



Designation: D3574 – 16

# Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams<sup>1</sup>

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 ( $\epsilon$ ) 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:*<sup>2</sup>

[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](#)

<sup>1</sup> 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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<sup>2</sup> 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.

## 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](#).

\*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 <sub>1</sub>	Indentation Force Deflection Test—Specified Deflection (IFD)	16 – 22
Test B <sub>2</sub>	Indentation Residual Gauge Length Test—Specified Force (IRGL)	23 – 29
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Test E	Tensile Test	45 – 52
Test F	Tear Resistance Test	53 – 60
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Test I <sub>1</sub>	Static Force Loss Test at Constant Deflection	77 – 85
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Test I <sub>3</sub>	Dynamic Fatigue Test by Constant Force Pounding	95 – 103
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Aging Test J	Steam Autoclave Aging	122 – 127
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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  $23 \pm 2$  °C and  $50 \pm 10$  % relative humidity, unless otherwise specified in the individual test method. The product shall be conditioned, undeflected and undistorted, at  $23 \pm 2$  °C and  $50 \pm 10$  % 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<sup>2</sup>. 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  $\pm 1$  % 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 uncured 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<sup>3</sup> (~0.61 in.<sup>3</sup>) 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<sup>2</sup> 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<sup>3</sup>.

**14. Report**

14.1 Report the following information:

14.1.1 Density to the nearest 0.1 kg/m<sup>3</sup>, 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<sub>1</sub> —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  $50 \pm 5$  mm/min and determine the thickness while applying a contact force of  $4.5 \pm 0.5$  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  $50 \pm 5$  mm/min 25 % of this thickness and observe the force in newtons after  $60 \pm 3$  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  $60 \pm 3$  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<sub>2</sub>—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  $200 \pm 20$  mm/min, allowing the indenter foot to fully clear the top of the specimen after each preflex. Allow the specimen to rest for  $6 \pm 1$  min after the final preflex.

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

27.3 Apply the 110-N force at  $50 \pm 5$  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  $60 \pm 3$  s.

27.4 Without removing the specimen, apply the 220-N force at  $50 \pm 5$  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  $60 \pm 3$  s.

## 28. Report

28.1 Report the specimen thickness, in mm, at 4.5 N instantaneously and at 110 N and 220 N after  $60 \pm 3$  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<sup>2</sup> 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).

$$\text{Compression Force Deflection, } kPa = \left[ \frac{\text{force, in } N}{\text{specimen area, in } mm^2} \times 10^3 \right]$$

### 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 constructed from steel and have sufficient stiffness to ensure that they are not deflected under the force necessary to compress all of the specimens.

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<sup>2</sup>. 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.<sup>3</sup> 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  $23 \pm 2$  °C and in an atmosphere of  $50 \pm 10$  % 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  $50 \pm 1$  %,  $75 \pm 1$  %, or  $90 \pm 1$  % 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, uncured and/or molded.

#### 44. Precision and Bias

44.1 See Section 151 for Precision and Bias statements.

<sup>3</sup> 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  $500 \pm 50$  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.

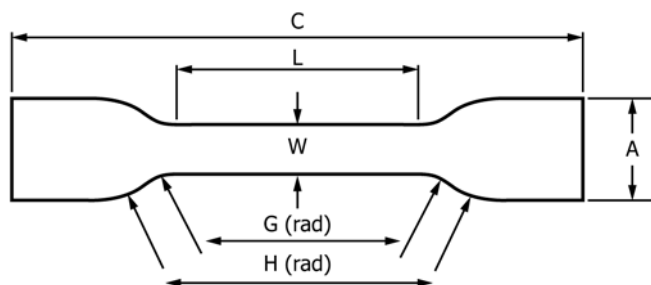


FIG. 1 Tensile Dumbbell Specimen Dimension Key

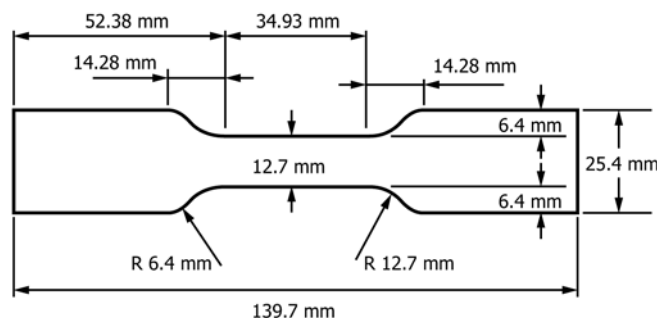


FIG. 2 Die for Stamping Tensile Dumbbell Specimens—D3574 Die

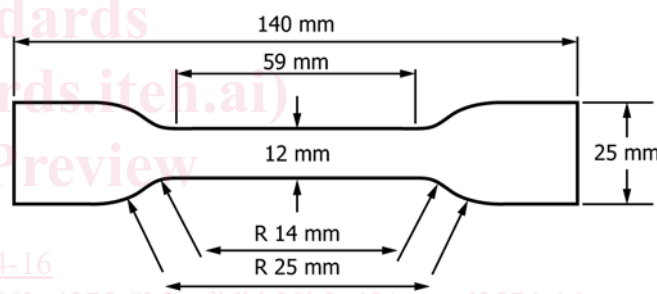


FIG. 3 Die for Stamping Tensile Dumbbell Specimens—D412A Die

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  $500 \pm 50$  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  $500 \pm 50$  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.

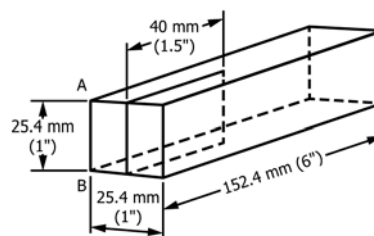


FIG. 4 Tear Resistance Test Specimens



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.<sup>4</sup> 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.

<sup>4</sup> 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.

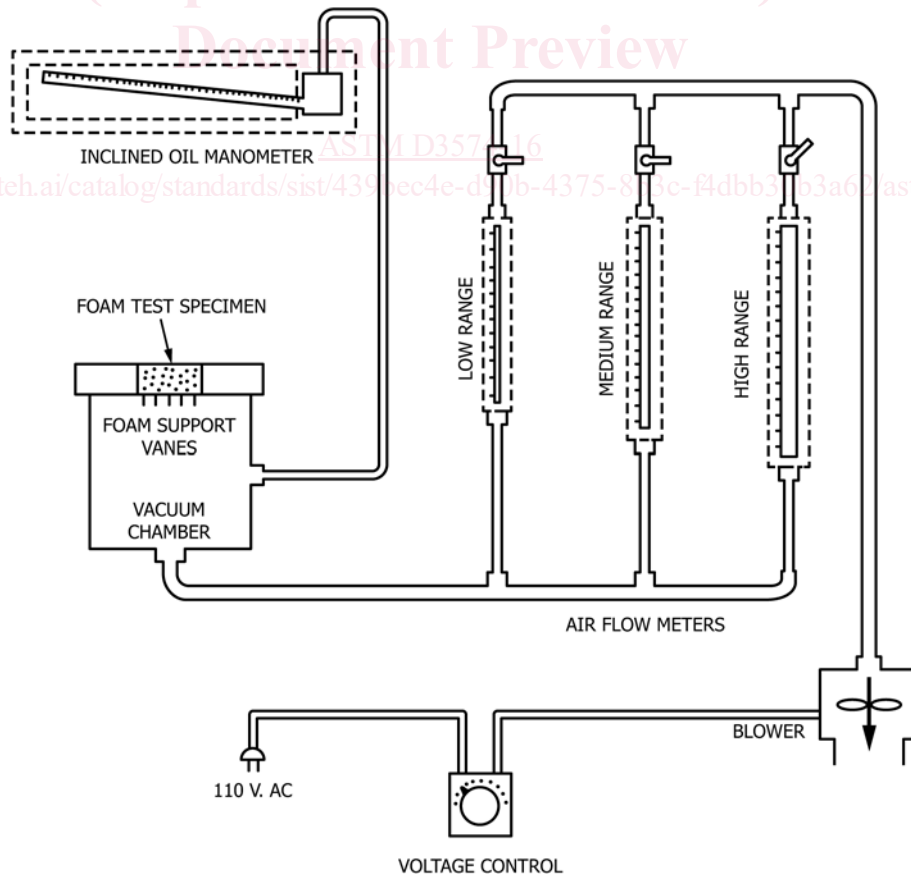


FIG. 5 Air Flow Apparatus Schematic Diagram

The specimen mount cavity shall be  $50.0 \pm 0.5$  by  $50.0 \pm 0.5$  by  $25.0 \pm 0.5$  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  $\pm 2$  %, 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  $\pm 2$  % 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  $0.01 \text{ m}^3/\text{s}$  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  $\frac{1}{3}$  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  $51.0 \pm 0.3$  by  $51.0 \pm 0.3$  by  $25.0 \pm 0.5$  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  $125 \pm 1$  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  $40 \pm 4$ -mm inside diameter vertical clear plastic (such as acrylic) tube, into which a  $16.0 \pm 0.2$ -mm diameter steel ball, weighing  $16.3 \pm 0.2$  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  $16.0 \pm 0.2$  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  $120^\circ$  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  $16.0 \pm 0.2$  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<sub>1</sub>—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  $4.5 \pm 0.5$  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  $\pm$  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  $24 \pm 1$  h of recovery time rather than  $60 \pm 5$  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, %,