



## Standard Specification for Polypropylene Injection and Extrusion Materials<sup>1</sup>

This standard is issued under the fixed designation D 4101; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

### INTRODUCTION

This specification is not intended for the selection of materials but only as a means to call out plastic materials to be used for the manufacture of parts. The selection of these materials is to be made by personnel with expertise in the plastics field where the environment, inherent properties of the materials, performance of the part, part design, manufacturing process, and economics are considered.

#### 1. Scope \*

1.1 This specification covers polypropylene materials suitable for injection molding and extrusion. Polymers consist of homopolymer, copolymers, and elastomer compounded with or without the addition of impact modifiers (ethylene-propylene rubber, polyisobutylene rubber, and butyl rubber), colorants, stabilizers, lubricants, or reinforcements.

1.2 This specification allows for the use of those polypropylene materials that can be recycled, reconstituted, and reground, provided that: (1) the requirements as stated in this specification are met, and (2) the material has not been modified in any way to alter its conformance to food contact regulations or similar requirements. The proportions of recycled, reconstituted, and reground material used, as well as the nature and the amount of any contaminant, cannot be practically covered in this specification. It is the responsibility of the supplier and the buyer of recycled, reconstituted, and reground materials to ensure compliance. (See Guide D 5033.)

1.3 The values stated in SI units are to be regarded as the standard.

NOTE 1—The properties included in this specification are those required to identify the compositions covered. There may be other requirements necessary to identify particular characteristics important to specific applications. These will be designated by using the suffixes given in Section 1.

1.4 The following safety hazards caveat pertains only to the test methods portion, Section 13, of this specification: *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 2—There is no similar or equivalent ISO standard.

#### 2. Referenced Documents

##### 2.1 ASTM Standards:

- C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus<sup>2</sup>
- D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies<sup>3</sup>
- D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation<sup>3</sup>
- D 256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics<sup>4</sup>
- D 257 Test Methods for D-C Resistance or Conductance of Insulating Materials<sup>3</sup>
- D 495 Test Method for High Voltage, Low Current, Dry Arc Resistance of Solid Electrical Insulation<sup>3</sup>
- D 523 Test Method for Specular Gloss<sup>5</sup>
- D 543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents<sup>4</sup>
- D 570 Test Method for Water Absorption of Plastics<sup>4</sup>
- D 618 Practice for Conditioning Plastics for Testing<sup>4</sup>
- D 635 Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position<sup>4</sup>
- D 638 Test Method for Tensile Properties of Plastics<sup>4</sup>
- D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position<sup>4</sup>

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.06.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 10.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 06.01.

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

- D 695 Test Method for Compressive Properties of Rigid Plastics<sup>4</sup>
- D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer<sup>4</sup>
- D 732 Test Method for Shear Strength of Plastics by Punch Tool<sup>4</sup>
- D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact<sup>4</sup>
- D 785 Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials<sup>4</sup>
- D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials<sup>4</sup>
- D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement<sup>4</sup>
- D 883 Terminology Relating to Plastics<sup>4</sup>
- D 1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer<sup>4</sup>
- D 1435 Practice for Outdoor Weathering of Plastics<sup>4</sup>
- D 1499 Practice for Filtered Open-Flame Carbon-Arc Exposures of Plastics<sup>4</sup>
- D 1505 Test Method for Density of Plastics by the Density-Gradient Technique<sup>4</sup>
- D 1525 Test Method for Vicat Softening Temperature of Plastics<sup>4</sup>
- D 1531 Test Methods for Relative Permittivity (Dielectric Constant) and Dissipation Factor by Liquid Displacement Procedures<sup>3</sup>
- D 1600 Terminology for Abbreviated Terms Relating to Plastics<sup>4</sup>
- D 1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials<sup>4</sup>
- D 1898 Practice for Sampling of Plastics<sup>6</sup>
- D 2117 Test Method for Melting Point of Semicrystalline Polymers by Hot Stage Microscopy Method<sup>7</sup>
- D 2240 Test Method for Rubber Property—Durometer Hardness<sup>8</sup>
- D 2565 Practice for Xenon Arc Exposure of Plastics Intended for Outdoor Applications<sup>9</sup>
- D 2584 Test Method for Ignition Loss of Cured Reinforced Resins<sup>9</sup>
- D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)<sup>9</sup>
- D 2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep Rupture of Plastics<sup>9</sup>
- D 3012 Test Method for Thermal-Oxidative Stability of Polypropylene Using a Specimen Rotator Within an Oven<sup>9</sup>
- D 3418 Test Method for Transition Temperatures of Polymers By Differential Scanning Calorimetry<sup>9</sup>
- D 3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials<sup>9</sup>
- D 3801 Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position<sup>9</sup>
- D 3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer<sup>9</sup>
- D 3892 Practice for Packaging/Packing of Plastics<sup>9</sup>
- D 4000 Classification System for Specifying Plastic Materials<sup>9</sup>
- D 4329 Practice for Fluorescent UV Exposure of Plastics<sup>10</sup>
- D 4364 Practice for Performing Accelerated Outdoor Weathering of Plastics Using Concentrated Natural Sunlight<sup>10</sup>
- D 4805 Terminology for Plastics Standards<sup>10</sup>
- D 4812 Test Method for Unnotched Cantilever Beam Impact Resistance of Plastics<sup>10</sup>
- D 5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics<sup>10</sup>
- D 5279 Test Method for Measuring the Dynamic Mechanical Properties of Plastics in Torsion<sup>10</sup>
- D 5420 Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)<sup>10</sup>
- D 5630 Test Method for Ash Content in Thermoplastics<sup>10</sup>
- D 5947 Test Methods for Physical Dimensions of Solid Plastics Specimens<sup>10</sup>
- D 6290 Test Method for Color Determination of Plastic Pellets<sup>10</sup>
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>11</sup>
- E 313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates<sup>5</sup>
- E 831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis<sup>11</sup>
- G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>12</sup>
- G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials<sup>12</sup>
- 2.2 *Military Standard:*  
MIL-STD-105 Sampling Procedure and Tables for Inspection by Attributes<sup>13</sup>
- 2.3 *DOT Standard:*  
Federal Motor Vehicle Safety Standard 302 Flammability of Interior Materials<sup>14</sup>
- 2.4 *UL Standard:*  
UL 94 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances<sup>15</sup>
- 2.5 *SAE Standards:*<sup>16</sup>

<sup>6</sup> Discontinued. See 1997 *Annual Book of ASTM Standards*, Vol 08.01.

<sup>7</sup> Discontinued. See 1993 *Annual Book of ASTM Standards*, Vol 08.01.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 09.01.

<sup>9</sup> *Annual Book of ASTM Standards*, Vol 08.02.

<sup>10</sup> *Annual Book of ASTM Standards*, Vol 08.03.

<sup>11</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>12</sup> Discontinued; see 1999 *Annual Book of ASTM Standards*, Vol 14.04.

<sup>13</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094.

<sup>14</sup> Available from U.S. Dept. of Transportation, National Highway Traffic Safety Administration, Office of Public Affairs and Consumer Participation, 400 7th St., SW, Washington, DC 20590.

<sup>15</sup> Available from Underwriters Laboratories, 333 Pingston Rd., Northbrook, IL 60062.

<sup>16</sup> Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

- SAE J1545 Instrumental Color Difference Measurement for Exterior Finishes, Textiles and Color Trim
- SAE J1885 Accelerated Exposure of Automotive Interior Materials Using Controlled Irradiance Water Cooled Xenon-Arc Apparatus
- SAE J1960 Accelerated Exposure of Automotive Exterior Materials Using Controlled Irradiance Water Cooled Xenon-Arc Apparatus
- SAE J2019 Accelerated Exposure of Automotive Exterior Materials Using Controlled Irradiance Air Cooled Xenon Arc Apparatus
- SAE J2212 Accelerated Exposure of Automotive Interior Materials Using Controlled Irradiance Air Cooled Xenon Arc Apparatus

### 3. Terminology

3.1 *Definitions*— See Terminologies D 883 and D 4805 for definitions of terms related to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *back pressure, n*—the constant pressure that is applied to the end of the screw while the screw is rotating and retracting to prepare for the next injection.

3.2.2 *cooling time, n*—the time in which the material is in the closed mold with no pressure applied.

3.2.3 *cycle time, n*—the time required to complete a full injection molding cycle, including injection time, cooling time, and mold open time.

3.2.4 *injection pressure, n*—the constant pressure that is applied to the end of the screw causing the melted material to fill the mold. The injection pressure along with the injection speed determines the volumetric fill rate of the mold.

3.2.5 *injection speed, n*—the constant amount of injection pressure applied at the end of the screw.

3.2.5.1 *Discussion*—Injection speed is a set position on the injection molding machine ranging from slow to fast. The injection speed along with the injection pressure determines the volumetric fill rate of the mold.

3.2.6 *injection time, n*—the time in which a constant specified pressure is applied to the melted material.

3.2.7 *melt temperature, n*—the temperature of the material as it is being injected into the mold, measured by a pyrometer.

3.2.8 *mold open time, n*—the time beginning when the mold is opened and ending when the mold is closed.

3.2.9 *mold temperature, n*—the temperature of the mold during the molding cycle, measured in all mold cavities and on both platens.

3.2.10 *polypropylene [PP]*—a propylene plastic prepared by the polymerization of propylene or propylene with other alpha olefins. (See also PP-B, PP-H, and PP-R.)

3.2.11 *polypropylene heterophasic copolymers [PP-B, PP+EPR, or PP+EPDM]*—a propylene plastic consisting of two or more separate phases. The phases consist of a polypropylene homopolymer (PP-H) or a polypropylene random copolymer (PP-R) matrix containing a dispersed olefinic elastomer having no other functional group, added in situ or physically blended into the polypropylene matrix.

3.2.12 *polypropylene homopolymer [PP-H]*—a propylene plastic prepared by the polymerization of propylene only.

3.2.13 *polypropylene random copolymer [PP-R]*—a propylene plastic containing another olefinic monomer (or monomers) having no functional group other than the olefinic group copolymerized with propylene. Polypropylene random copolymers containing more than one additional monomer are often called “terpolymers.”

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### 4. Classification

4.1 Unreinforced polypropylene materials are classified into groups according to basic composition. These groups are subdivided into classes and grades, as shown in Table PP.

NOTE 3—An example of this classification system is as follows. The designation PP0113 would indicate: PP = polypropylene, as found in Terminology D 1600, 01 (group) = homopolymer, 1 (class) = general purpose, and 3 (grade) = with requirements given in Table PP.

4.1.1 To facilitate the incorporation of future or special materials not covered by Table PP, the “other/unspecified” category for group (00), class (0), and grade (0) is shown on the table with the basic properties to be obtained from Table A, Table B, Table C, Table G, and Table T, as they apply (see 4.3).

4.2 Reinforced versions of the polypropylene materials are classified in accordance with Table PP, Table A, Table B, Table C, Table G, and Table T. Table PP and Table B specify the properties of the unreinforced material, and Tables A, C, G, or T specify the properties after the addition of reinforcements, pigments, fillers, or lubricants, at the nominal level indicated (see 4.2.1).

4.2.1 *Reinforcements and Additive Materials*—A symbol (single letter) will be used for the major reinforcement or combinations thereof, along with two numbers that indicate the percentage of addition by mass, with the tolerances as tabulated as follows:

Symbol	Material	Tolerance
G	Glass reinforced—	
	<15 %	±2 percentage points
	>15 %	±3 percentage points
L	Lubricant (that is, graphite, silicone, and stearates)	to be specified
M	Mineral-reinforced—	
	<15 %	±2 percentage points
	>15 %	±3 percentage points
R	Reinforced-combinations/ mixtures of reinforcements or other fillers/reinforcements	±3 percentage points based on the total reinforcement

NOTE 4—This part of the system uses the type and percentage of additive to designate the modification of the base material. To facilitate this designation, the type and percentage of additive can be shown on the supplier’s Technical Data Sheet, unless it is proprietary in nature. If necessary, additional requirements shall be indicated by the use of the suffix part of the system as given in Section 5.

4.2.2 Specific requirements for reinforced, pigmented, filled, or lubricant polypropylene materials will be shown by a six-character designation. The designation will consist of the letter A, B, C, G, or T and the five digits comprising the cell numbers for the property requirements in the order in which they appear in Table A, Table B, Table C, Table G, or Table T.

4.2.2.1 Although the values listed are necessary to include the range of properties available in existing materials, they should not be interpreted as implying that every possible combination of the properties exists or can be obtained.

4.2.3 When the grade of the basic materials is not known or is not important, the use of “0” grade classification will be used for reinforced materials in this system. (See Note 5.)

NOTE 5—An example of this classification system for a reinforced-polypropylene material is as follows. The designation PP0110M20A21130 would indicate the following, with the material requirements from Table A:

- PP0110 = General-purpose polypropylene hemopolymer from Table PP
- M20 = Mineral reinforced, 20 %
- A = Table A property requirements.
- 2 = 35-MPa tensile stress, min,
- 1 = 1000-MPa flexural modulus (1 % secant), min,
- 1 = 15-J/m Izod impact, min,
- 3 = 110°C deflection temperature, min, and
- 0 = Unspecified.

If no properties are specified, the designation would be PP0110M20-A00000.

4.3 Table B has been incorporated into this specification to facilitate the classification of special materials where Table PP does not reflect the required properties of that unreinforced material. This table will be used in a manner similar to Tables A, C, G, and T.

NOTE 6—Mechanical properties of polypropylene materials with pigments or colorants can differ from the mechanical properties of natural material, depending on the choice and the concentration.

NOTE 7—An example of a special material using this classification system is as follows. The designation PP0310B55443 would indicate the following with the material requirements from Table B:

- PP0310 = low impact polypropylene copolymer,
- B = Table B property requirements,
- 5 = 25-MPa tensile stress, min,
- 5 = 1000-MPa flexural modulus (1 % scant), min,
- 4 = 200-J/m Izod impact, min,
- 4 = 80°C deflection temperature, min, and
- 3 = >1.0 to 3.0 nominal flow rate.

## 5. Suffixes

5.1 When additional requirements are needed for the materials covered in this specification that are not covered in Table PP, Table A, Table B, Table C, Table G, or Table T then those requirements shall be designated through the use of suffixes. The primary suffix list can be found in Suffix Requirements, Section 7, of Classification D 4000. Other suffixes that pertain only to the material requirements in this specification are listed as follows. In general, the suffix letter indicates the requirement needed; the first number (digit) indicates the test condition, and the second number (digit) indicates the specimen requirement.

NOTE 8—Suffixes from Classification D 4000 will contain two letters followed by three numbers while suffixes from this specification will contain a single letter followed by two or three numbers. An example would be weatherability; a designation of WA510 would indicate that it is a Classification D 4000 suffix with the following requirements:

- W = Weather resistant,
- A = Practice D 1435,
- 5 = Elongation properties,
- 1 = 10 % change, and
- 0 = 10 % change.

A designation of W210 would indicate that it is a Specification D 4101 suffix with the following requirements:

- W = Weatherability,
- 2 = Practice D 1499, Type DH,
- 1 = 200-h exposure, and
- 0 = Change in properties to be specified.

### Suffixes:

- E = Electrical requirements as designated by the following digits:
- First Digit
- 0 = To be specified by user.
  - 1 = Specimens preconditioned 40 h at 23°C and 50 % relative humidity, then 14 days in distilled water at 23 ± 1°C.
- Second Digit
- 0 = To be specified by user.
  - 1 = Insulation resistance, dielectric constant, and dissipation factor meet property limits as shown below. These are electrical limits usually applied to unreinforced polypropylene when control of their electrical properties is required.

### Electrical Properties:

Dielectric constant, max	Test Methods D 1531 or D 150	2.30
Dissipation factor, max	Test Methods D 1531	0.0005
Insulation resistance, min, Ω	Test Methods D 257	1 × 10 <sup>15</sup>
Water immersion stability	Test Methods D 1531 or D 150	Shall meet the dielectric constant and dissipation factor requirements

- W = Weatherability requirements as designated by the following digits:
- First Digit

- 0 = To be specified.
- 1 = Specimens exposed to xenon-arc type light source, as described in Practice D 2565, Type BH. Irradiance level shall be 0.35 W/m<sup>2</sup> at 340 nm. Specimens shall be Test Method D 638, Type I tensile bars.
- 3 = Specimens exposed to fluorescent UV-condensation (CON) type light source, as described in Practice D 4329. Fluorescent lamps shall be UVA-340. Test cycle shall be 8 h UV/60°C 4 h CON/50°C. Specimens shall be Test Method D 638, Type I tensile bars.
- 4 = Specimens exposed to conditions specified in SAE J 1960. Specimens shall be Test Method D 638, Type I tensile bars.
- 5 = Specimens exposed to conditions specified in SAE J 1885. Specimens shall be Test Method D 638, Type I tensile bars.
- 6 = Specimens shall be exposed to carbon-arc type light source as described in Practice D 1499, Type DH, with black panel temperature of 83°C and without water spray.
- 7 = Specimens exposed to conditions in accordance with SAE J2019. Specimens shall be Test Method D 638 Type I tensile bars.
- 8 = Specimens exposed to conditions in accordance with SAE J2212. Specimens shall be Test Method D 638 Type I tensile bars.
- 9 = Specimens exposed to concentrated natural sunlight in accordance with Practice D 4364. Total UV irradiation below 385 nm, in MJ/m<sup>2</sup>. Specimens shall be Test Method D 638 Type I tensile bars.

### Second Digit

- 0 = To be specified by user.
- 1 = 200-h exposure.
- 2 = 500-h exposure.
- 3 = 1000-h exposure.
- 4 = 2000-h exposure.
- 5 = 1250 kJ/m<sup>2</sup> at 340 nm.
- 6 = 2500 kJ/m<sup>2</sup> at 340 nm.
- 7 = 1000 MJ/m<sup>2</sup> total UV irradiation (approximately 3 years).

8 = 336-h exposure.

Third Digit

0 = To be specified by user.

1 = The exposed specimens shall not exhibit surface changes (such as dulling and chalking) or deep-seated changes (such as checking, crazing, warping, and discoloration). The tensile strength after exposure must be no less than 50 % of the original.

2 = American Association of Textile Chemists and Colorists (AATCC) rating 4 to 5.

3 = Colorfastness by SAE J 1545, CIELAB color difference, 10° observer, Illuminant D 65.

$$\Delta E = 2.5 \text{ max}$$

Z = Other special requirement characteristics (for example, internal mold release agent) not covered by existing call-out capabilities may be assigned. These will be spelled out in detail and identified in sequence, that is, 01 UV-stabilized, 02 special color, and 03, etc.

Additional suffixes will be added to this specification as test methods and requirements are developed or requested, or both.

## 6. Basic Requirements

6.1 Basic requirements from property or cell tables, as they apply, are always in effect unless these requirements are superseded by specific suffix requirements in the “Line Call-Out.”

## 7. General Requirements

7.1 The plastic composition shall be uniform and shall conform to the requirements specified herein. The color and form of the material shall be specified. Note specification changes due to the effects of colorants and, when necessary, cover them by suffixes.

7.2 For recycled, reconstituted, and reground materials the level of contamination by nonpolymeric materials other than fillers and additives shall not be of a significant level that it prevents the product from meeting the performance criteria for which it was manufactured.

## 8. Detail Requirements

8.1 Test specimens for the various materials shall conform to the requirements prescribed in Table PP, Table A, Table B, Table C, Table G, Table T, and to the suffix requirements as they apply.

8.2 Observed or calculated values obtained from analysis, measurement, or test shall be rounded in accordance with Practice E 29 to the nearest unit in the last right-hand place of figures used in expressing the specified limiting value. The value obtained is compared directly with the specified limiting value. Conformance or nonconformance with the specification is based on this comparison.

## 9. Sampling

9.1 Unless otherwise specified, the materials shall be sampled in accordance with the sampling procedure prescribed in Practice D 1898. Adequate statistical sampling shall be considered an acceptable alternative. A batch or lot of resin shall be considered as a unit of manufacture as prepared for shipment and may consist of a blend of two or more production runs of material.

## 10. Number of Tests

10.1 The number of tests conducted shall be consistent with

the requirements of Section 13.

## 11. Specimen Preparation

11.1 All test specimens other than those for heat stability testing (see 11.2) shall be injection molded in accordance with the following specific procedures:

NOTE 9—Physical and mechanical properties are dependent upon the technique of specimen preparation. Specimen preparation by means other than those described as follows can lead to significant variation in test results, with resultant departure from specification values.

11.1.1 *Specimen Mold*—A Type I tension test specimen (Test Method D 638) mold, with a thickness of  $3.2 \pm 0.1$  mm, shall be used in accordance with Practice D 3641.

11.1.2 *Cavity Gate Dimensions*—The cavity gate dimensions shall be 2.5 by 2.5-mm minimum to 3.2 by 6.4-mm maximum.

11.1.3 *Mold Temperature*—The temperature of the mold shall be  $60 \pm 3^\circ\text{C}$ . Temperature measurements shall be made in each cavity of the mold after machine conditions are at equilibrium and shall be made with a surface-type pyrometer, or equivalent, to an accuracy of  $\pm 2^\circ\text{C}$  after equilibrium or cycle conditions have been established.

11.1.4 *Cycle*—The total molding cycle time shall be 45 s, consisting of 20-s injection, 20-s cooling, and 5-s mold open.

11.1.5 *Melt Temperature*—The melt temperature for molding test specimens for materials with melt flows of 1 to 30 g/10 min shall correlate with the polymer melt flow (Test Method D 1238, Condition 230/2.16) as shown in Table 1. Melt temperatures shall be measured on cycle by taking the temperatures of several successive free shots with a needle-type pyrometer to an accuracy of  $\pm 3^\circ\text{C}$ . The needle should be moved around in the plastic mass, and a sufficient number of measurements be made to establish a reliable result. To minimize heat loss from the plastic during measurement, the mass should be collected in a heated container, or in one made from material of low thermal conductivity. The quantity of plastic in the free shot should be controlled to be equivalent to the weight of a complete injection-molded shot. To avoid excessive thermal history the shot size shall be kept to a minimum; therefore, the cushion shall be 5 to 10 mm.

NOTE 10—For materials with melt flows less than 1 g/10 min, the temperature of the melt should be raised in  $5^\circ\text{C}$  increments from  $250^\circ\text{C}$  until the part weight of the entire shot is equivalent to the part weight of a 1 to 5-g/10 min material. Due to degradation and thermal expansion of the material do not exceed  $270^\circ\text{C}$ . If unable to obtain the weight at  $270^\circ\text{C}$ , make slight adjustments in the injection pressure to achieve the proper weight. The melt temperature shall be  $190^\circ\text{C}$  for materials with melt flows greater than 30 g/10 min.

11.1.6 *Back Pressure*—The back pressure shall be set at 0.7 MPa (gage).

11.1.7 *Injection Pressure and Speed*—All materials less than 30-g/10 min melt flow shall be molded using a single stage pressure. For a given machine and a given mold, the injection pressure and the injection speed controls shall be set to produce equal part weights, including sprue and runners ( $\pm 2\%$ ) regardless of material flow rates. The injection speed and injection pressure shall be set to minimize sink and flash. The maximum amount of flash shall not exceed 1 mm and will only be acceptable in the nontesting area. Once the injection

speed and pressure are determined for a given machine and mold they shall not be varied by more than  $\pm 2\%$ .

NOTE 11—A single stage pressure can be obtained in two different ways: (1) Injection pressure may be set to reach a specified pressure then allowed to shift over to a hold pressure; the hold pressure maintains the pressure at the maximum pressure generated by the injection pressure, and (2) The cavity may be filled using hold pressure only; the first method is the preferred method. For materials with melt flow rates above 30 g/10 min the injection and hold pressures may be set to different pressures. Normally the hold pressure is set lower than the injection pressure, but must be high enough to finish filling out the molded part. For these high melt flow rate materials the injection and hold pressure shall be specified by the manufacturer.

11.1.8 *Reporting*—Report the injection molding conditions in accordance with Practice D 3641.

11.2 Prepare test specimens for heat stability testing in accordance with Test Method D 3012.

## 12. Conditioning

### 12.1 *Conditioning*:

12.1.1 Once specimens are molded, they shall be moved to a standard laboratory atmosphere or a controlled laboratory atmosphere. For natural unfilled polypropylene the controlled laboratory atmosphere shall be  $23 \pm 2^\circ\text{C}$ . Specimens may be stored in storage medium, such as boxes, paper bags or envelopes, plastic bags, or racks, whichever is most practical for the laboratory storing the specimens. It is recommended that specimens be allowed to cool for about 30 min on a bench or in a rack before they are placed in any container where the specimens may come in contact with each other. For filled and reinforced polypropylene or polypropylene blends, which contain a hydrophilic comonomer or modifier the specimens should be conditioned in a standard laboratory atmosphere of  $23 \pm 2^\circ\text{C}$  and  $50 \pm 5\%$  relative humidity, unless sufficient testing has been conducted that indicates that specific material type's properties are not affected by humidity. In those cases, the storage medium can be the same as for unfilled materials. Materials whose properties are affected by humidity, must be stored in accordance with Practice D 618, Procedure A. For all materials to be conditioned for electrical testing, conditioning shall comply with the requirements of the standard test methods for electrical testing. In all cases the laboratory shall report both the temperature and humidity conditions during the conditioning period.

NOTE 12—When the temperature in the molding area exceeds  $28^\circ\text{C}$  or the humidity level exceeds 55% (applies only to filled materials) specimens should be moved as quickly as possible to the standard laboratory atmosphere.

12.1.2 Testing, except for those tests where a test time is specified, shall be conducted within 40 to 96 h after molding. This test time range shall apply to all testing conducted for development of a line callout, data for publication, or for cases of dispute over testing values.

12.1.3 Specimens that are to be tested for Izod or Charpy impact shall be notched within 1 to 16 h after molding. Once notched the specimens shall condition for a minimum of 40 h before testing. Specimens should be tested within 96 h after molding.

NOTE 13—Extending the conditioning time may result in increased or

decreased test results. Polypropylene properties change with time as a result of amorphous densification and, in some cases, due to a small degree of secondary crystallization in the rubbery phase.

12.2 *Test Conditions*—Natural unfilled polypropylene shall be tested in a controlled laboratory atmosphere of  $23 \pm 2^\circ\text{C}$ . For filled and reinforced polypropylene and polypropylene blends, which contain a hydrophilic comonomer or modifier the specimens should be tested in a standard laboratory atmosphere of  $23 \pm 2^\circ\text{C}$  and  $50 \pm 5\%$  relative humidity, unless sufficient testing has been conducted that indicates that specific materials type's properties are not affected by humidity. For all materials to be tested for electrical properties, the laboratory shall comply with the requirements of the standard test methods for electrical testing. In all cases the laboratory shall report both the temperature and humidity conditions during testing.

## 13. Test Methods

13.1 Determine the properties enumerated in this specification in accordance with the ASTM test methods as they apply, unless otherwise stated herein.

13.1.1 *Flow Rate*—Condition 230/2.16 of Test Method D 1238. Make two determinations on the material in the form that it is to be molded (such as powder, pellets, or granules).

NOTE 14—This test method serves to indicate the degree of uniformity of the flow rate of the polymer of a single manufacturer as made by an individual process and, in this case, may be indicative of the degree of uniformity of molded specimens, and therefore other properties. However, uniformity of flow rate among various polymers of various manufacturers as made by various processes does not, in the absence of other tests, indicate uniformity of other properties and vice versa.

13.1.2 *Measurement of Test Specimen Dimensions*—The width and thickness of the test specimen shall be measured to an incremental discrimination of at least 0.025 mm. Measurements shall be made with a micrometer, preferably with ratchet, having a movable circular contact foot and a lower anvil foot, both  $6.35 \pm 0.025$  mm in diameter. Specimens shall be measured in accordance with Test Methods D 5947.

13.1.3 *Tensile Stress*—Test Type I specimens using Test Method D 638. The material shall be tested at 50 mm/min when the material is one that shows a yielding or breaking strain greater than 10%, or at 5 mm/min when the material breaks at a strain equal to or less than 10%.

13.1.4 *Flexural Modulus (1% Secant)*—Test Methods D 790, Method I, Procedure A, with a 50-mm span, a  $5.0 \pm 0.1$ -mm radius support and loading nose, and a 1.3-mm/min testing speed using the center test region of a Test Method D 638 Type I specimen. It is mandatory that the toe correction be made to correct for the slack in the test fixture and load cell. Center the specimen between the span flatwise and test with a crosshead speed of 1.3 mm/min. Calculate the average value of the flexural modulus (1% secant) at 1% strain in the outer surface of the test specimen.

NOTE 15—If the Test Method D 638 Type I specimens were molded on a mold containing a draft angle, the specimens will be trapezoidal. Therefore the flexural modulus may vary slightly depending on which side is placed away from the loading nose.

13.1.4.1 Calculate the deflection of the test specimen corresponding to 1% strain (0.01 mm/mm) as follows: