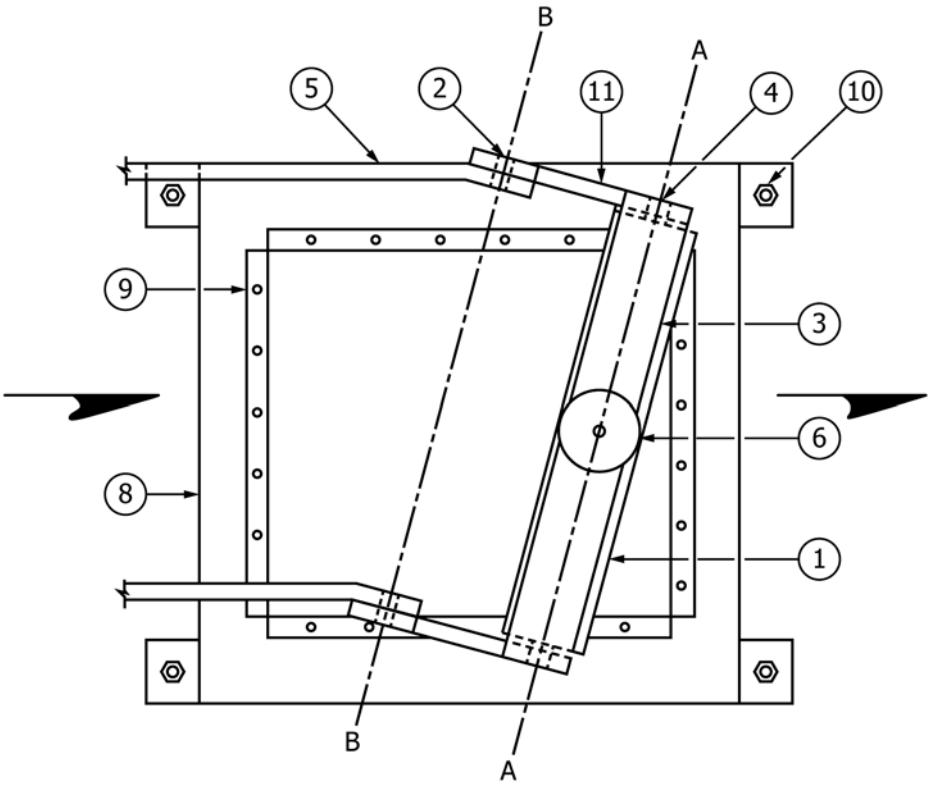


FIG. X2.1 Roller Shear Machine—Top View

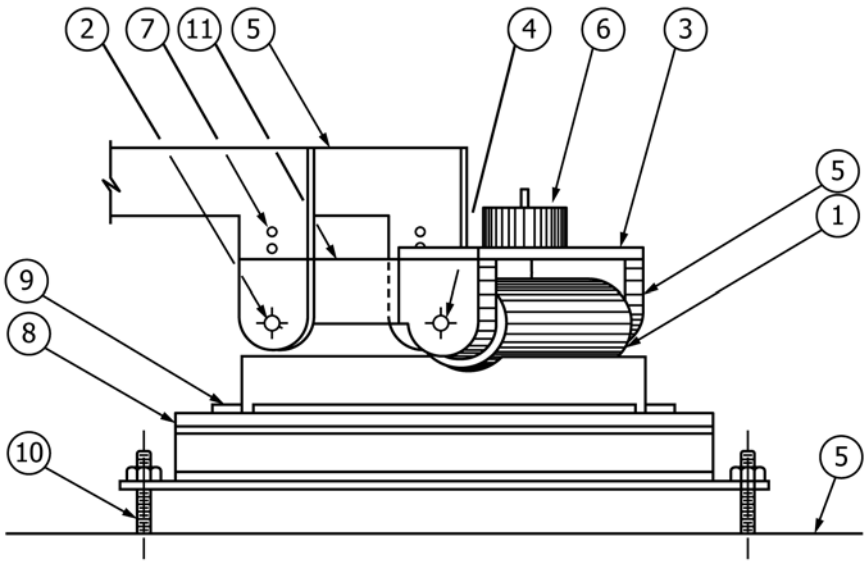


FIG. X2.2 Roller Shear Machine—Side View

## X3. DEFINITIONS OF TERMS USED TO DESCRIBE THE FORCE-DEFLECTION CURVE OF FLEXIBLE URETHANE FOAM

X3.1 *support factor*—the ratio of the 65 % indentation force deflection to the 25 % indentation force deflection determined after 1 min of rest. Most specifications are based on the 25 % IFD value of a 100-mm foam. The support factor thus indicates what 65 % IFD value would be acceptable for a particular application. The 65 % IFD measures the support region of the stress-strain curve. Seating foams with low support factors will usually bottom out and give inferior performance.

$$\text{Support factor (SF)} = (65\,\%\ \text{IFD}/25\,\%\ \text{IFD}) \quad \text{(X3.1)}$$

Synonyms—Sag factor, hardness ratio, comfort factor. These terms are recommended to be removed from the vocabulary. Support factor is the term of choice.

X3.2 *guide factor*—the ratio of the 25 % indentation force deflection to the density after a 1-min rest. Most specifications do not have a density requirement; therefore the product with the highest guide factor has the cost advantage but not necessarily the performance advantage.

$$\text{Guide factor (GF)} = (25\,\%\ \text{IFD/density}) \quad \text{(X3.2)}$$

X3.3 *initial hardness factor*—the ratio of the 25 % indentation force deflection force to the 5 % indentation force deflection determined without the 1-min rest. The initial hardness ratio defines the surface feel of a flexible urethane foam. Supple or soft surface foam will have a high value, while boardy or stiff surface foams will have a low value (Note X3.1).

$$\text{Initial hardness factor (IHF)} = (25\,\%\ \text{IFD}/5\,\%\ \text{IFD}) \quad \text{(X3.3)}$$

Synonym— Comfort factor.

NOTE X3.1—Standard IFD curves can be used to generate the IHF, IM, and MIF data.

X3.4 *hardness index*—the term used in some specifications for the 50 % IFD value. The chair designer will often design furniture for a maximum 50 % indentation. Bar stools, on the other hand, are often designed for only a 20 % deflection.

X3.5 *indentation modulus*—the force required to produce an indentation of an additional 1 % between the limits of 20 % indentation force deflection and 40 % indentation force deflection, determined without the 1-min rest. The slope of this line depends upon the resistance of the cells struts to post buckling (Note X3.1).

$$\text{Indentation modulus (IM)} = (40\,\%\ \text{IFD} - 20\,\%\ \text{IFD}/20\,\%\ \text{IFD}) \quad \text{(X3.4)}$$

X3.6 *modulus irregularity factor*—the intercept produced on the stress axis by extrapolation of the linear portion of the stress-strain curve. The indentation modulus, that is, the slope of the line, can be substantially constant up to and beyond the 40 % indentation level. In this event, the indentation stress-strain curve is linear and passes through the origin Fig. X3.1. The indentation modulus usually varies at low levels of strain before reaching a constant value at above approximately 10 per strain. The stress-strain curve can exhibit a marked step in that region, which can result in some discomfort in seating applications, Fig. X3.2 and Fig. X3.3. The MIF value is calculated from the same data necessary to derive the modulus of the foam as a seating material (Note X3.1).

$$\text{Modulus irregularity factor (MIF)} = 2 \times 20\,\%\ \text{IFD} - 40\,\%\ \text{IFD} \quad \text{(X3.5)}$$

X3.7 *IFD Hysteresis Loss*—historically, a simple method for measuring the hysteresis loss was to calculate the percentage difference between the 25 % IFD and the 25 % IFD attained during decompression after the 65 % IFD is measured (25 % IFD RT). The current and more definitive method for measuring hysteresis loss is defined in 146, which measures the difference in area under the curves during loading and unloading, representing the energy loss.

$$\text{IFD Hysteresis Loss} = 100 \times [(25\,\%\ \text{IFD} - 25\,\%\ \text{IFD RT})/25\,\%\ \text{IFD}] \quad \text{(X3.6)}$$

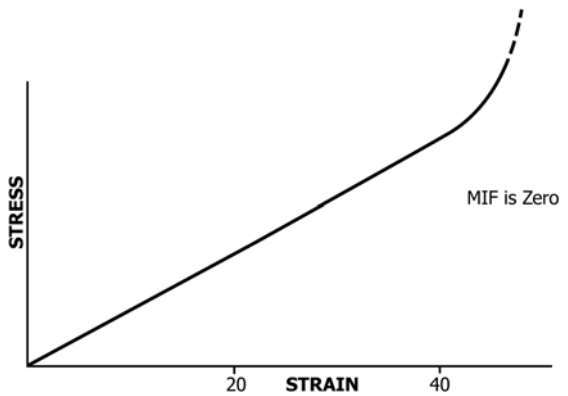


**FIG. X3.1 Indentation Stress-Strain Curve (MIF is Zero)**

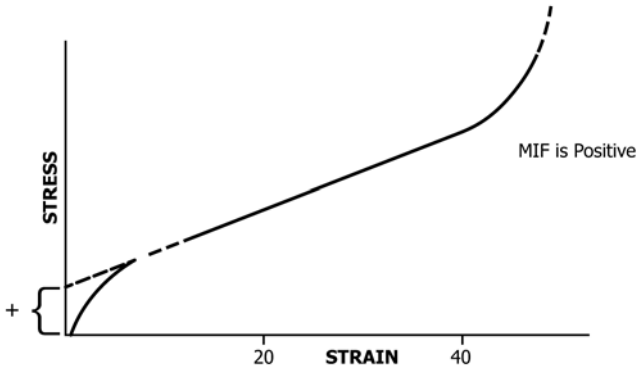


**FIG. X3.2 Indentation Stress-Strain Curve (MIF is positive)**

## X4. SUGGESTED TESTS FOR DETERMINING COMBUSTIBILITY OF FLEXIBLE URETHANE FOAM

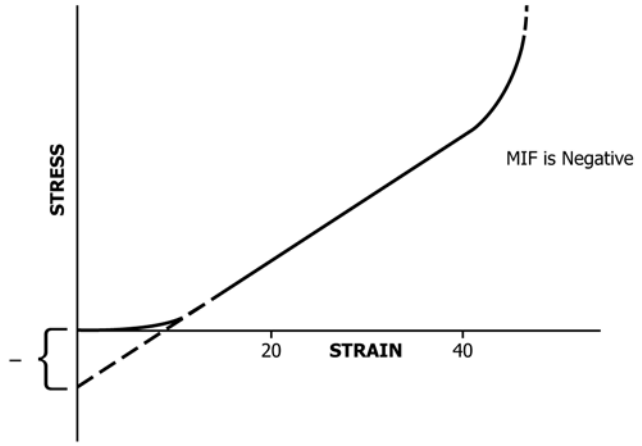


**FIG. X3.3 Indentation Stress-Strain Curve (MIF is negative)**

X4.1 This appendix lists for informational purposes only the test methods commonly used for determining the combustion properties of flexible urethane foams. These tests have been found useful in ascertaining the effectiveness of additives and reactants to modify the combustion characteristics of these materials. See 1.3.

X4.2 *Some Applicable Codes and Regulations for Specified Applications:*

| Application | Regulation |
|---|---|
| Automotive | DOT MVSS 302 |
| Mattress and cushion | DOC FF 4-72 |
| Mattress and cushion | CAL TB 117 |
| Mattress and cushion | CAL TB 133[A] |
| Mattress and cushion | CAL AB 603[A] |
| Mattress and cushion | NFPA 260[A] |
| Mattress and cushion | NFPA 261[A] |
| Mattress and cushion | BSI 5852[A] |
| Mattress and cushion | 16CFR Part 1633[A] |
| Aviation | FAA Part 25.853 Par (b) App F |
| Aviation | FAA Oil Burner Test |
| Carpet cushion | ASTM E84 |
| Carpet cushion | DOC FFI-70 (Pill Test) |
| Miscellaneous | ASTM D3675 |

[A]Composite test. Foam, fabric, and other components can have a synergistic effect on each other.

Various governmental bodies have issued regulations based on Test Methods E162 and E662. The regulations are not the same for all bodies issuing them. Hence, the regulation of the government having jurisdiction shall be consulted.

These standards are used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but do not by themselves incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.

X4.2.1 *Sources:*

| | |
|---|---|
| Government Documents | Superintendent of Documents, US Government Printing Office, Washington, DC 20402 |
| California | California Bureau of Home Furnishings, 3485 Orange Grove Ave., North Highlands, CA 95660 |
| National Fire Protection Association | 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269 |
| British Standard | British Standards Institute, 2 Park Street, London, England W1A 2B5 |

## X5. SUGGESTED METHOD FOR THE VERIFICATION OF AN INCLINED OIL MANOMETER

X5.1 Adjust the feet to level the manometer. With a height gauge resting on a level and flat surface, measure the distance to the top of the glass tube at each major mark. Determine the area of the tube by direct measurement. The area of the reservoir is calculated by adding a measured amount of fluid with both ends of the manometer at atmospheric pressure. The calculation for the area of the reservoir ($A$):

$$A = (v - ay)/h \quad \text{(X5.1)}$$

where:

$v$ = the volume added,
$a$ = the area of the inside of the tube,
$y$ = the distance between readings, and
$h$ = the change in height.

X5.2 Change in pressure is calculated by:

$$Pm - Pn = wy\,(\sin\theta + a/A) \quad \text{(X5.2)}$$

where:

$Pm$ = the low reading,
$Pn$ = the high reading,
$w$ = the specific gravity of the indicating fluid,
$y$ = the distance between readings,
$\theta$ = the angle of the tube to normal,
$a$ = the area of the inside of the tube, and
$A$ = the area of the reservoir.

X5.3 The error is the difference between the calculated and the indicated value.

## SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D3574 - 16) that may impact the use of this standard. (March 1, 2017)

*(1)* Revised 38.1.

Committee D20 has identified the location of selected changes to this standard since the last issue (D3574 - 11) that may impact the use of this standard. (November 1, 2016)

*(1)* General Test Conditions, Section 6, for both conditioning and testing, made standard for all test methods.
*(2)* Tolerance and Dimension changes:
*(a)* Relative humidity tolerance changed to ±10 %.
*(b)* Test A—Density: Replaced 1000 $mm^3$ minimum sample size to 10,000 $mm^3$ (~0.61 $in.^3$).
*(c)* Test H—Resilience (Ball Rebound) Test:
i) 69.1: Diameter of steel ball changed to 16.0 ± 0.2 mm.
ii) 69.1: Weight of steel ball added (16.3 ± 0.2 g).
*(d)* Preloads: added tolerance of ±10 % to all preloads.
*(3)* Removed permissive language / minor additions / editorial changes
*(4)* Added more definitive description/content to test methods D (Constant Deflection Compression Set Test), E (Tensile Test), and F (Tear Resistance Test).
*(5)* Added Test N—Hysteresis Loss: moved from appendix to test method.
*(6)* Fixed indenter specified in 31.1 (Compression Force Deflection) and 96.2 (Dynamic Fatigue Test by Constant Force Pounding).
*(7)* Test $I_3$ (Dynamic Fatigue Test by Constant Force Pounding): removed 96.4 sentence (The indenter shall be free to be lifted in its mounting to prevent overloading of the test specimen.) and replaced with expanded verbiage in 96.2, which explains the former 96.4 and aligns with equivalent standard ISO 3385. 96.2; expanded verbiage italicized:
*A flat circular fixed indenter that exerts a force of 750 ± 20 N on the test specimen at maximum indentation. The indenter shall have an overall diameter of 250 ± 1 mm with a 25 ± 1 mm radius at the lower edge, to prevent cutting hard foam. The indenter mechanism is usually comprised of either A) a weighted system, or B) a system using a platen and force measuring device (for example, load cell) to ensure the specified constant force. If a weighted system is used, the indenter shall be fashioned to be completely supported by only*

*the specimen at the end of its stroke (that is, at the end of its stroke, zero force exerted by the machine, all force due to the machine-unsupported indenter weight only), in order to prevent overloading of the specimen. Specimen softening will necessitate stroke distance adjustments, in order to maintain constant force.*