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An American National Standard

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

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] 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 Nov. 24, 1989. 10, 2000. Published January 1989. 2001. Originally published as D 955 – 48T. Last previous edition D 955 – 89 (1996).

1. Scope*

1.1 This test method is intended to measure batch-to-batch uniformity in initial shrinkage from mold cavity to molded dimensions of either thermoplastic or thermosetting materials thermoplastics when molded by compression, injection, compression or transfer under injection processes with specified process conditions.

1.2 This test method does not provide for the measurement of shrinkages that 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 m parts with varying flow paths, wall thicknesses, pressure gradients and process conditions. Differences in mold shrinkage, mafty also be observed between the first 48 h out of the mold.

1.3 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.

1.45 *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 618 Practice 374 Test Methods for Conditioning Plastics and Thickness of Solid Electrical Insulating Materials for Testing Insulation[2]

[2] *Annual Book of ASTM Standards*, Vol 10 8.01.

D 6477<u>18</u> Practice for ~~Design of Molds for Test Specimens of Plastic Molding~~ Conditioning Plastics and Electrical Insulating Materials for Testing[3]

D 788 ~~Spec~~Classification System for Poly(Methyl Methacrylate) (PMMA) Molding and Extruension Compounds[3]

D ~~796 Practice for Compression Molding Test Specimens of Phenolic Molding Compounds[2]~~ 883 Terminology Relating to Plastics[3]

D ~~883 Terminology Relating to Plastics[2]~~ 3641 Practice for Injection Molding of Test Specimens of Thermoplastic Molding and Extrusion Materials[4]

D ~~956 Practice~~ 4066 Specification for ~~Compression Molding Specimens of Amino Molding Compounds[2]~~ Nylon Injection and Extrusion Materials[4]

D ~~1896 Practice~~ 4181 Specification for ~~Transfer~~ Acetal (POM) Molding ~~Test Specimens of Thermosetting Compounds[2]~~ and Extrusion Materials[4]

D ~~1897 Practice~~ 4549 Specification for ~~Injection~~ Polystyrene Molding ~~Test Specimens of Thermoplastic Molding~~ and Extrusion Materials (PS)[5]

D ~~1898 Practice~~ 4703 Practice for ~~Sa~~ Compression Molding of ~~P~~ Thermoplastic Materials into Test Specimens, Plaques, Sheets[5]

D ~~3419 Practice~~ 4976 Specification for ~~In-Line Screw-Injection~~ Polyethylene Plastics Molding ~~Test Specimens from Thermosetting Compounds[3]~~ and Extension Materials[5]

D ~~4066 Specification~~ 5947 Test Methods for ~~Nylon Injection and Extrusion Materials[3]~~

~~D 4181 Specification for Acetal (POM) Molding and Extrusion Materials[3]~~

D 4549 Specification for Polystrene Molding and Extrusion Materials (PS)[6]
D 4976 Specification for Polyethylene Physical Dimensions of Solid Plastics Molding and Extrusion Materials[4] Specimens[5]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[7]
2.2 *ISO Standards:*
ISO 293 Plastics—Compression Moulding Test Specimens of Thermoplastic Materials[8]
ISO 294-3 Plastics—Injection Moulding of Test Specimens of Thermoplastic Materials—Part 3: Small Plates[7]
ISO 294-4 Plastics—Injection Moulding of Test Specimens—Part 4: Determination of Moulding Shrinkage[7]

3. Terminology

3.1 *Definitions*—General—D 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.

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

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 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
5.1 *Injection Molding*—In injection molding, as in compression molding, the difference between the dimensions of the a mold cavity and of the molded article produced therein from a given material specimen may vary according to the design and operation of the mold. The difference may vary with the type mold 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 molding process. Factors such 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 melt temperature, fill times, and packing conditions are known to be forced firmly into all of the recesses of the mold. The plasticity of the material used may affect shrinkage indirectly, significantly. Adherence to the specified mold design (see 7.1) and specifications outlined in that Practice D 3641 or ISO 294-4 or the more readily plasticized appropriate material will require a lower molding temperature.
4.3 *Transfer improve the reproducibility of the test.*
5.2 *Compression Molding*—In transfer molding, as in compression or injection molding, the difference between the dimensions of the a mold cavity and of the molded article produced therein from a given material specimen may vary according to the design of the mold and operation of the mold. It is affected by molding process. Factors, such as the size and temperature amount of the pot or cylinder material in charge, cooling time, 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.

5. Sample Preparation

5.1 Some materials require special treatment before they application are molded. For example, thermoplastics which absorb moisture must be dried before molding. Materials known to be tested shall be prepared for molding in accordance with the manufacturer's recommendations. The preparation given affect shrinkage significantly. Adherence to the material prior to molding shall be recorded 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.

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[3] *Annual Book of ASTM Standards*, Vol 08.021.
[5] *Annual Book of ASTM Standards*, Vol 14.02. 08.03.
[6] *Annual Book of ASTM Standards*, Vol 08.032.
[7] Supporting data are available from
[7] *Annual Book of ASTM Headquarters. Request RR: D-20-1158. Standards*, Vol 14.02.
[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

~~6.1 *Compression Mold*—A single bar, single-cavity positive mold having a cavity cross-section 12.7 by 127 mm (½ by 5 in.) and a loading depth sufficient to obtain a molded bar 12.7 mm (½ in.) in thickness, or for diametral shrinkage, a single cavity positive 102-mm (4-in.) disk mold. Both shall conform to Practice D 647.~~

~~6.2 *Injection Mold*—For shrinkage parallel to flow, an impact bar mold having a cavity 12.7 by 127 mm (½ by 5 in.). The thickness shall be 3.2 mm (⅛ in.), unless otherwise agreed upon by the seller and the purchaser. The mold shall have at one end a gate 6.4 mm (¼ in.) in width by 3.2 mm (⅛ in.) in depth (Note 1). For diametral shrinkage, where shrinkage both parallel to flow and transverse to flow are to be measured, the mold shall have a cavity 102 mm (4 in.) in diameter by 3.2 mm (⅛ in.) in thickness with a gate, placed radially at the edge, 12.7 mm (½ in.) in width by 3.2 mm (⅛ in.) in depth.~~

~~NOTE 1—If, for any reason, a test specimen of thickness greater than 3.2 mm (⅛ in.) is agreed upon, the depth of the gate may be greater than 3.2 mm (⅛ in.) and must be reported.~~

~~6.3 *Transfer Mold*—An impact bar mold having a cavity 12.7 by 12.7 by 127 mm (½ by ½ by 5 in.) and having either an end gate or top gate at one end 6.4 by 1.52 mm (⅛ by 0.060 in.) in depth.~~

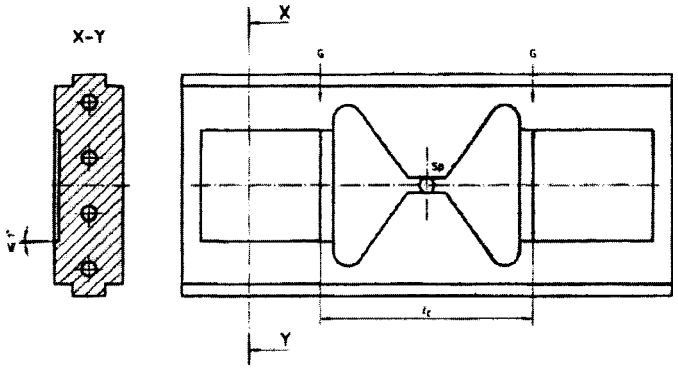
~~6.4 *Compression Press*—A suitable hydraulic press that will deliver a pressure of 20 to 35 MPa (3000 to 5000 psi) to the material in the mold.~~

7.1 *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 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.

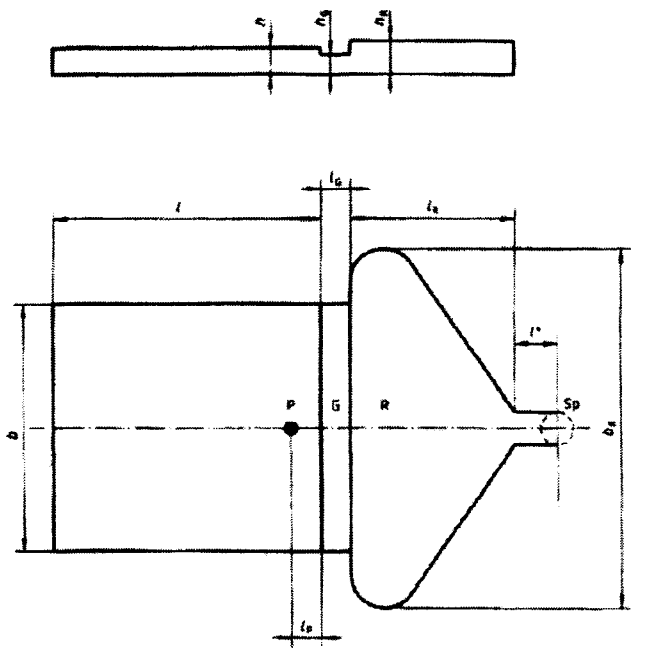
7.3 *Injection Press*—A suitable injection- molding machine that will fill the test molds when it is operated in the range from ~~one half~~ 20 to ~~three fourths~~ 80 % of its rated shot capacity at ~~melt temperatures recommended by~~ the molding parameters specified in Practice D 3641, ISO 294-3 or the appropriate material ~~supplier. Different screw and barrel configurations are required for thermoplastic and thermoset materials.~~ specification.

NOTE 2—If the injection machines of appropriate capacity are not available, the requirements of ~~6.5~~ 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.



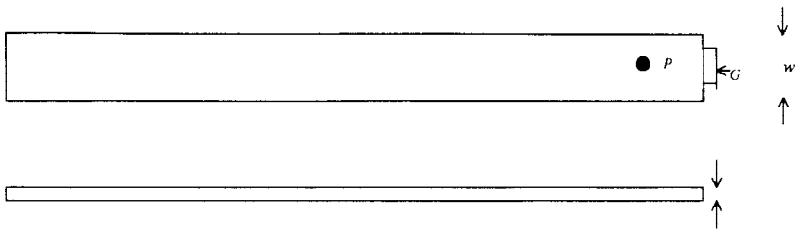
Sp	sprue	molding volume = 30 000 mm^3
G	gate	projected area = 11 000 mm^2
lc = distance between the lines along which the test specimens are cut from the runners		

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_G	length of gate	4.0 ± 0.1
h_G	height of gate	(0.75 ± 0.05) × h^3
l_R	length of runner	25 to 40
b_R	width of runner	≥ (b + 6)
h_a	depth of runner at gate	h + (1.5 ± 0.5)
l*	unspecified distance	. . .
l_p	distance of pressure sensor from gate	5 ± 2

FIG. 2 Type D2



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

FIG. 3 Bar Specimen

6.6 *Transfer Press*—A suitable hydraulic press that will deliver a pressure of 70 to 140 MPa (10 000 to 20 000 psi) on the material in the pot of the die or the cylinder of the press.

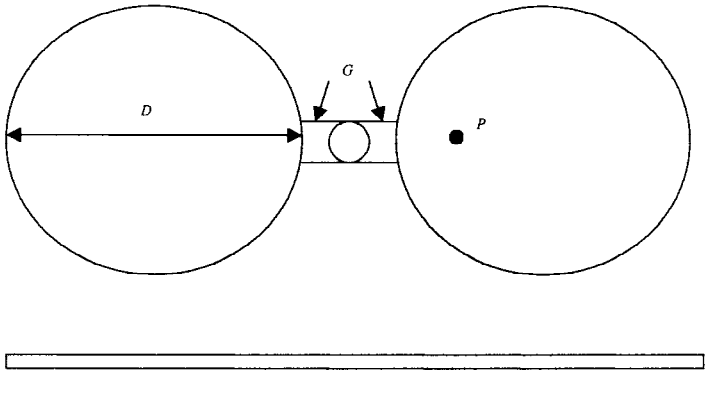
6.7 *Balance*—A balance for weighing compression-molding charges.

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 the test specimens.

7. Test Specimens

7.1 *Compression-Molding Materials*—For mold shrinkages of compression-molding materials, the test specimens shall be bars, 12.7 by 12.7 by 127 mm (½ by ½ by 5 in.), or a disk 3.2 mm (⅛ in.) in thickness and 102 mm (4 in.) in diameter, made in a positive



t = 3.2 +/- 0.05 mm
D = 100 +/- 2mm
G = Gate
P = Pressure Transducer

FIG. 4 Disk Specimen

mold in such a way as conforming to minimize lateral movement of the plastic during the molding.

7.2 *Injection-Molding Materials*—For mold shrinkage of injection-molding materials, specimens of two types shall be used: (*1*) bars 12.7 by 3.2 by 127 mm (½ by ⅛ by 5 in.), gated at the end to provide flow throughout the entire length, shall be used for measurements of shrinkage measuring tool requirements in the direction of flow, and (*2*) disks, 3.2 mm (⅛ in.) in thickness and 102 mm (4 in.) in diameter, gated radially at a single point in the edge, shall be used for measurements of shrinkages of diameters parallel and perpendicular to the flow.

7.3 *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, shall be used for measurement of shrinkage in the direction of flow. A disk specimen 3.2 mm (⅛ in.) in thickness and 102 mm (4 in.) in diameter gated radially at a single point in the edge, shall be used for measurements of shrinkages of diameters parallel and perpendicular to the flow. Test Methods D 374.

8. Conditioning Test Specimen

8.1 *Conditioning*—ConditioningSpecimen Type D2—For mold shrinkage in both flow and cross flow of compression and injection molding materials the preferred specimens shall be 60 × 60 × 2 mm depth coneforming to the Standard Laboratory Atmosphere, 4.2, dimensions of Practice D 618 for various lengths of time as discussed in 9.3. Fig. 2.

8.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphereSpecimen Type A—For shrinkage parallel to flow, a bar mold having a cavity of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 percent relative humidity, 12.7 × 127 mm may be used as shown in Fig. 3. The thickness shall be 3.2 mm unless otherwise specified in agreed upon by the test methods or 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 specification. In cases of disagreement, specimen may be used to determine mold shrinkage in both the flow and cross flow directions, the filling patteran does not produce uniform flow lengths and orientation. Consequently, there mally be ±1°C (±1.8°F) 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 ±2 percent relative humidity. 8.2.

9. Conditioning

9.1 *Conditioning*—Conditioning of molded specimens shall be done in the Standard Laboratory Atmosphere, 23 ± 2°C and 50 % ± 5 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 % ± 5 RH, if not otherwise specified in the appropriate materials standard.

10. Procedure

910.1 Measure the length and width of the mold cavity of at the bar mold, center of each edge or at the diameter of the cavity of the disk mold parallel and perpendicular molded scribe marks, to the flow, to the nearest 0.025 mm (0.001 in.). Make the measurements at standard laboratory temperature 23 ± 2°C and 50 % ± 5 RH. Record these values as defined in 4.1 of Practice D 618.

9.2 Mold *l* and *w*, respectively.

10.2 Mold at least five sound flat test specimens from the sample to be tested, under such conditions of pressure, temperature, time, etc., as the manufacturer and the purchaser may agree are suitable for the material. In the absence of other definite

recommendations, the following are suggested as suitable molding procedures for plastics of various types:

9.2.1 *Thermoplastics Molded tests.*

NOTE 4—Flat is represented by Compression—For thermoplastics, such as cellulose acetate, load the mold evenly at room temperature a specimen with the requisite quantity of granular material, also at room temperature, and place the mold less than 3 % warp. Three percent warp is defined as 3 mm depth deflection, positive or negative, per 100 mm in a hydraulic press such that a pressure of 20 to 35 MPa (3000 to 5000 psi) on the projected area of the mold cavity can be applied and the mold can be heated to 121 to 129°C (250 to 265°F) in 5 to 10 min. Apply heat and pressure, within these ranges, to mold the specimen. Cool the mold to room temperature under pressure and discharge the specimen. The rate of heating, the maximum temperature reached, and the rate of cooling do not seem critical, but the temperature of the mold at the time of discharge should be definitely controlled.

9.2.2 length.

10.2.1 *Thermoplastics Molded by Injection*—Molding of thermoplastic materials should shall be carried out conducted in accordance with the appropriate material standard, Practice D 1897. D 3641, or ISO 294-3, or both. The molding machine used should be such that it is operated without exceeding one half to three fourths of its rated shot capacity. The temperature of the heating cylinder should and the mold shall be maintained at a point which will which, on a cycle selected, produce a melt at a will produce temperature within the range recommended by the manufacturer of the material. The mold should be maintained at material molding standard. Begin with a temperature recommended by short shot to insure flow is straight and not partly radial and that the material manufacturer flow is laminar and should be maintained within 3°C (5°F) of does not exhibit melt fracture. Collect samples after the prescribed temperature.

9.2.3 machine is at equilibrium.

10.2.2 *Thermoplastics Molded by Transfer*— The press used for transfer Compression—For thermoplastics, molding thermoplastics should shall be of a size that will permit operation under a pressure on conducted in accordance with the stock pot appropriate material standard or cylinder D 4703.

10.3 *Treatment of from 70 to 140 MPa (10 000 to 20 000 psi). The temperature of the cylinder and of the die should be maintained at a point that will yield smooth pieces.*

9.2.4 *Thermosetting Materials Molded by Compression Specimens After Demolding*:

9.2.4.1 *Urea Type*—Molding of thermosetting materials of

10.3.1 In order to minimize warpage, separate the urea type should be carried out test specimens from the runners in accordance with Practice D 956.

9.2.4.2 *Phenolic Type*—Molding of thermosetting materials of the phenolic type should be carried out 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 accordance with Practice D 796.

9.2.4.3 *Epoxy Type*—Molding a horizontal position at room temperature by placing them on a material of thermosetting materials of the epoxy type low thermal conductivity to make physical and electrical test 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 *Dimensional Measurement Conditioning Time Specification*:

10.3.2.1 Initial shrinkage measurement shall be carried out as follows:

Item	Molding Condition made on the specimen
	within one hour after the specimen has been demolded.

10.3.2.2 Twenty four hour shrinkage measurements shall be mad

10.3.2.3 Forty eight hour shrinkage measurements shall be made

11. Calculation and Report

11.1

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

where:

	Charge
S_w	=
Preheating	none
Molding temperature	149 to 178°C (300 to 350°F)
Molding temperature	149the shrinkage perpendicular to 178°C (300 to 350°F)
Pressure flow, %,	
W_m	=
W_m	=
Molding time flow, %	
W_s	=

W_s =

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

9.2.5 *Thermosetting Materials Molded by Transfer*—The press used should be such that pressure in the stock pot or cylinder can be maintained in the range between 55 and 140 MPa (8000 and 20 000 psi). The temperature of the cylinder should be such that the entire charge can be forced into the die before premature curing can take place, which would be evidenced by roughness and poor finish.

NOTE 3—Soft flow epoxy molding materials require a press suitable to deliver 4 to 14 MPa (500 to 2000 psi) to the material in the pot. See also Practice D 1896.

9.2.6 *Thermosetting Materials Molded by Injection*—The molding machine used shall be such that the injection pressure can be controlled between 70 and 140 MPa (10 000 to 20 000 psi). The capacity shall be adequate to produce a shot within one half to three fourths of the rated capacity. The cylinder and mold heating systems shall be capable of heating the shot and the mold to the temperatures required by the material specification. The molding should be carried out in accordance with Practice D 3419.

9.3 After molding, allow the specimens to cool in the Standard Laboratory Atmosphere prescribed in 4.2 of Methods D 618 before being measured. Standard

where:

S_1 = the shrinkage measurements shall be made parallel to determine the "48-h" or "normal" flow, %,

L_m = the mold shrinkage. Shrinkage occurring during shorter periods of time designated "initial" molding shrinkage or "24-h shrinkage" as defined below are optional and may be made upon agreement between the buyer and the seller. The period of storage for "initial molding shrinkage" for specimens 3.2 mm (⅛ in.) in thickness shall be from 1 dimension parallel to 2 h; for specimens 6.4 mm (¼ in.) in thickness, 2 to 4 h; and for specimens 12.7 mm (½ in.) in thickness, from 4 to 6 h. Measure the length or diameter of each flow, %, and,

L_s = the specimen at Standard Room Temperature dimension parallel to the nearest 0.02 mm (0.001 in.) and then return the specimens to storage in the Standard Laboratory Atmosphere. Measure the specimens again not less than 16 nor more than 24 h after molding, in order to obtain the "24-h shrinkage," and again not less than 40 nor more than 48 h after molding, in order to determine the "48-h" or "normal" flow.

Report mold shrinkage.

10. Calculation and Report

10.1 Calculate the shrinkage per millimetre (or inch) by subtracting the dimension of the specimen from the corresponding dimension of the mold cavity in which it was molded both flow and dividing the difference by the latter.

NOTE 4—Expansion per millimetre (or inch) is calculated by subtracting the dimension of the mold from the corresponding dimension of the specimen and dividing by the former. The positive value thus obtained must be specifically reported as expansion.

10.2 The cross direction to two significant figures.

11.2 The report shall include the following:

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

10.1.2.2 The molding procedure used.

10.2.3 For compression molding, used, following the form and distribution of the mold charge and the molding pressure, temperature, and time.

10.2.4 For report as outlined in Practice D 3641 for injection molding, the temperatures of the cylinder, the mold, and the plastic from the nozzle, the type and size of the nozzle, the molding pressure, the molding cycle, and Practice D 4703 for compression molding.

11.2.3 The initial shrinkage, the make, type, 24 h shrinkage and size of the machine used.

10.2.5 For transfer molding, the temperature of the pot or cylinder, the mold temperature, the pressure on the pot, and the molding cycle.

10.2.6 The "48-h" 48 h shrinkage, and the "initial" and "24-h shrinkage", if these were to be obtained, shall be expressed in millimetres per millimetre (or inches per inch) percent (mm/mm) with each value representing the mean of values determinations obtained on five or more specimens.

11 12. Precision and Bias

11 12.1 *Precision*:

11 12.1.1 Tables 1-3 summarize data from a round robin[9] 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 1897.~~ 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.~~8~~

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.

11 12.1.2 Repeatability estimates ~~S_r~~ 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~~ 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. The repeatability estimates may, however, be used to judge individual members of the five sample sets as described in 11.1.3.~~

~~NOTE 5—**Caution:** The~~ evaluated.

12.1.3 The following explanations of *r* and ~~and *R* (11.1.3-11.1.3.3) are~~ 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~~ 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 E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of ~~11.1.3-11.1.3.3 would~~ 11.1.3 through 11.3.3 then would be valid for such data.

11 12.1.3 4 *Concept of r and R*—If ~~S_r~~ and ~~S_R~~ 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:*

11 12.1.3 4.1 *Repeatability, r (Comparing Two Test Results, as Defined in ~~r (comparing two test results~~ 12.1.2, for the s Same m Material o Obtained by the s Same o Operator u Using the s Same e Equipment on the s Same d Day)*—The two test results should be judged not equivalent if they differ by more than the *r* value for that material.

11 12.1.3 4.2 *Reproducibility, R (~~c~~Comparing ~~t~~ Two ~~t~~ Test ~~r~~ Results for the ~~s~~ Same ~~m~~ Material ~~o~~ Obtained by ~~d~~ Different ~~o~~ Operators ~~u~~ Using ~~d~~ Different ~~e~~ Equipment on ~~d~~ Different ~~d~~ Days)*—The two test results should be judged not equivalent ~~if~~ of they differ by more than the *R* value for that material.

11 12.1.3 4.3 Any judgment made in accordance with ~~11.1.2.1~~ 12.4.1 and ~~11.1.2.2~~ 12.4.2 has an approximate 95 % ~~(0.95)~~ probability of being correct.

11 12.1.4.4 *Results*—The *r* and ~~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.

11 12.2 *Bias*—It is known that the test result is as dependent ~~on~~ 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

[9] 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 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[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 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[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 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

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.