Designation: D6289 – 13

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

This standard is issued under the fixed designation D6289; 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 shrinkage from mold cavity to molded dimensions of thermosetting plastics 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 after aging (post–shrinkage at elevated temperatures).

1.3 This method will give comparable data based on standard specimens and can not predict absolute values in actual molded parts with varying flow paths, wall thicknesses, pressure gradiants and process conditions. Differences in mold shrinkage generally is observed between the specimen geometries described in this test method.

1.4 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.

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

1.6 *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:*[2]

D618 Practice for Conditioning Plastics for Testing

D796 Practice for Compression Molding Test Specimens of Phenolic Molding Compounds (Withdrawn 1992)[3]

D883 Terminology Relating to Plastics

D1896 Practice for Transfer Molding Test Specimens of Thermosetting Compounds

D3419 Practice for In-Line Screw-Injection Molding Test Specimens From Thermosetting Compounds

D5224 Practice for Compression Molding Test Specimens of Thermosetting Molding Compounds

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

2.2 *ISO Standards:*[4]

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 D883.

3.2 *Definitions:*

3.2.1 For the purpose of this test method, the following definitions apply:

3.2.2 *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.

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.09 on Specimen Preparation.

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

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

3.2.3 *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 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 are higher where the charge must flow in the mold cavity but does not receive and transmit enough pressure to be forced firmly into all its recesses, or where the molded article is not fully hardened when discharged. The plasticity of the material used affects shrinkage insofar as it affects the retention and compression of the charge.

4.2 *Injection Molding*—In injection molding, as in compression molding, the differences between the dimensions of the mold and of the molded article produced therein from a given material vary according to the design and operation of the mold. The differences 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 are 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 affects 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 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.

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.

4.5 *Utility*—Measurement of batch-to-batch consistency in initial shrinkage from mold to molded dimensions is useful for evaluating the quality of thermosetting plastics.

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 are 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, it is possible that resulting variations in test specimen density can 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, a forced draft type is recommended.

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.

8. Test Specimen

8.1 *Compression-Molding Materials*—For mold shrinkage 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 lateral 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 ⅛ by 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 (⅛ in.) in thickness and 102 mm (4 in.) in diameter gated 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.

NOTE 3—Different specimens give differing shrinkage. For comparison purposes, use the same specimen.

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 D618, T-23).

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

NOTE 4—From time to time, check molds for wear. As an alternate to measuring directly the lengths of the cold molds, the gauge for the molds can 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 D796, Practice D5224, 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 D3419. If the material standards are not available, consult the manufacturer of the material for the molding conditions.

NOTE 5—In the case of those fibrous materials that are to be injection-molded as a plaque, test at least four specimens.

9.2.3 *For Transfer Molding*—Mold the specimens under the conditions outlined in the relevant material standard or Practice D1896 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. Unless otherwise specified in the appropriate material standard, store them at a temperature of 23 ± 2°C and a relative humidity of 50 ± 10 % (ISO 291, Atmosphere 23/50 or Practice D618, Procedure F, Condition 23/50) for between 16 and 72 h, or for such shorter time to be shown to give the same test results.

NOTE 6—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. Measure the plaque specimens at a distance of 20 mm from the corners, two measurements in the same direction.

NOTE 7—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 8—Post shrinkage depends on the time of exposure for some materials. If exposure times different from those noted in 10.2 are used, these shall be noted in the report in accordance with 11.1.6 and, if appropriate, specified in the material standard.

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 50 ± 10 % for at least three hours unless otherwise specified in the appropriate material standard.

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 9—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 10—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, including the times of exposure if different from those noted in 10.2,

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 In one laboratory, four operators compression molded three phenolic materials and evaluated the specimens for mold shrinkage. The results are as follows:

	Average Mold Shrinkage, %		
Operator	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

12.2 No precision and bias have been determined for this test method. The chairperson of ASTM subcommittee D20.09 seeks laboratories interested in participating in an interlaboratory evaluation of this test method. 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

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D6289 - 08) that may impact the use of this standard. (April 1, 2013)

(1) Made editorial changes.
(2) Updated conditioning requirements in 9.3 and 9.7.
(3) Edited permissive language.