Designation: D955 – 08 (Reapproved 2014)

Standard Test Method of Measuring Shrinkage from Mold Dimensions of Thermoplastics[1]

This standard is issued under the fixed designation D955; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

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 shrinkage measurements at 24 and 48 hours.

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 and temperature gradients and process conditions. Differences in mold shrinkage may also be observed among 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 standard and ISO 294-3 are equivalent in the design of specimen D2. This test method is equivalent to ISO 294-4 where Type D2 specimens and the procedure in Appendix X2 are used.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

D788 Classification System for Poly(Methyl Methacrylate) (PMMA) Molding and Extrusion Compounds

D883 Terminology Relating to Plastics

D3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials

D4066 Classification System for Nylon Injection and Extrusion Materials (PA)

D4549 Classification System and Basis for Specification for Polystyrene and Rubber-Modified Polystyrene Molding and Extrusion Materials (PS)

D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets

D4976 Specification for Polyethylene Plastics Molding and Extrusion Materials

D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens

D6778 Classification System and Basis for Specification for Polyoxymethylene Molding and Extrusion Materials (POM)

D6779 Classification System for and Basis of Specification for Polyamide Molding and Extrusion Materials (PA)

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

2.2 *ISO Standards:*[3]

ISO 293 Plastics—Compression Moulding Test Specimens of Thermoplastic Materials

ISO 294-1 Plastics—Injection Moulding of Test Specimens of Thermoplastic Materials—Part 1: General Principles, and Moulding of Multipurpose and Bar Test specimens

ISO 294-3 Plastics—Injection Moulding of Test Specimens of Thermoplastic Materials—Part 3: Small Plates

ISO 294-4 Plastics—Injection Moulding of Test Specimens—Part 4: Determination of Moulding Shrinkage

3. Terminology

3.1 *Definitions*—General definitions of terms applying to this test method appear in Terminology D883.

3.2 *Definitions of Terms Specific to This Standard:*

[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.

Current edition approved Aug. 1, 2014. Published August 2014. Originally approved in 1948. Last previous edition approved in 2008 as D955 - 08. DOI: 10.1520/D0955-08R14.

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

3.2.1 *jetting, n*—non-uniform multi-directional flow front apparent on the surface of the mold due to rapid filling of the mold cavity.

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 D3641 or ISO 294-4 or the appropriate material specification 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 D4703 or ISO 293 or the appropriate material specifications will improve the reproducibility of the test.

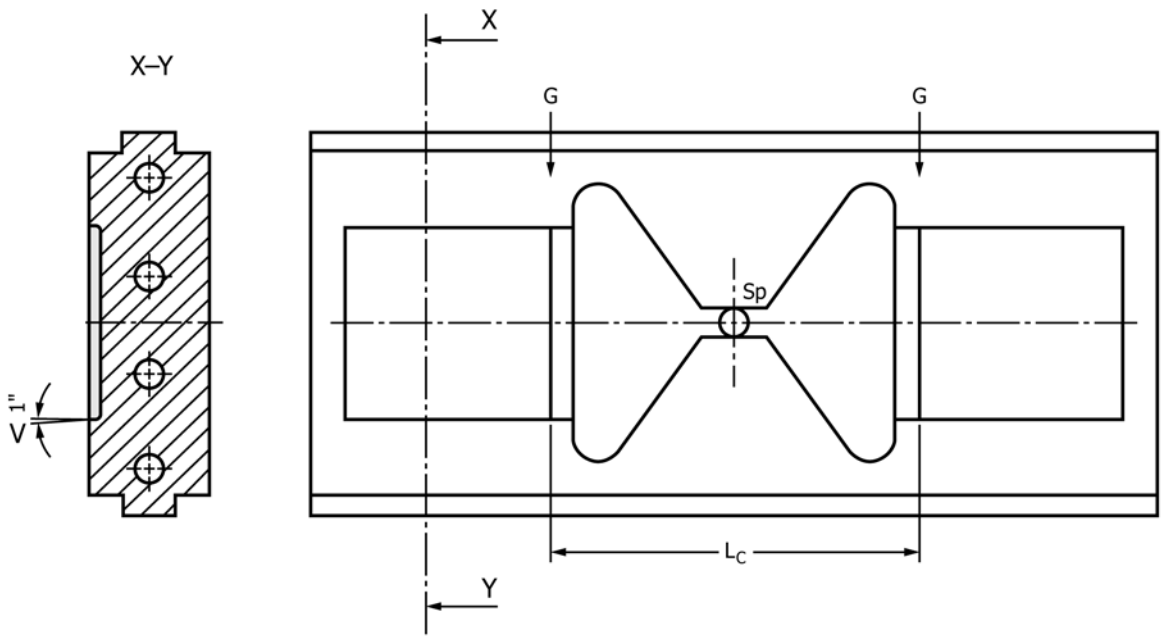
6. Sample Preparation

6.1 Some materials require special treatment before they are molded. For example, thermoplastics, which absorb moisture must be dried before molding. For required conditions for sample preparation, refer to the appropriate material specification or the manufacturer's recommendations if no specification is available. The preparation given to the material prior to molding shall be recorded and reported.

7. Apparatus

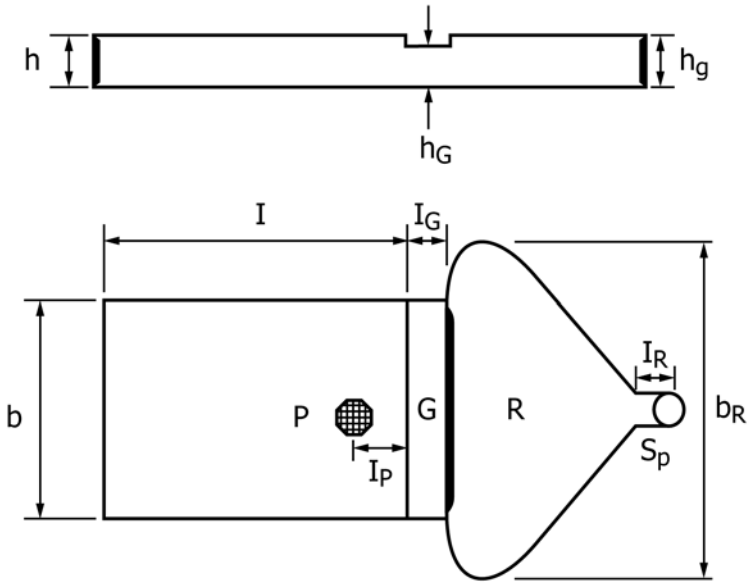
7.1 *Injection Mold*—Specimens shall be molded in a two cavity mold conforming with dimensions as shown in Figs. 1 and 2 for the 60 × 60-mm plaque specimen (Type D2), Fig. 3 for the 12.7 by 127-mm bar specimen (Type A) and Fig. 4 for the 100 mm by 3.2-mm disk specimen (Type B). Pressure transducers for monitoring the pressure in at least one cavity are mandatory for Type D2. Mold shrinkage measurements shall 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.



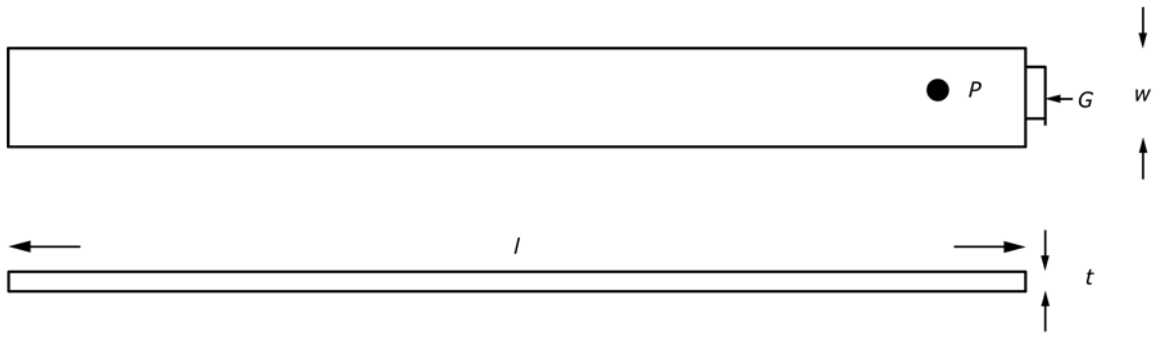
Sp I sprue
G I gate
L_c = distance between the lines along which the test specimens are cut from the runners
Molding volume = 20 000 mm^3
Projected area = 11 000 mm^2

FIG. 1 Type D2 (Mold Layout)



Sp	sprue	
G	gate	
R	runner	
P	pressure sensor	
l	length of plate	60 ± 2 mm
b	width of plate	60 ± 2 mm
h	thickness of plate	2.0 ± 0.1 mm
l_G	length of gate	4.0 ± 0.1 mm
h_G	height of gate	(0.75 ± 0.05) × h
l_R	length of runner	25 to 40 mm
b_R	width of runner	≥ (b + 6) mm
h_g	depth of runner at gate	
l*	unspecified distance	. . .
l_p	distance of pressure sensor from gate	5 ± 2 mm

FIG. 2 Type D2 (Cavity Details)



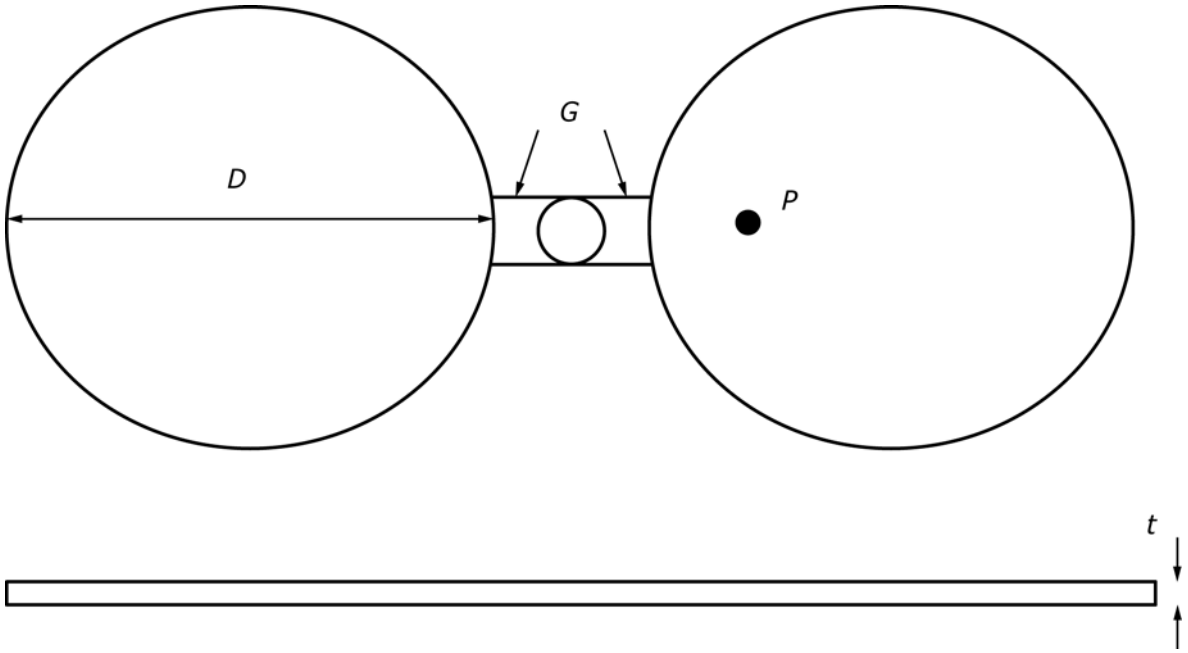
w = 12.7 ± 0.2 mm
t = 3.2 ± 0.05 mm
l = 127 ± 2 mm
G = Gate
P = Pressure Transducer

FIG. 3 Bar Specimen

NOTE 2—Although scribe marks are not required, if they are used for injection or compression molded specimens for the measurement of shrinkage, the scribe marks shall be 1.0 mm long by 0.1 mm wide located 4.0 mm from each edge on one side of the mold.

7.3 *Injection Press*—A suitable injection molding machine that shall fill the test molds when it is operated in the range from 20 to 80 % of its rated shot capacity at the molding parameters specified in Practice D3641, ISO 294-3 or the appropriate material specification.

NOTE 3—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



t = 3.2 ± 0.05 mm
D = 100 ± 2 mm
G = Gate
P = Pressure Transducer

FIG. 4 Disk Specimen

fall within the specified limits.

7.4 *Compression Press*—A suitable hydraulic press that shall 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 D5947.

8. Test Specimen

8.1 The following specimen dimensions are applicable for both compression and injection molding. Orientation effects due to flow direction do not generally pertain to compression molding.

8.1.1 *Specimen Type D2*—For mold shrinkage in both flow and cross flow the preferred specimen shall be 60 by 60 by 2 mm depth conforming to the dimensions of Fig. 2.

8.1.2 *Specimen Type A*—For shrinkage parallel to flow, a bar mold having a cavity of 12.7 by 127 mm shall 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.

8.1.3 *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, shall be used.

NOTE 4—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 8.1.1 and 8.1.2.

9. Conditioning

9.1 *Conditioning*—Conditioning of molded specimens shall be done in the Standard Laboratory Atmosphere, 23 ± 2°C and 50 % ± 10 RH, if not otherwise specified in the appropriate materials standard.

9.2 *Test Conditions*—Conduct measurement in the standard laboratory atmosphere of 23 ± 2°C and 50 % ± 10 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 ± 2°C and 50 % ± 10 RH. Record these values as *l* and *w*, respectively.

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

NOTE 5—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 D3641 or ISO 294-3. 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 ensure the flow front is straight and not radial and that the flow is laminar and does not exhibit melt fracture (jetting). 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 D4703.

10.3 *Treatment of Specimens after Removal from the Mold:*

10.3.1 In order to minimize warpage, separate the test specimens from the runners in the gate area immediately after removal from the mold. 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 ± 2°C and 50 % ± 5 RH, unless otherwise specified in the material standard.

10.3.2 *Specification of Measurement Time:*

10.3.2.1 Twenty four hour shrinkage measurements shall be made 24 ± 0.5 h after the specimen has been removed from the mold.

10.3.2.2 Forty eight hour shrinkage measurements shall be made 48 ± 0.5 h after the specimen has been removed from the mold.

11. Calculation and Report

11.1

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

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

$$S_1 = (L_m - L_s) \times 100/Lm \quad (2)$$

where:

S_1 = 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 material preparation, such as drying, which the material received before molding;

11.2.2 The molding procedure used, following the report as outlined in Practice D3641 for injection molding and Practice D4703 for compression molding.

11.2.3 The 24-hour shrinkage and the 48-hour shrinkage 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[4] 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 D3641. Each test result is the average of five individual determinations from successive injection molding cycles. Each laboratory obtained one test result for each material.[8]

NOTE 6—A repeatability study was conducted in Europe using specimen Type D2. The results, including suggested cavity hold pressure for various materials, are shown in Appendix X1.

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 rejected 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 E691 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.

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.

[4] Supporting data are available from ASTM Headquarters. Request RR: D-20-1158.

TABLE 1 Shrinkage from Mold Dimensions of I.M. Bars[A]

Material [B]	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

[A] Values expressed in mm/mm (in./in.).

[B] 1 = Polystyrene — Specification D4549 — PS110B56152
2 = Polyethylene — Specification D4976 — PE235
3 = PMMA — Specification D788 — PMMA0131V0
4 = Acetal — Specification D6778 — POM0213
5 = Nylon (Polyamide) — Specification D6779 — PA0111

TABLE 2 Shrinkage from Mold Dimensions of I.M. Disks Flow Direction[A]

Material [B]	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

[A] Values expressed in mm/mm (in./in.).

[B] 1 = Polystyrene Specification D4549 PS110B56152
2 = Polyethylene Specification D4976 PE235
3 = PMMA Specification D788 PMMA0131V0
4 = Acetal Specification D6778 POM0213
5 = Nylon (Polyamide) Specification D6779 PA0111

TABLE 3 Shrinkage from Mold Dimensions of I.M. Disks Cross Direction[A]

Material [B]	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

[A] Values expressed in mm/mm (in./in.).

[B] 1 = Polystyrene Specification D4549 PS110B56152
2 = Polyethylene Specification D4976 PE235
3 = PMMA Specification D788 PMMA0131V0
4 = Acetal Specification D6778 POM0213
5 = Nylon (Polyamide) Specification D6779 PA0111

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 of 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 form 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

APPENDIXES

(Nonmandatory Information)

X1. REPEATABILITY STUDY DATA

X1.1 See Table X1.1.

TABLE X1.1 Repeatability Data for ISO 294-3⁄-4 Moulding Shrinkage

Material	Cavity hold pressure	Shrinkage (standard deviation)	
	MPa	%, In Flow	%, Cross Flow
PA 6	70	0.958(0.004)	1.007(0.003)
PA 6-GF15	70	0.418(0.003)	0.553(0.004)
PA 6-GF30	70	0.205(0.004)	0.671(0.004)
PA 6-GF50	70	0.204(0.008)	0.672(0.007)
PA 6-BM 230	70	0.925(0.004)	0.067(0.007)
PA 6-3-T	70	0.444(0.006)	0.468(0.006)
PA 4.6	70	1.538(0.006)	1.655(0.004)
PA 6/6T	90	0.319(0.006)	0.338(0.003)
PA 66-GF30	70	0.355(0.006)	0.951(0.002)
PA 612	70	1.399(0.004)	1.388(0.005)
PA 11	70	1.236(0.003)	1.265(0.004)
PA 12	70	1.066(0.005)	1.195(0.005)
PBT	70	1.680(0.006)	1.665(0.005)
PBT-GF10	70	0.695(0.005)	0.924(0.006)
PBT-GF15	70	0.508(0.003)	0.928(0.008)
PBT-GF20	70	0.385(0.002)	0.882(0.004)
PBT-GF30	70	0.293(0.004)	0.846(0.004)
PBT-GF50	70	0.260(0.003)	0.640(0.003)
PBT-GK30	60	1.632(0.006)	1.497(0.003)
PEBA	50	0.644(0.004)	1.222(0.004)
PMMA	70	0.371(0.002)	0.401(0.006)
PS	50	0.459(0.003)	0.457(0.002)
PS-HI	50	0.434(0.003)	0.451(0.003)
SAN	50	0.420(0.003)	0.406(0.003)
ABS (mass)	50	0.567(0.005)	0.596(0.004)
ABS (emulsion)	50	0.619(0.004)	0.625(0.002)

TABLE X1.1 *Continued*

Material	Cavity hold pressure	Shrinkage (standard deviation)	
	MPa	%, In Flow	%, Cross Flow
PC	50	0.743(0.003)	0.745(0.003)
PC-GF20	50	0.327(0.004)	0.476(0.003)
PET-GF30	70	0.253(0.003)	0.774(0.005)
PPE	50	1.057(0.006)	1.065(0.005)
PVDF	50	2.550(0.002)	2.210(0.004)
PP	70	0.806(0.002)	0.945(0.005)
POM (homo)	90	2.139(0.004)	2.100(0.005)
POM (copo)	90	1.910(0.007)	1.846(0.004)
LCP-GF30	50	0.010(0.002)	0.348(0.003)
PSU	50	0.719(0.002)	0.760(0.003)
PES	50	0.817(0.004)	0.849(0.006)
PPS-GF40	50	0.232(0.004)	0.588(0.004)
PS	70	0.238(0.003)	0.237(0.003)

X2. SPECIMEN D2 PREPARATION

X2.1 The molding shrinkage is preferably determined for one or more values of the cavity pressure at hold selected from 20 MPa, 40 MPa, 60 MPa, 80 MPa and 100 MPa. Intermediate values may also be used, however.

NOTE X2.1—For values higher than 80 MPa, a correspondingly high locking force will be necessary, and this may not be possible with normal commercial equipment.

X2.2 Determine the hold pressure which corresponds to each selected value of cavity pressure at hold and mold test specimens at each of these pressures, taking into account of the following additional instructions.

X2.2.1 Select the change-over point, between the injection and hold periods carefully to avoid a depression in the time against pressure curve (see Fig. X2.1, Curve c) and to avoid a peak that, during the 1 second following the change-over point, exceeds the cavity pressure at hold by more than 10 % (see Fig. X2.1, Curve b). Due to the inertia of the injection-molding machine, the effective change-over time is longer than its nominal value. The correct change-over point shall therefore be adjusted individually for each value of the injection speed and for each material under test.

NOTE X2.2—Peaks in the cavity pressure lead to transient overloading of the cavity, followed by partial backflow of the melt. Thus the mass of material injected into the cavity is not clearly defined and the orientation of the material near the gate will be perturbed.

X2.2.2 Keep the hold pressure constant during the hold period.

X2.2.3 For the hold time, see 5.2.4 of ISO 294-1:1996. The decrease in the cavity pressure at hold to zero indicates that the material in the gate has solidified sufficiently to stop flow into the cavity.

X2.2.4 Select the cooling time to be the minimum value at which the moldings can be removed from the mold without distortion. As the cooling rate of the material is proportional to the square of the reciprocal of the thickness, the minimum

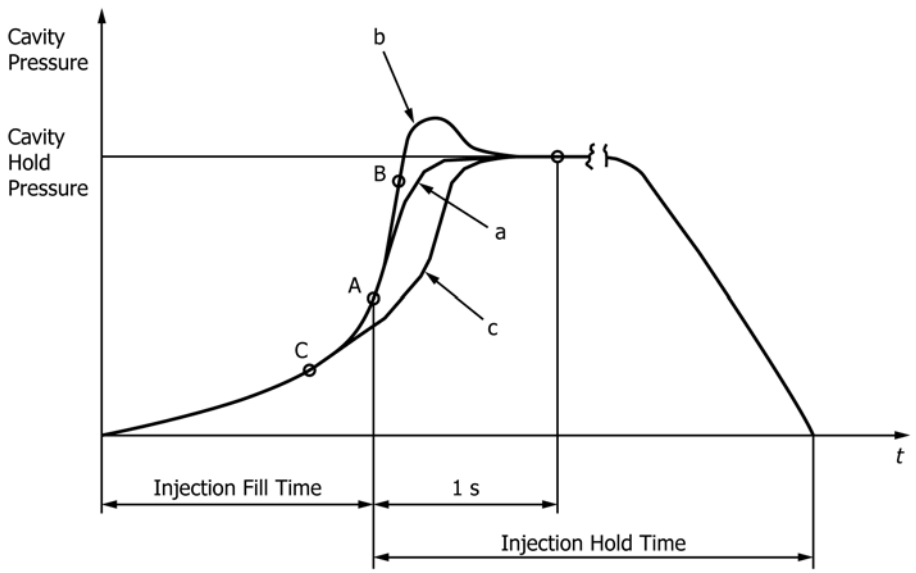


FIG. X2.1 Schematic Plot of Cavity Pressure Versus Time Showing the Influence of the Injection Time When Selected Correctly (near point A, resulting in Curve a), When too Late (for example, at point B, resulting in Curve b), and When too Early (for example, at point C, resulting in Curve c)

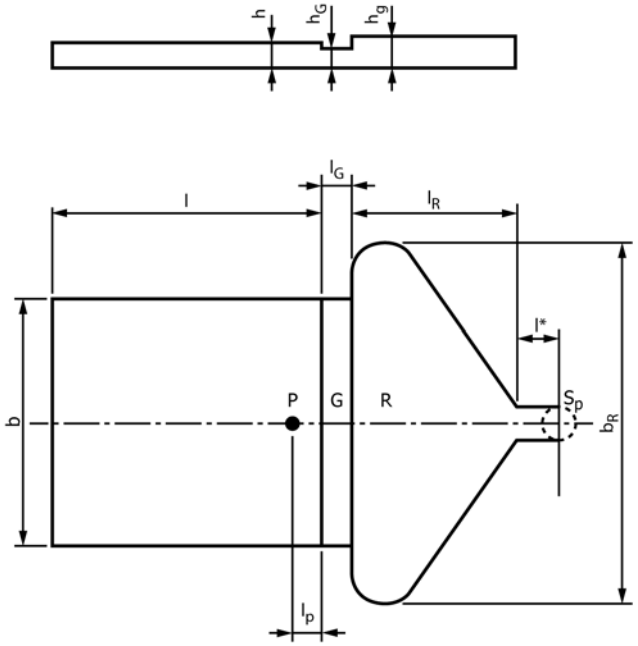
cooling time (for the cavity) can be expected to be close to 1.8 times the hold time (cooling time for the gate) for the gate height to plate thickness ration of 3:4 in ISO 294-3.

X2.2.5 For the maintenance of steady-state conditions, see 5.2.5 of ISO 294-1:1996.

X2.2.6 The change in curvature near A in Fig. X2.1 indicates the transition from the melt-flow period to the bulk-compression period. At point R, the value of the cav ity pressure at hold is recorded. The minimum hold time can be read from the decrease of the cavity pressure to zero.

X3. D955–00 SPECIMEN D2 (OBSOLETE)

X3.1 See Fig. X3.1.



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_G	length of gate	4.0 ± 0.1
h_G	height of gate	(0.75 ± 0.05) × h
l_R	length of runner	25 to 40
b_R	width of runner	≥ (b + 6)
h_g	depth of runner at gate	h + (1.5 ± 0.05)
l*	unspecified distance	. . .
l_p	distance of pressure sensor from gate	5 ± 2

FIG. X3.1 ASTM D955-00 Fig. 2 Type D2