Designation: D 6289 – 98

Standard Test Method for Measuring Shrinkage from Mold Dimensions of Molded Thermosetting Plastics[1]

This standard is issued under the fixed designation D 6289; 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 is intended to measure batch-to-batch uniformity in initial shrinkage from mold to molded dimensions of thermosetting materials when molded by compression, injection, or transfer under specified conditions.

1.2 This test method provides for the measurement of shrinkage of thermosetting plastics from their molds both initially (within 16 to 72 h of molding) and as they age (post–shrinkage at elevated temperatures).

1.3 Knowledge of the initial shrinkage of plastics is important for the construction of molds and knowledge of post molding shrinkage is important for determining the suitability of the molding material for manufacturing thermosetting plastic components with accurate dimensions.

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—This test method and ISO 2577-1984 are equivalent when bars of 120 mm length, 15 mm width, and 10 mm thickness are used for compression molding; or flat, square plaques approximately 120 by 120 by 4 mm are used for injection molding.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 796 Practice for Compression Molding Test Specimens of Phenolic Molding Compounds[2]

D 883 Terminology Relating to Plastics[2]

D 956 Practice for Compression Molding Specimens of Amino Molding Compounds[3]

D 1896 Practice for Transfer Molding Test Specimens of Thermosetting Compounds[2]

D 1898 Practice for Sampling of Plastics[2]

D 3419 Practice for In-line Screw-Injection Molding of Test Specimens from Thermosetting Compounds[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[5]

2.2 *ISO Standards:*[6]

ISO 291 Plastics—Standard Atmospheres for Conditioning and Testing

ISO 295 Plastics—Compression Molding Test Specimens of Thermosetting Materials

ISO 10724 Plastics—Thermosetting Molding Materials—Injection Molding of Multipurpose Test Specimens

ISO 2577-1984 Plastics—Thermosetting Moulding Materials—Determination of Shrinkage

3. Terminology

3.1 *General*—Definitions of terms applying to this test method appear in Terminology D 883.

3.2 *Definitions*—For the purpose of this test method, the following definitions apply:

3.2.1 *molding shrinkage*—the difference in dimensions between a molding and the mold cavity in which it was molded, both the mold and the molding being at 23 ± 2°C when measured.

3.2.2 *post-shrinkage*—shrinkage of a plastic product after molding, during post-treatment, storage or use.

4. Significance and Use

4.1 *Compression Molding*—In compression molding, the difference between the dimensions of a mold and of the molded article produced therein from a given material may vary according to the design and operation of the mold. It is probable that shrinkage will approach a minimum where design and operation are such that a maximum of material is forced solidly into the mold cavity or some part of it, or where the molded article is hardened to a maximum while still under pressure, particularly by cooling. In contrast, shrinkages may be much higher where the charge must flow in the mold cavity but does not receive and transmit enough pressure to be forced

[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.09 on Specimen Preparation.
Current edition approved July 10, 1998. Published February 1999.

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

[3] Discontinued. Replaced by Practice D 5224.

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

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

[6] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

firmly into all its recesses, or where the molded article is not fully hardened when discharged. The plasticity of the material used may affect shrinkage insofar as it affects the retention and compression of the charge.

4.2 *Injection Molding*—In injection molding, as in compression molding, the difference between the dimensions of the mold and of the molded article produced therein from a given material may vary according to the design and operation of the mold. The difference may vary with the type and size of molding machine, the thickness of molded sections, the degree and direction of flow or movement of material in the mold, the size of the nozzle, sprue, runner, and gate, the cycle on which the machine is operated, the temperature of the mold, and the length of time that follow-up pressure is maintained. As in the case of compression molding, shrinkages will approach a minimum where design and operation are such that a maximum of material is forced solidly into the mold cavity and where the molded article is hardened to a maximum while still under pressure as a result of the use of a runner, sprue, and nozzle of proper size, along with proper dwell. As in compression molding, shrinkages may be much higher where the charge must flow in the mold cavity but does not receive and transmit enough pressure to be forced firmly into all of the recesses of the mold. The plasticity of the material used may affect shrinkage indirectly, in that the more readily plasticized material will require a lower molding temperature.

4.3 *Transfer Molding*—In transfer molding, as in compression or injection molding, the difference between the dimensions of the mold and of the molded article produced therein from a given material may vary according to the design and operation of the mold. It is affected by the size and temperature of the pot or cylinder and the pressure on it, as well as on mold temperature and molding cycle. Direction of flow is not as important a factor as might be expected, although it can have some bearing on results.

4.4 *Materials Standards*—Always refer to material standards for special treatment prior to molding, molding conditions and special handling of the test specimens after molding. In the event the material standard is unavailable, contact the manufacturer for these recommendations.

5. Sample Preparation

5.1 Some materials require special treatment before they are molded. Materials to be tested shall be prepared for molding in accordance with the relevant material standard or the manufacturer's recommendations. The preparation given to the material prior to molding shall be recorded and reported.

6. Apparatus

6.1 *Mold, Press, etc.*, suitable for molding the test specimens specified in Section 8. For transfer or compression molding, a positive or a semi-positive mold with single or multiple cavities shall be used. For injection molding, the type of mold is defined.

6.1.1 If required, marks may be engraved in the mold near opposite ends of the specimen to facilitate the accurate measurement of the length of the cavity and the specimens.

NOTE 2—If multiple cavities are used with a positive mold, resulting variations in test specimen density may be sufficient to produce inconsistent shrinkage.

6.2 *Equipment*, suitable for measuring the lengths of the test specimen and the corresponding cavity of the mold to within 0.02 mm.

6.3 *Oven*, for post-shrinkage only.

7. Sampling

7.1 A representative sample shall be taken from the molding material and be kept at room temperature in airtight containers, without any conditioning, until molded into test specimens (see Practice D 1898).

8. Test Specimen

8.1 *Compression-Molding Materials*—For mold shrinkages of compression-molding materials, the test specimens shall be bars 120 by 15 by 10 mm, bars 12.7 by 12.7 by 127 mm (½ by ½ by 5 in.), or disks 3.2 mm (⅛ in.) in thickness and 102 mm (4 in.) in diameter made in a positive mold in such a way as to minimize laterial movement of the plastic during the molding.

8.2 *Injection-Molding Materials*—For mold shrinkage of injection-molding materials, the test specimens shall be bars 12.7 by 3.2 by 127 mm (½ by ⅛by 5 in.) gated at the end, bars 12.7 by 12.7 by 127 mm (½ by ½ by 5 in.) disks 3.2 mm (⅛in.) in thickness and 102 mm (4 in.) in diameter grated radially at a single point in the edge, plaques 120 by 120 by 4 mm or plaques 60 by 60 by 2 mm gated with a full edge gate.

8.3 *Transfer-Molding Materials*—For shrinkage of transfer-molding materials, specimens 12.7 by 12.7 by 127 mm (½ by ½ by 5 in.) gated at the end or at the top near one end, so as to provide flow throughout their entire length or disk specimen 3.2 mm (⅛ in.) in thickness and 102 mm (4 in.) in diameter gated radically at a single point in the edge.

8.4 The specimens shall be molded to shape by compression, transfer or injection molding using a mold with single or multiple cavities.

9. Procedure

9.1 If not already known, measure the lengths of the cavities (or the distances between the engraved marks in the mold) to the nearest 0.02 mm at a temperature of 23 ± 2°C (ISO 291, Atmosphere 23 or Practice D 618, T-23).

9.1.1 Record these measurements for use in the calculations of shrinkage.

NOTE 3—From time to time, molds should be checked for wear, etc. As an alternate to measuring directly the lengths of the cold molds, the gauge for the molds may be obtained very precisely by cold-molding specimens from lead and measuring their lengths.

9.2 Mold at least two specimens from the sample to be tested, under the conditions given below.

9.2.1 *For Compression Molding*—Mold the specimens under the conditions of pressure, temperature, time, etc., specified in the relevant standard for the material, in ISO 295, Practice D 796, Practice D 956, or at the recommendations of the material manufacturer if the standards are not available.

9.2.2 *For Injection Molding*—Mold the specimens under the conditions outlined in the relevant material standard, ISO 10724 or Practice D 3419. If the material standards are not

available, consult the manufacturer of the material for the molding conditions.

NOTE 4—In the case of those fibrous materials that are to be injection-molded as a plaque, at least four specimens should be tested.

9.2.3 *For Transfer Molding*—Mold the specimens under the conditions outlined in the relevant material standard or Practice D 1896 or at the recommendations of the material manufacturer.

9.3 After removal from the mold, allow the test specimens to cool to room temperature by placing them on a material with low thermal conductivity and under an appropriate load to avoid warping. Store them at a temperature of 23 ± 2°C and a relative humidity of 45 % to 55 % (ISO 291, Atmosphere 23/50 or Practice D 618, Procedure F, Condition 23/50) for between 16 and 72 h, or for such shorter time as can be shown to give the same test results.

NOTE 5—It is recommended that a minimum of two specimens be measured and the average reported.

9.4 Before measuring the lengths of the test specimens, place them on a flat surface or against a straight edge in order to determine any warp or distortion. Any test specimen that has a warp exceeding 1 % of its length shall be discarded.

9.5 For the determination of molding shrinkage, measure, to the nearest 0.02 mm, the lengths of the bar specimens parallel to their major axis between opposite end faces or the distances between the gauge marks, at a temperature of 23 ± 2°C. Measurement of plaque specimens shall be made at distance of 20 mm from the corners, two measurements in the same direction.

NOTE 6—In order to measure the effect of orientation on the shrinkage of an injection-molded specimen, shrinkages in two directions at right-angles (each of which is calculated from an average of two measurements in the same direction) are measured and calculated independently.

9.6 For the determination of post-shrinkage, place the test specimens, measured as described in 9.5, in an oven maintained at the temperature given below. Support the specimens (preferably on an open grid) to avoid deformation and in such a way that they are separated from each other.

9.6.1 The heating temperatures shall be: 80 ± 2°C for urea-formaldehyde molding materials; 110 ± 3°C for all other thermosetting molding materials.

9.6.2 The times of exposure shall be: 48 ± 1 h for rapid determination; 168 ± 2 h for normal determination.

NOTE 7—Post shrinkage depends strongly on the time of exposure. Therefore the exposure time should be noted (see 10.2 and 11f) and should be specified in the specification for the material.

9.7 At the end of the heating period, remove the test specimens from the oven and allow them to cool in a standard atmosphere of 23 ± 2°C and a relative humidity of 45 % to 55 % for at least 3 h.

9.8 After the cooling period examine the specimens as in 9.4 and then measure the test specimens again, at a temperature of 23 ± 2°C to the nearest 0.02 mm, as specified in 9.5.

10. Interpretation of Results

10.1 The molding shrinkage (MS) is given, as a percentage, by the following formula:

$$MS = \frac{L_0 - L_1}{L_0} \times 100 \quad (1)$$

where:

L_0 = length of the dimension of the mold, determined as in 9.1, mm, and

L_1 = length of the corresponding dimension measured on the test specimen, in accordance with 9.5, mm.

NOTE 8—When shrinkage is being determined using injection-molded plaques, L_0 and L_1 are each the averages of two readings, measured in the same direction, taken 20 mm from the corners of the mold and the test specimen respectively.

10.2 Post-shrinkage (PS) is given, as a percentage, by the following formula:

$$PS_{48\,h} \text{ or } PS_{168\,h} = \frac{L_1 - L_2}{L_1} \times 100 \quad (2)$$

where:

L_2 = length of the same dimension of the test specimen, measured after heat treatment at 48 h or 168 h, in accordance with 9.6, mm.

NOTE 9—When post-shrinkage is being determined using injection molded plaques, L_2 is the average of two readings, measured in the same direction, taken 20 mm from the corners of the test specimen.

11. Report

11.1 Report the following information:

11.1.1 Reference to this test method,

11.1.2 The grade and designation of the molding material,

11.1.3 The type and number of test specimens used (bar, plaque or disk),

11.1.4 The method of molding the specimens (compression, injection or transfer) and the molding conditions,

11.1.5 The number of test specimens discarded because of excessive warping,

11.1.6 The conditions of heat treatment for the determination of post-shrinkage,

11.1.7 The molding shrinkage (MS) and the post-shrinkage ($PS_{48\,h}$ or $PS_{168\,h}$, or both), as a percentage, including the individual values, the arithmetic mean and, for injection-molded plaques, the direction of measurement with respect to the direction of injection, and

11.1.8 The dates of molding the test specimens, measurement of molding shrinkage, post-shrinkage heat treatment, and measurement of post-shrinkage.

12. Precision and Bias

12.1 This is a new test method for which precision and bias have not been determined. In one laboratory, four operators compression molded three phenolic materials and evaluated the specimens for mold shrinkage. The results are as follows:

Operator	Average Mold Shrinkage, %		
	Material A	Material B	Material C
1	0.85	0.71	0.31
2	0.80	0.67	0.30
3	0.81	0.67	0.27
4	0.83	0.66	0.28

To develop precision and bias, ASTM Subcommittee D20.09 is seeking a minimum of six laboratories to participate in a round robin testing protocol. Anyone wishing to participate in

the development of precision and bias data should contact the chairman of subcommittee D20.09 at ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

13. Keywords

13.1 molding shrinkage; post-molding shrinkage; thermoset plastics