Designation: D 3576 – 98

Standard Test Method for Cell Size of Rigid Cellular Plastics[1]

This standard is issued under the fixed designation D 3576; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This test method covers the determination of the apparent cell size of rigid cellular plastics by counting the number of cell-wall intersections in a specified distance.

1.2 Procedure A requires the preparation of a thin slice, not more than one half the average cell diameter in thickness, that is mechanically stable. For most rigid cellular plastics this limits the test method to materials with an average cell size of at least 0.2 mm.

1.3 Procedure B is intended for use with materials whose friable nature makes it difficult to obtain a thin slice for viewing.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *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.*

NOTE 1—The annex to ISO 2896 is technically equivalent to this test method.

2. Referenced Documents

2.1 *ASTM Standards:*

D 883 Terminology Relating to Plastics[2]

D 2842 Test Method for Water Absorption of Rigid Cellular Plastics[3]

D 2856 Test Method for Open-Cell Content of Rigid Cellular Plastics by the Air Pycnometer[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[4]

2.2 *ISO Standard:*

ISO 2896 Cellular Plastics, Rigid—Determination of Water Absorption[5]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms applicable to this test method are given in Terminology D 883.

4. Summary of Test Method

4.1 *Procedure A*— The cellular plastic specimen is cut to not more than one half the average cell diameter in thickness on a slicer and the shadowgraph is projected on a screen by the use of a cell-size scale slide assembly and a projector. The average chord length is obtained by counting the cells on cell-wall intersections and converting this value to average cell size by mathematical derivation.

4.2 *Procedure B*— The cellular plastic specimen is sliced to provide a smooth surface. The cell walls are accented by the use of a marking pen. The average chord length is obtained by counting the cell wall intersections and converting this value to average cell size by mathematical derivation.

5. Significance and Use

5.1 Several physical properties of rigid cellular plastics are dependent on cell size and cell orientation. Measuring water absorption and open-cell content in accordance with Test Method D 2842 and Test Method D 2856 requires knowledge of surface cell volume, which uses cell size values in the calculations.

5.2 This test method provides an apparent cell size because it assumes that there is no measurable edge to edge or top to bottom variation in average cell size and that the cell size distribution about the average cell size is normal. If the analyst is concerned there may be significant variation in either the average cell size or the cell size distribution more detailed analysis may be required.

5.3 Before proceeding with this test method, reference should be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or a combination thereof, covered in the materials specification shall take precedence over those mentioned in this test method. If there are no material specifications, then the default conditions apply

[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.22 on Cellular Plastics.

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[2] *Annual Book of ASTM Standards,* Vol 08.01.

[3] *Annual Book of ASTM Standards,* Vol 08.02.

[4] *Annual Book of ASTM Standards,* Vol 14.02.

[5] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

FIG. 1 Razor Blade Cell Size Specimen Slicer

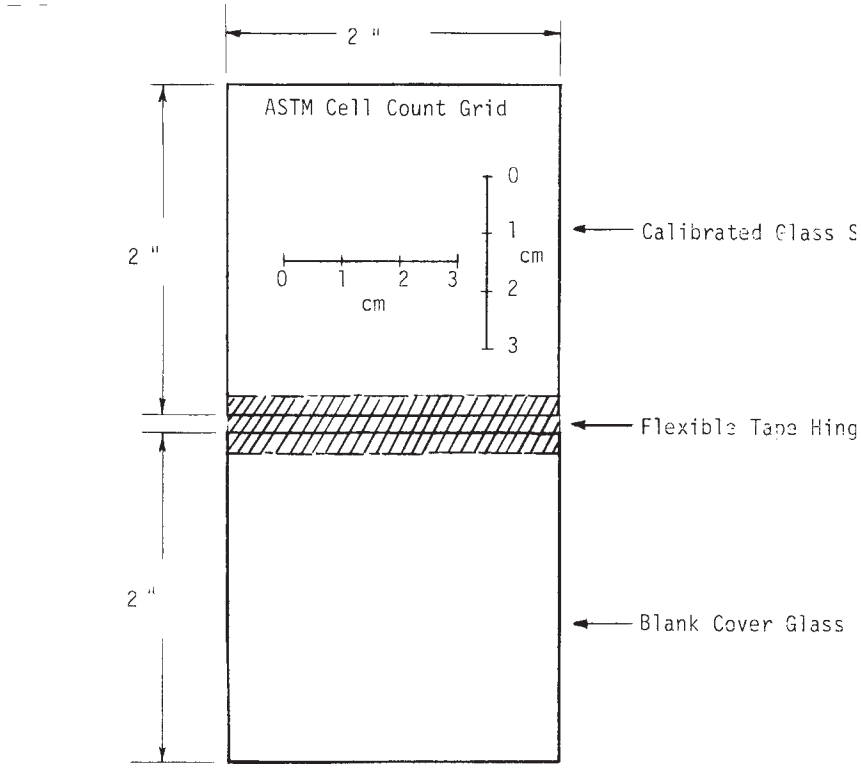

FIG. 2 Cell Size Scale Slide Assembly

6. Apparatus

6.1 The apparatus required to perform the test as defined by Procedure A is listed as follows:

6.1.1 *Cell Size Specimen Slicer* [6] —Cutting blade apparatus capable of slicing thin specimens (0.02 mm) for cell size viewing. Fig. 1 shows an acceptable alternative slicing apparatus.

6.1.2 *Cell Size Projector*—Conventional 35-mm slide projector that accepts standard 50 by 50-mm (2 by 2-in.) slides.

6.1.3 *Cell Size Scale Slide Assembly,* consisting of two pieces of slide glass[7] hinged by tape along one edge, between which a calibrated scale (30 mm in length) printed on a thin plastic sheet is placed (see Fig. 2).

6.2 The apparatus required to perform the test as defined by Procedure B is listed as follows:

6.2.1 *Cell Size Specimen Slicer* [6] —Cutting blade apparatus capable of providing a smooth surface.

6.2.2 *Optical Magnification System,* capable of 5 to 25× magnification with a calibrated scale of the appropriate length.

6.2.3 *Highlighting Market,* that does not contain a solvent which will attack the polymer system. The ink used should contrast with the color of the foam.

7. Sampling

7.1 Generally one specimen is sufficient to determine the apparent cell size of a sample.

7.2 The number of samples may be dictated by the end-use data needed.

8. Procedures

8.1 *Procedure A*:

8.1.1 Cut a specimen 50 by 50 mm by thickness (2 by 2 in. by thickness) from the sample in the area to be tested.

8.1.2 Prepare the cell size viewing specimen by cutting a thin slice (less than monocellular) from one of the cut surfaces of the specimen (slice thickness should be as thin as practicable; so that a shadowgraph will not be occluded by overlapping cell walls. Optimum slice thickness will vary with the average cell size of the foam, with smaller cell foams requiring thinner slices.)

NOTE 2—One cell size measurement will provide a representative apparent cell size for cellular plastics having symmetric cells of relatively uniform size. However, if the cell size in the three normal directions is suspected of varying by a value greater than the precision of this test method, all three directions should be measured and reported for maximum accuracy. An acceptable procedure, in this case, is to determine the cell size in two planes perpendicular to each other. The size of the cells in the three normal directions can then be compared and reported separately if desired.

8.1.3 Insert the thin-sliced foam specimen into the cell size slide assembly. Position the zero on the grid line at the top of the area to be measured. Reassemble the slide.

8.1.4 Insert the slide assembly into the projector. Focus the projector on the wall or screen so that a sharp image shadowgraph results.

8.1.5 Count the number of cell walls that intersect the reference line.[8]

8.1.6 Determine the average cell chord length, *t.* Divide the length of the reference line by the number of cells counted to obtain the average chord length, *t.* The length of the reference line is expressed in millimetres.

8.2 *Procedure B*:

8.2.1 Cut a 25-mm (1-in.) section across the width of the sample.

8.2.2 Identify the length *(L)* and width *(W)* direction in the middle of the strip.

8.2.3 Cut a 25-mm (1-in.) section with the *L* and *W* marking from the center of the strip giving a specimen of 25 by 25 mm by thickness (1 by 1 in. by thickness).

8.2.4 Shave adjacent planes of the sample giving exposed cut cells in the *L, W,* and thickness *(T)* directions (see Note 2).

8.2.5 Coat the shaved planes with the marker with a uniform coating in such a manner that additional cell walls are not broken.

8.2.6 Place the sample in a manner to observe cells in the *T* direction. The sample holder should be of sufficient size and integrity so as to hold the sample steady during measurement (see Note 3).

NOTE 3—For samples with an apparent cell size of 0.3 mm or smaller the cell size may be measured by the use of a B&L Model STZ-201 Monocular Zoomscope[9] with a 10-mm calibrated reference line. For samples with an apparent cell size of 1.0 mm or greater a handheld eyepiece[10] with a calibrated scale of 30-mm length can be used.

8.2.7 Count the number of cell walls which intersect the reference line.[8]

8.2.8 The cells counted must be a random selection, however, the specific placement of the line should be adjusted to start the count to include a full cell at the beginning of the line.

8.2.9 Determine the average cell chord length, *t.* Divide the length of the reference line by the number of cells counted to obtain the average chord length, *t.* The length of the reference line is expressed in millimetres.

9. Calculation

9.1 Calculate the cell size for each direction measured as follows:

$$d = t(1.623)$$

where:

d = cell size, mm, and

t = average cell chord length, mm.

See Appendix X1for the derivation of the equation.

10. Report

10.1 Report the following information:

10.1.1 Material type and manufacturer,

10.1.2 Lot number/production date of the material evaluated,

[6] Hobart Model 610-1, an electrically operated slicer, available from the Hobart Corp., 2136 Hardy Parkway, Grove City, OH 43123.

[7] Cell size grid decals can be obtained from ASTM Headquarters.

[8] The reference line length should be suitable to the cell size being measured. A minimum cell count of 20 should be adequate.

[9] Available from LEICA, 111 Deer Lake Rd., Deerfield, IL 60015.

[10] Available from Edmund Scientific, 101 E. Gloucester Pike, Barrington, NJ 07007.

TABLE 1 Precision Data Summary, Procedure A

Material	Nominal Thickness, in.	Average Cell Size, mm	% γ_r [A]	% γ_R [B]	r [C]	R [D]	Number of Laboratories in Research Report
Extruded Polystyrene Foam	0.75	0.36	5.7	9.3	16.3	26.4	4
Extruded Polystyrene Foam	2	0.79	7.3	12.3	20.7	34.7	4
Extruded Polystyrene Foam	6.5	1.6	5.3	15.1	14.9	42.8	4
Polyisocyanurate Foam (Glass Fibers Reinforced)	2	0.33	9.4	18.3	26.6	51.8	3
Phenolic Foam	1	0.37	17.2	17.4	48.7	49.2	3

[A] γ_r is the within-laboratory coefficient of variation of the average.
[B] γ_R is the between-laboratories coefficient of variation of the average.
[C] r is the within-laboratory repeatability limit = 2.8 γ_r.
[D] R is the between-laboratories reproducibility limit = 2.8 γ_R.

TABLE 2 Precision Data Summary, Procedure B

Material	Nominal Thickness, in.	Average Cell Size, mm	% γ_r [A]	% γ_R [B]	r [C]	R [D]	Number of Laboratories in Research Report
Extruded Polystyrene Foam	0.75	0.35	8.7	11.6	24.8	32.9	6
Extruded Polystyrene Foam	2	0.74	6.2	19.4	17.47	54.9	6
Extruded Polystyrene Foam	6.5	1.7	5.2	15.1	14.7	42.7	5
Polyisocyanurate Foam (Glass Fibers Reinforced)	2	0.39	10.3	31.0	29.1	87.7	7
Polyurethane Foam	1	0.37	10.5	32.1	29.7	90.8	6
Phenolic Foam	1	0.13	8.7	14.8	24.5	41.9	3

[A] γ_r is the within-laboratory coefficient of variation of the average.
[B] γ_R is the between-laboratories coefficient of variation of the average.
[C] r is the within-laboratory repeatability limit = 2.8 γ_r.
[D] R is the between-laboratories reproducibility limit = 2.8 γ_R.

10.1.3 Procedure used (A or B),

10.1.4 The number of specimens evaluated, and

10.1.5 The average cell size in millimetres for each direction measured. For those foams having a cell size larger than 1.0 mm, report the value to the nearest 0.1 mm. For those smaller than 1.0 mm, report the value to the nearest 0.01 mm.

11. Precision and Bias[11]

11.1 Tables 1 and 2 are based on a round robin conducted in 1989 in accordance with Practice E 691 involving six materials for Procedures A and B. Due to equipment limitations, only four of the participants were able to obtain data with Procedure A. All seven participants obtained data using Procedure B. All of the samples were prepared at one source but the individual specimens were prepared at the laboratories that tested them. Each test result was the average of three determinations. Each laboratory obtained one test result for each material.

NOTE 4—**Caution:** Sections 11.2-11.2.3 are intended only to give an approximate precision of this test method. When data is obtained from less than six laboratories, it should be viewed with extreme caution. The data should not be rigorously applied to acceptance or rejection of material. The data is specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories. Users of this test method should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 11.2-11.2.3 a would then be valid for such data.

11.2 *Concept of r and R*—If S_r and S_R were calculated from a large enough body of data, and for test results consisting of one determination per test result:

11.2.1 *Repeatability Limit, r*—(Comparing two test results for the same material, obtained by the same operator using the same equipment on the same day.) The two test results should be judged not equivalent if they differ by more than the " *r*" value for that material.

11.2.2 *Reproducibility Limit, R*—(Comparing two test results for the same material, obtained by different operators using different equipment in different laboratories on different days.) The two test results should be judged not equivalent if they differ by more than the "R" value for that material.

11.2.3 Any judgment in accordance with 11.2.1 or 11.2.2 would have an approximate 95 % (0.95) probability of being correct.

11.3 There are no recognized standards by which to estimate bias of this test method.

12. Keywords

12.1 cell size; rigid cellular plastics

[11] Supporting data are available from ASTM Headquarters, Request RR: D20-1185.

APPENDIX

(Nonmandatory Information)

X1. DERIVATION OF CELL SIZE

X1.1 Assumptions made in this derivation are that the cell shape is spherical and that the cells are relatively uniform with respect to size.

X1.2 Subsection 7.6 of this test method describes the procedure for determining *t*, the average measured chord length of the randomly truncated cells. The relationship between *t* and the average cell diameter, *d′*, appearing at the plane of the cut surface, may be calculated as follows:

X1.2.1 The mean value of the ordinates in the first quadrant for any circle $x^2 + y^2 = r^2$ is:

$$\bar{y}=(1/r)\int_0^r r^2-x^2dx=\pi r/4 \quad \text{(X1.1)}$$

where:
r = radius of the cell in the surface plane, and
6 = $t/2$.

Therefore:

$$t/2=\pi r/4 \quad \text{(X1.2)}$$

Since $r = d'/2$ then:

$$t=\pi d'/4 \quad \text{(X1.3)}$$

Rearrangement of Eq X1.3 yields:

$$d'=t/0.785 \quad \text{(X1.4)}$$

X1.3 The average cell diameter of the circular segments, *d′*, is related to the diameter of the sphere, *d* in the same manner. The average sphere diameter is larger than the average circular segment diameter, *d′*, because the cells are randomly truncated with respect to depth at the plane of the specimen surface. The mean value of the chord length with respect to diameter (see Eq X1.3) again applies:

$$d=d'/0.785 \quad \text{(X1.5)}$$

Combining Eq X1.4 and X1.5 yields:

$$d=t/(0.785)^2=t/0.616 \quad \text{(X1.6)}$$

$$=t(1.623) \quad \text{(X1.7)}$$

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D-20 has highlighted those changes that may impact the use of this test method. This section may also include descriptions of the changes or reasons for the changes, or both.

D 3576 – 98:
(*1*) Revised Significance and Use section to add a reference to material specifications.
(*2*) Added a Keyword section.