



## Standard Test Method of Measuring Shrinkage from Mold Dimensions of Thermoplastics<sup>1</sup>

This standard is issued under the fixed designation D 955; 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 thermoplastics when molded by compression or injection processes with specified process conditions.

1.2 This test method covers initial shrinkage measurements. The method also accommodates shrinkage at 24 and 48 h, which may be critical for some materials.

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 gradients and process conditions. Differences in mold shrinkage may also be observed between the three specimen geometries described in this test method.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are given 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 is technically identical to ISO 294-4 where Type D2 specimens are used except that pressure transducers are an option in this test method and required in ISO 294-4.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 374 Test Methods for Thickness of Solid Electrical Insulation<sup>2</sup>
- D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing<sup>3</sup>
- D 788 Classification System for Poly(Methyl Methacrylate) (PMMA) Molding and Extension Compounds<sup>3</sup>

<sup>1</sup> 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. Current edition approved Nov. 10, 2000. Published January 2001. Originally published as D 955 – 48T. Last previous edition D 955 – 89 (1996).

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 10.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 08.01.

D 883 Terminology Relating to Plastics<sup>3</sup>

D 3641 Practice for Injection Molding of Test Specimens of Thermoplastic Molding and Extrusion Materials<sup>4</sup>

D 4066 Specification for Nylon Injection and Extrusion Materials<sup>4</sup>

D 4181 Specification for Acetal (POM) Molding and Extrusion Materials<sup>4</sup>

D 4549 Specification for Polystyrene Molding and Extrusion Materials (PS)<sup>5</sup>

D 4703 Practice for Compression Molding of Thermoplastic Materials into Test Specimens, Plaques, Sheets<sup>5</sup>

D 4976 Specification for Polyethylene Plastics Molding and Extension Materials<sup>5</sup>

D 5947 Test Methods for Physical Dimensions of Solid Plastics Specimens<sup>5</sup>

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method<sup>6</sup>

#### 2.2 ISO Standards:

ISO 293 Plastics—Compression Moulding Test Specimens of Thermoplastic Materials<sup>7</sup>

ISO 294-3 Plastics—Injection Moulding of Test Specimens of Thermoplastic Materials—Part 3: Small Plates<sup>7</sup>

ISO 294-4 Plastics—Injection Moulding of Test Specimens—Part 4: Determination of Moulding Shrinkage<sup>7</sup>

### 3. Terminology

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

#### 3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *demolding, n*—removing the specimens from the mold.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 08.02.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 08.03.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>7</sup> 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.

## 4. Summary of Test Method

4.1 The principle of this test method is to compare mold cavity dimensions with specimen dimensions and report the differences in percent.

## 5. Significance and Use

5.1 *Injection Molding*—In injection molding, the difference between the dimensions of a mold cavity and of the molded specimen may vary according to the design of the mold and operation of the molding process. Factors such as mold and melt temperature, fill times, and packing conditions are known to affect shrinkage significantly. Adherence to the specified mold design (see 7.1) and specifications outlined in Practice D 3641 or ISO 294-4 or the appropriate material will improve the reproducibility of the test.

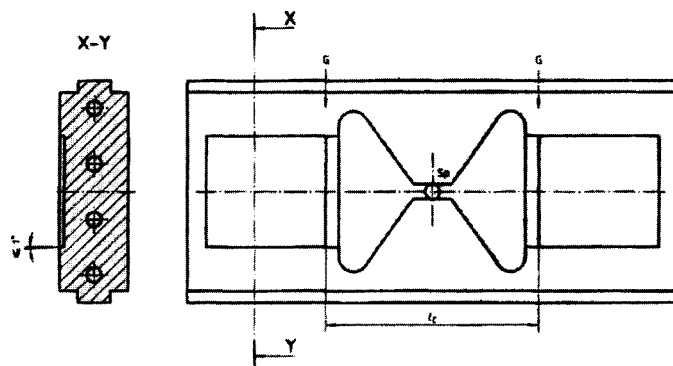
5.2 *Compression Molding*—In compression molding, the difference between the dimensions of a mold cavity and of the molded specimen may vary according to the design of the mold and operation of the molding process. Factors, such as the amount of material in charge, cooling time, and pressure application are known to affect shrinkage significantly. Adherence to the specified mold design (see 7.2) and specifications outlined in Practice D 4703 or ISO 293 or the appropriate material specifications will improve the reproducibility of the test.

## 6. Sample Preparation

6.1 Some materials require special treatment before they are molded. For example, thermoplastics, which absorb moisture must be dried before molding. Refer to the manufacturer's recommendations for required conditions or appropriate material specification. The preparation given to the material prior to molding shall be recorded and reported.

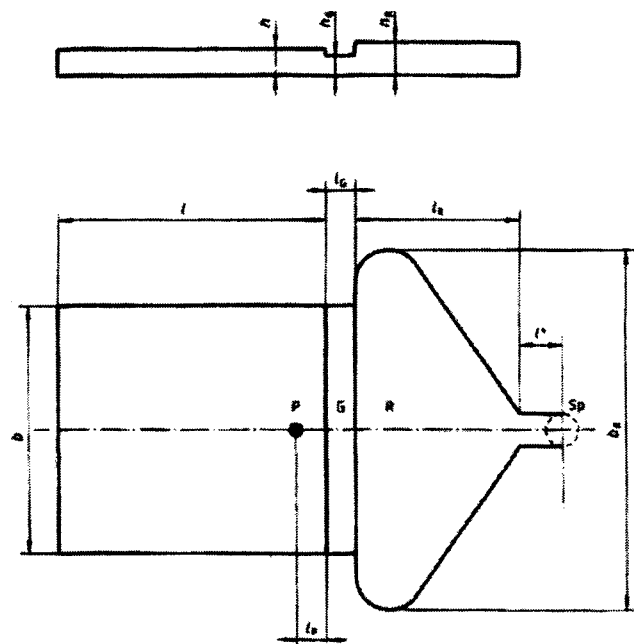
## 7. Apparatus

7.1 *Injection Mold*—Specimens shall be molded in a two cavity mold conforming with dimensions as shown in Figs. 1 and 2 for the 60 × 60-mm plaque specimen (Type D2), Fig. 3 for the 12.7 × 127-mm bar specimen (Type A) and Fig. 4 for the 100mm × 3.2-mm disk specimen (Type B). The mold may



Sp	sprue	molding volume = 30 000 mm <sup>3</sup>
G	gate	projected area = 11 000 mm <sup>2</sup>
lc = distance between the lines along which the test specimens are cut from the runners		

FIG. 1 Type D2



Sp	sprue	
G	gate	
R	runner	
P	pressure sensor	dimensions in mm
l	length of plate	60 ± 2
b	width of plate	60 ± 2
h	thickness of plate	2.0 ± 0.1
l <sub>G</sub>	length of gate	4.0 ± 0.1
h <sub>G</sub>	height of gate	(0.75 ± 0.05) × h <sup>3</sup>
l <sub>R</sub>	length of runner	25 to 40
b <sub>R</sub>	width of runner	≥ (b + 6)
h <sub>R</sub>	depth of runner at gate	h + (1.5 ± 0.5)
l*	unspecified distance	...
l <sub>p</sub>	distance of pressure sensor from gate	5 ± 2

FIG. 2 Type D2

have scribe marks included for the measurement of shrinkage. The scribe marks shall be 1.0 mm long by .01 mm wide located 1.0 mm from each edge on one side of the mold. Pressure transducers for monitoring the pressure in at least one cavity are mandatory for Type D2. Mold shrinkage measurements should be made on specimens that have been molded at one of the following cavity pressures ± 3 % from the selected pressure: 20 MPa, 40 MPa, 60 MPa, 80 MPa, 100 MPa, or as specified in the appropriate material specification. Pressure transducers are recommended, but not mandatory for specimens Type A and Type B.

7.2 *Compression Mold*—A single cavity positive mold having cavity dimensions conforming to the dimensions of Fig. 2 for the 60 × 60-mm plaque (Type D2) Fig. 3 for the 12.7 × 127-mm bar specimen (Type A) and Fig. 4 for the 100-mm × 3.2-mm disk specimen (Type B), not including the sprue, runner or gate. The mold may have scribe marks included for the measurement of shrinkage. The scribe marks shall be 1.0 mm long by 0.1 mm wide located 1.0 mm from each edge on one side of the mold.

7.3 *Injection Press*—A suitable injection molding machine that will fill the test molds when it is operated in the range from 20 to 80 % of its rated shot capacity at the molding parameters

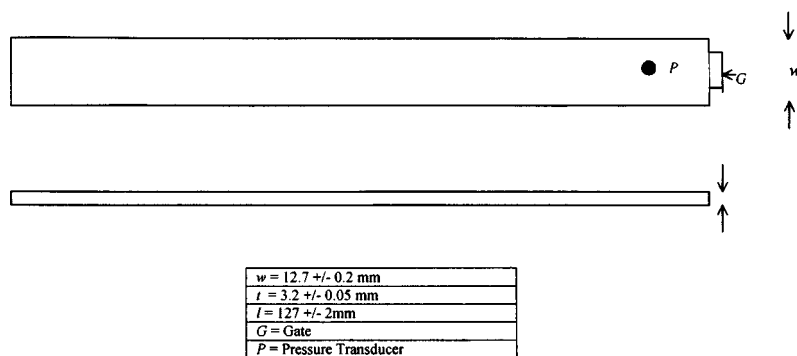


FIG. 3 Bar Specimen

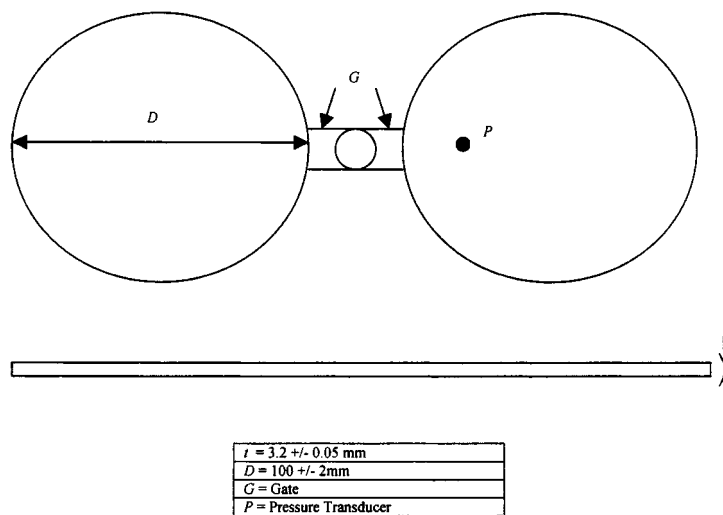


FIG. 4 Disk Specimen

specified in Practice D 3641, ISO 294-3 or the appropriate material specification.

NOTE 2—If the injection machines of appropriate capacity are not available, the requirements of 7.3 may be met in machines of larger capacities by providing test molds with multiple cavities (maximum of four) to be filled from a common sprue and having a balanced filling pattern, so that the total weight of the shot, including sprue and runner will fall within the specified limits.

7.4 *Compression Press*—A suitable hydraulic press that will deliver a pressure of 20 to 35 MPa (3000 to 5000 psi) to the material in the mold.

7.5 *Measuring Tools*—Measuring tools (micrometers, vernier calipers, etc.) accurate to 0.025 mm (0.001 in.) for measuring the molds and test specimens conforming to the measuring tool requirements in Test Methods D 374.

## 8. Test Specimen

8.1 *Specimen Type D2*—For mold shrinkage in both flow and cross flow of compression and injection molding materials the preferred specimen shall be  $60 \times 60 \times 2 \text{ mm}$  depth conforming to the dimensions of Fig. 2.

8.2 *Specimen Type A*—For shrinkage parallel to flow, a bar mold having a cavity of  $12.7 \times 127 \text{ mm}$  may be used as shown in Fig. 3. The thickness shall be 3.2 mm unless otherwise agreed upon by the seller and the purchaser. The mold shall have at one end a gate 6.4 mm in width by 3.2 mm in depth.

8.3 *Specimen Type B*—A disc shaped specimen, as shown in Fig. 4, having a cavity 100 mm in diameter by 3.2 mm in thickness with a gate 12.7 mm in width by 3.2 mm in depth, placed radially at the edge, may also be used.

NOTE 3—Although this specimen may be used to determine mold shrinkage in both the flow and cross flow directions, the filling pattern does not produce uniform flow lengths and orientation. Consequently, there may be significant differences when measuring the specimen at different points around the circumference. Values would not be expected to be in agreement with those obtained using the specimens described in clauses 8.1 and 8.2.

## 9. Conditioning

9.1 *Conditioning*—Conditioning of molded specimens shall be done in the Standard Laboratory Atmosphere,  $23 \pm 2^\circ\text{C}$  and  $50 \% \pm 5 \text{ RH}$ , if not otherwise specified in the appropriate materials standard.

9.2 *Test Conditions*—Conduct measurement in the standard laboratory atmosphere of  $23 \pm 2^\circ\text{C}$  and  $50 \% \pm 5 \text{ RH}$ , if not otherwise specified in the appropriate materials standard.

## 10. Procedure

10.1 Measure the length and width of the mold cavity at the center of each edge or at the molded scribe marks, to the nearest 0.025 mm at  $23 \pm 2^\circ\text{C}$  and  $50 \% \pm 5 \text{ RH}$ . Record these values as  $l$  and  $w$ , respectively.

10.2 Mold at least five flat test specimens from the sample to be tests.

NOTE 4—Flat is represented by a specimen with less than 3 % warp. Three percent warp is defined as 3 mm depth deflection, positive or negative, per 100 mm in length.

10.2.1 *Thermoplastics Molded by Injection*—Molding of thermoplastic materials shall be conducted in accordance with the appropriate material standard, Practice D 3641, or ISO 294-3, or both. The temperature of the heating cylinder and the mold shall be maintained at a point which, on a cycle selected, will produce temperature within the range recommended by the material molding standard. Begin with a short shot to insure flow is straight and not partly radial and that the flow is laminar and does not exhibit melt fracture. Collect samples after the machine is at equilibrium.

10.2.2 *Thermoplastics Molded by Compression*—For thermoplastics, molding shall be conducted in accordance with the appropriate material standard or D 4703.

### 10.3 Treatment of Specimens After Demolding:

10.3.1 In order to minimize warpage, separate the test specimens from the runners in the gate area immediately after demolding. Do not modify or alter the edges used for the measurement of dimensions. It is recommended to cool specimens in a horizontal position at room temperature by placing them on a material of low thermal conductivity to minimize warpage. After the first hour, condition the specimens at  $23 \pm 2^\circ\text{C}$  and  $50\% \pm 5\text{ RH}$ , unless otherwise specified in the material standard.

### 10.3.2 Dimensional Measurement Conditioning Time Specification:

10.3.2.1 Initial shrinkage measurement shall be made on the specimen within one hour after the specimen has been demolded.

10.3.2.2 Twenty four hour shrinkage measurements shall be made  $24 \pm 0.5\text{ h}$  after the specimen has been demolded.

10.3.2.3 Forty eight hour shrinkage measurements shall be made  $48 \pm 0.5\text{ h}$  after the specimen has been demolded.

## 11. Calculation and Report

### 11.1

$$S_w = (W_m - W_s) \times 100/W_m \quad (1)$$

where:

$S_w$  = the shrinkage perpendicular to flow, %,

$W_m$  = the mold dimension perpendicular to flow, %,

$W_s$  = the specimen dimension perpendicular to flow, and

$$S_l = (L_m - L_s) \times 100/L_m \quad (2)$$

where:

$S_l$  = the shrinkage parallel to flow, %,

$L_m$  = the mold dimension parallel to flow, %, and,

$L_s$  = the specimen dimension parallel to flow.

Report mold shrinkage in both flow and cross direction to two significant figures.

### 11.2 The report shall include the following:

11.2.1 Details of any special preparation, such as drying, which the material received before molding;

11.2.2 The molding procedure used, following the report as outlined in Practice D 3641 for injection molding and Practice D 4703 for compression molding.

11.2.3 The initial shrinkage, the 24 h shrinkage and the 48 h shrinkage, if these were obtained, shall be expressed in percent (mm/mm) with each value representing the mean of determinations obtained on five or more specimens.

## 12. Precision and Bias

### 12.1 Precision:

12.1.1 Tables 1-3 summarize data from a round robin<sup>8</sup> conducted in 1988, using specimens Type A and Type B, involving five thermoplastics materials tested by eight laboratories. Each material was supplied in granular form to each of the testing laboratories by a single supplier. The resins were handled in accordance with the supplier's instructions and were molded in accordance with Practice D 3641. Each test result is the average of five individual determinations from successive injection molding cycles. Each laboratory obtained one test result for each material.<sup>8</sup>

NOTE 5—A round robin was conducted in Europe using specimen Type D2. When the results are published, they will be appended editorially to this test method.

12.1.2 Repeatability estimates  $S_r$  and  $r$  were made by treating the five individual determinations from successive injection molding cycles as test results. Poorer precision (larger values of  $S_r$  and  $r$ ) would be expected if the same operator were to shutdown and then restart the injection molding machine on the same day with the same mold, material and operating set points. Repeatability under such circumstances was not evaluated.

12.1.3 The following explanations of  $r$  and  $R$  only are intended to present a meaningful way of considering the approximate precision of this test method. The data in Tables 1-3 should not be rigorously applied to acceptance or rejection of material, as those data are 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 11.1.3 through 11.3.3 then would be valid for such data.

<sup>8</sup> Supporting data are available from ASTM Headquarters. Request RR: D-20-1158.

TABLE 1 Shrinkage from Mold Dimensions of I.M. Bars<sup>A</sup>

Material <sup>B</sup>	Average	$S_r$	$S_R$	$r$	$R$
1	0.00513	0.00008	0.00124	0.00022	0.00347
2	0.04108	0.00022	0.00754	0.00062	0.02111
3	0.00474	0.00021	0.00127	0.00059	0.00356
4	0.02107	0.00013	0.00280	0.00036	0.00784
5	0.01731	0.00017	0.00389	0.00048	0.01089

<sup>A</sup> Values expressed in mm/mm (in./in.).

<sup>B</sup> 1 = Polystyrene	Specification D 4549	PS110B56152
2 = Polyethylene	Specification D 4976	PE235
3 = PMMA	Specification D 788	PMMA0131V0
4 = Acetal	Specification D 4181	POM213
5 = Nylon (Polyamide)	Specification D 4066	PA111



**TABLE 2 Shrinkage from Mold Dimensions of I.M. Disks Flow Direction<sup>A</sup>**

Material <sup>B</sup>	Average	$S_r$	$S_R$	$r$	$R$
1	0.00463	0.00008	0.00124	0.00022	0.00347
2	0.03799	0.00035	0.00923	0.00098	0.02584
3	0.00420	0.00018	0.00170	0.00050	0.00476
4	0.02327	0.00021	0.00294	0.00059	0.00823
5	0.01941	0.00028	0.00348	0.00078	0.00974

<sup>A</sup> Values expressed in mm/mm (in./in.).

<sup>B</sup> 1 = Polystyrene	Specification D 4549	PS110B56152
2 = Polyethylene	Specification D 4976	PE235
3 = PMMA	Specification D 788	PMMA0131V0
4 = Acetal	Specification D 4181	POM213
5 = Nylon (Polyamide)	Specification D 4066	PA111

**TABLE 3 Shrinkage from Mold Dimensions of I.M. Disks Cross Direction<sup>A</sup>**

Material <sup>B</sup>	Average	$S_r$	$S_R$	$r$	$R$
1	0.00403	0.00010	0.00162	0.00028	0.00454
2	0.02040	0.00019	0.00247	0.00053	0.00692
3	0.00427	0.00013	0.00142	0.00036	0.00398
4	0.02528	0.00037	0.00471	0.00104	0.01319
5	0.02068	0.00047	0.00506	0.00132	0.01417

<sup>A</sup> Values expressed in mm/mm (in./in.).

<sup>B</sup> 1 = Polystyrene	Specification D 4549	PS110B56152
2 = Polyethylene	Specification D 4976	PE235
3 = PMMA	Specification D 788	PMMA0131V0
4 = Acetal	Specification D 4181	POM213
5 = Nylon (Polyamide)	Specification D 4066	PA111

12.1.4 *Concept of  $r$  and  $R$* —If  $S_r$  and  $S_R$  (standard deviations) have been calculated from a large enough body of data, and for test results that were averages from testing five specimens:

12.1.4.1 *Repeatability,  $r$  (Comparing Two Test Results, as Defined in 12.1.2, 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.

12.1.4.2 *Reproducibility,  $R$  (Comparing Two Test Results for the Same Material Obtained by Different Operators Using Different Equipment on Different Days)*—The two test results should be judged not equivalent if they differ by more than the  $R$  value for that material.

12.1.4.3 Any judgment made in accordance with 12.4.1 and 12.4.2 has an approximate 95 % probability of being correct.

12.1.4.4 *Results*—The  $r$  and  $R$  values are obviously a function of each material and its molding characteristics. It would be incorrect to assume values from Tables 1-3 for any new material.

12.2 *Bias*—It is known that the test result is as dependent in the experimental conditions as on the material itself. It is the intent of this method to control and document as many of these variables as possible. There are no recognized standards by which to estimate the bias of this test method.

### 13. Keywords

13.1 mold shrinkage; shrinkage; thermoplastics

## SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D20 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 955–00:

(1) This is a complete revision of Test Method D 955 and harmonization with ISO 294-3, -4. After several ballots, the negatives and comments that were accepted have been incorporated in this edition. The following changes have been made:  
(2) Title and Scope were changed to reflect that the test method is for thermoplastics only. New Test Method D 6289,

Test Method for Measuring Shrinkage from Mold Dimensions of Molded Thermosetting Plastics, was developed for thermosetting plastics.

- (3) 60 by 60 mm Type D2 specimens were added.
- (4) Drawings of specimens were added.
- (5) ISO equivalency statement was added.
- (6) Keywords were added.

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