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## 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 7209.)

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:*<sup>2</sup>

D 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

D 150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation

D 256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

D 257 Test Methods for DC Resistance or Conductance of Insulating Materials

D 495 Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation

D 523 Test Method for Specular Gloss

D 543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D 570 Test Method for Water Absorption of Plastics

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials. Current edition approved April 1, 2008-2009. Published May 2008-September 2009. Originally approved in 1982. Last previous edition approved in 2007-2008 as D 4101 - 07 $\epsilon$ .

<sup>2</sup> 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.

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

- D 618 Practice for Conditioning Plastics for Testing
- D 635 Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
- D 638 Test Method for Tensile Properties of Plastics
- D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
- D 695 Test Method for Compressive Properties of Rigid Plastics
- D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between 30C and 30C with a Vitreous Silica Dilatometer
- D 732 Test Method for Shear Strength of Plastics by Punch Tool
- D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
- D 785 Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials
- D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
- D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
- D 883 Terminology Relating to Plastics
- D 1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
- D 1435 Practice for Outdoor Weathering of Plastics
- D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
- D 1525 Test Method for Vicat Softening Temperature of Plastics
- D 1531 Test Methods for Relative Permittivity (Dielectric Constant) and Dissipation Factor by Fluid Displacement Procedures
- D 1600 Terminology for Abbreviated Terms Relating to Plastics
- D 1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
- D 1898 Practice for Sampling of Plastics<sup>3</sup>
- D 2117 Test Method for Melting Point of Semicrystalline Polymers by the Hot Stage Microscopy Method<sup>0</sup>
- D 2240 Test Method for Rubber Property Durometer Hardness
- D 2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
- D 2584 Test Method for Ignition Loss of Cured Reinforced Resins
- D 2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
- D 2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
- D 3012 Test Method for Thermal-Oxidative Stability of Polypropylene Using a Specimen Rotator Within an Oven
- D 3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
- D 3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials
- D 3763 Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors
- D 3801 Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position
- D 3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer 01-09
- D 3892 Practice for Packaging/Packing of Plastics
- D 4000 Classification System for Specifying Plastic Materials
- D 4329 Practice for Fluorescent UV Exposure of Plastics
- D 4364 Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight
- D 4805 Terminology for Plastics Standards
- D 4812 Test Method for Unnotched Cantilever Beam Impact Resistance of Plastics
- D 5279 Test Method for Plastics: Dynamic Mechanical Properties: In Torsion
- D 5420 Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)
- D 5630 Test Method for Ash Content in Plastics
- D 5740 Guide for Writing Material Standards in the Classification D 4000 Format
- D 5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
- D 6110 Test Method for Determining the Charpy Impact Resistance of Notched Specimens of Plastics
- D 6290 Test Method for Color Determination of Plastic Pellets
- D 7209 Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
- E 831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis
- 2.2 *Military Standard:*
- MIL-STD-105 Sampling Procedure and Tables for Inspection by Attributes<sup>4</sup>

<sup>3</sup> Withdrawn.

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

### 2.3 DOT Standard:

MVSS-302 Federal Motor Vehicle Safety Standard 302 Flammability of Interior Materials<sup>5</sup>

### 2.4 UL Standard:

UL 94 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances<sup>6</sup>

### 2.5 SAE Standards:<sup>7</sup>

SAE J1545 Instrumental Color Difference Measurement for Exterior Finishes, Textiles and Color Trim

SAE J1767 Instrumental Color Difference Measurement for Colorfastness of Automotive Interior Trim Materials

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 J1976 Outdoor Weathering of Exterior Materials

## 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 *brittle failure, n*—one where the specimen test area is broken into two or more pieces, with sharp edges and shows almost no plastic flow.

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

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

3.2.5 *ductile brittle transition temperature, n*—the temperature at which a 80% of the specimens exhibit ductile failure

3.2.6 *ductile failure, n*—one where the specimen deforms plastically before fracturing. One where the puncture of the test plaque does not have cracks radiating more than 10 mm beyond the center of the impact point.

3.2.7 *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.

3.2.8 *injection speed, n*—the forward velocity of the screw during the injection step.

3.2.8.1 *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.

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

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

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

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

3.2.13 *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.)

3.2.14 *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.

3.2.15 *polypropylene homopolymer (PP-H)*—a propylene plastic prepared by the polymerization of propylene only.

3.2.16 *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.”

## 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

<sup>5</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>6</sup> Available from Underwriters Laboratories (UL), 333 Pfingsten Rd., Northbrook, IL 60062-2096, <http://www.ul.com>.

<sup>7</sup> Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

C, Table G, Table H, 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 C, Table G, and Table T. Table PP, Table B, and Table H 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
L	>15 %	±3 percentage points
	Lubricant (that is, graphite, silicone, and stearates)	to be specified
M	Mineral-reinforced—	
	<15 %	±2 percentage points
R	>15 %	±3 percentage points
	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. For Table H the designation will consist of the letter H and three digits comprising the cell numbers for the property requirements in the order in which they appear in Table H.

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 homopolymer 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. Table H has been incorporated into this specification to improve the callout of random copolymers and impact copolymers. Table H has a reduced callout based on flexural modulus, Izod impact, and the Multiaxial Impact Ductile-Brittle Transition Temperature. If a full line callout is required, use Table B.

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 PP0110B67253 would indicate the following with the material requirements from Table B:

- PP0110 = homopolymer, general purpose, other,
- B = Table B property requirements,
- 6 = 30-MPa tensile stress at yield, min,
- 7 = 1500-MPa flexural modulus, min,
- 2 = 50-J/m Izod impact resistance, min,
- 5 = 90°C deflection temperature, min, and
- 3 = >1.0 to 3.0 nominal melt flow rate.

NOTE 8—An example of a polypropylene copolymer material using Table H would be as follows. The designation PP0500H585 would indicate a material with the following requirements:

- PP0500 = copolymer or impact modified,
- H = Table H property requirements,
- 5 = 1200-MPa flexural modulus, min,
- 8 = Izod impact resistance, non-break failure mode, no value reported, and
- 5 = <-30°C ductile-brittle transition temperature

## 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, Table H, and Table T, 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 9—Suffixes from Classification D 4000 will contain two letters followed by three digits 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, and
- 10 = 10 % change.

A designation of W110 would indicate that it is a Specification D 4101 suffix with the following requirements:

- W = Weatherability,
- 1 = Practice D 2565, Test Cycle 1, specimens exposed in a xenon-arc accelerated test apparatus,
- 1 = 200-h exposure, and
- 0 = Change in properties to be specified.

*Suffixes:*

E = Electrical requirements as designated by the following digits:

- 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.

First Digit

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 in a xenon arc accelerated test apparatus that conforms to Practice D 2565 using Test Cycle 1 for exterior applications.
- 2 = Specimens exposed in a fluorescent UV/condensation accelerated test apparatus that conforms to Practice D 4329 using Test Cycle A for exterior applications.
- 3 = Specimens exposed in a xenon-arc accelerated test apparatus that conforms to SAE J1960 or equivalent for exterior applications.
- 4 = Specimens exposed in a xenon-arc accelerated test apparatus that conforms to SAE J1885 or equivalent for interior applications.
- 5 = Specimens exposed to concentrated natural sunlight in accordance with Practice D 4364 without water spray.
- 6 = Specimens exposed to concentrated natural sunlight in accordance with Practice D 4364 with water spray (Table 1, Cycle 1).
- 7 = Specimens exposed to natural sunlight in accordance with Practice D 1435 using a rack angle of 45° from the horizontal facing the equator, unless specified otherwise.
- 8 = Specimens exposed to natural sunlight in accordance with SAE J1976 Procedure A, unless specified otherwise.

Second Alphanumeric

- 0 = To be specified by user.
- 1 = 200-h exposure.
- 2 = 500-h exposure.
- 3 = 1000-h exposure.
- 4 = 2000-h exposure.
- 5 = 1240.8 kJ/(m<sup>2</sup>.nm) at 340 nm.
- 6 = 2500 kJ/(m<sup>2</sup>.nm) at 340 nm.
- 7 = 1000 MJ/m<sup>2</sup> solar total UV irradiation (approximately 3 years).
- 8 = 336-h exposure
- 9 = 720-h exposure
- A = 5000-h exposure
- B = 10000-h exposure
- C = 225.6 kJ/(m<sup>2</sup>.nm) at 340 nm
- D = 601.6 kJ/(m<sup>2</sup>.nm) at 340 nm.

NOTE 10—Conversion from hours to kilojoules (kJ) varies with irradiance and the light/dark cycle. Conversion to kJ from actual light hours (h) is based on the following relation:

$$kJ = \text{Irradiance in Watts} \times 3.6 \text{ kJ/h} \times h \text{ of light}$$

Thus, at an irradiance level of 0.55 W/(m<sup>2</sup>.nm) at 340 nm, the multiplication factor for converting light hours to kJ is 1.98 (0.55 × 3.6). Therefore, 100 light hours is equivalent to 396 kJ/(m<sup>2</sup>.nm) at 340 nm at this irradiance level.

Third Alphanumeric

- 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).
- 2 = The tensile strength after exposure must be no less than 50 % of the original.
- 3 = The tensile strength after exposure must be no less than 90 % of the original.
- 4 = American Association of Textile Chemists and Colorists (AATCC) rating 4 to 5.
- 5 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D 65, specular included, ΔE = 2.5 max.
- 6 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D 65, specular included, ΔE = 2.0 max.
- 7 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D 65, specular included, ΔE = 3.0 max.
- 8 = Colorfastness by SAE J1767, for interior materials, CIELAB color difference, 10° observer, Illuminant D 65, specular included, ΔE = 2.5 max.
- 9 = Colorfastness by SAE J1767, for interior materials, CIELAB color difference, 10° observer, Illuminant D 65, specular included, ΔE = 3.0 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 H, 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 11—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*—Molds designed in compliance with Practice D 3641 to mold the following test specimens:

11.1.1.1 A Test Method D 638, Type I tension test specimen with a thickness of  $3.2 \pm 0.1$  mm.

11.1.1.2 A rectangular bar, with dimensions of 127 mm by 12.7 mm by  $3.2 \pm 0.1$  mm.

11.1.1.3 Plate, with minimum dimensions of 100 mm<sup>2</sup> or 100-mm diameter with a thickness of  $3.2 \pm 0.2$  mm.

11.1.2 *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.

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

11.1.4 *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 12—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.

Since the needle-type pyrometer technique is somewhat tedious, a second technique using an infrared pyrometer may be used. The infrared pyrometer used must have an accuracy of 1 % of reading or  $\pm 1^\circ\text{F}$  or  $\pm 1^\circ\text{C}$ , a response time of at least 0.5 s, and a distance to target ratio of at least 30:1. It is recommended that the infrared pyrometer have a laser beam to establish the position being measured on the molten mass of polymer. This second technique shall only be used after a correlation between the needle-type pyrometer and the infrared pyrometer has been established. This correlation shall be verified at least every six months. The correlation shall be re-established each time either pyrometer is recalibrated.

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

11.1.6 *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 13—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.

NOTE 14—It is recommended that screw rotation speed be set to a minimum to allow the screw to rotate for 17 to 19 s of the 20-s cooling time. This slower screw speed will provide greater uniformity of the melt with respect to viscosity and temperature. It may be necessary to adjust the screw rotation speed for the various material types in order to achieve the 17 to 19-s time frame. The rate of screw movement backwards away from the mold is dependent on the back pressure, frictional effects, various additive types, and melt viscosity.

11.1.7 *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 shall 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 might come in contact with each other. For filled and reinforced polypropylene or polypropylene blends, which contain a hydrophilic comonomer or modifier the specimens shall be conditioned

in a standard laboratory atmosphere of  $23 \pm 2^\circ\text{C}$  and  $50 \pm 10\%$  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 15—When the temperature in the molding area exceeds  $28^\circ\text{C}$  or the humidity level exceeds  $60\%$  (applies only to filled materials) specimens shall 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 not less than 40 h after molding. The aging times as specified in this and subsequent sections 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.

12.1.4 Specimens that are to be tested for tensile or flexural properties shall be tested within 40 to 96 h after molding.

NOTE 16—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 shall be tested in a standard laboratory atmosphere of  $23 \pm 2^\circ\text{C}$  and  $50 \pm 10\%$  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 <sup>8</sup>

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 17—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 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 18—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:

$$D = rL^2/6d \quad (1)$$

where:

$D$  = deflection of the center of the test specimen at 1 % strain, mm

$r$  = strain in the outer surface of the test specimen = 0.01 mm/mm,

$L$  = test span = 50 mm, and

<sup>8</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D20-1213.



$d$  = specimen depth = 3.2 mm (nominal).

**Warning**—The load measured must be a minimum of 1 % of the load cell capacity. The test span shall be known to an accuracy of 0.05 mm, and this value shall be used in the calculations in 13.1.4.1. The loading nose shall be precisely centered between the supports. The test specimen shall be aligned perpendicular to the supports to an accuracy of 2° and the center of the specimen shall be directly below the center of the loading nose.

13.1.4.2 Calculate the stress corresponding to 1 % strain as follows:

$$S = 3PL/2bd^2 \quad (2)$$

where:

$S$  = stress in the outer surface of the test specimen at 1 % strain, MPa,

$P$  = load corresponding to 1 % strain, N

$L$  = test span = 50 mm,

$d$  = specimen depth = 3.2 mm (nominal), and

$b$  = specimen width = 12.7 mm (nominal).

The secant modulus at 1 % strain is the ratio of stress to strain or  $S/0.01$ .

13.1.5 *Impact Resistance (Izod)*—Test Method D 256 (A) shall be used for notched specimens tested at 23°C. Specimens shall be cut from the center section of the Test Method D 638, Type I tensile test specimen. Before cutting the test specimen from the tensile bar, draw a symbol of any design in the straight center section of the bar to indicate which is the gate end of the specimen. Cut out the 57.2 mm straight center-section of the bar. The specimens shall be notched in accordance with Test Method D 256 for tests at 23°C. Specimens shall be notched such that the notch is off-center on the 57.2 ± 1 mm long specimen. When notched, the apex of the notch shall be 25.4 ± 2 mm from the non-gated end and 31.8 ± 1 mm from the gated end of the specimen. The more critical dimension is the 31.8 ± 1 mm from the gated end of the specimen. Notched specimens must be conditioned after notching for a minimum of 40 h before testing. The specimen shall be inserted in the clamp with the 25.4 ± 2 mm in the clamp and the 31.8 ± 1 mm length above the clamp. When testing, the specimen shall be clamped in the grips with the minimum pressure necessary to prevent any movement of the specimen upwards or downwards during impact. Should this pressure deform the specimen, then the clamp pressure may be reduced.

NOTE 19—Although the 57.2 mm length of specimen does not comply with the minimum specimen length of 61.5 mm specified by Test Method D 256, studies with numerous types of polypropylene specimens has shown that clamp lengths as short as 19 mm are acceptable, with no change in test results. What is critical is that the length of material above the clamp, which is specified as 31.8 ± 1 mm. Failure to maintain the 31.8 ± 1 mm above the clamp will result in reduced or increased Izod impact values depending on whether the specimen length above the clamp is longer or shorter than that specified by Test Method D 256, Method A.

NOTE 20—With the design of each clamping system and the capacity of the pendulum used different from instrument to instrument it is difficult to specify a pressure will hold the specimen securely. What is important is that the clamp pressure be maintained constant from specimen to specimen and be sufficient to prevent specimen movement during the impact. Too low a clamp pressure may result in slightly higher Izod values with a wider scatter of impact values within a set of specimens. Too high a clamp pressure will induce stress in the specimen resulting in lower than expected test values. This is particularly true of propylene plastics when tested at sub-ambient temperatures close to their brittleness temperature.

Set up the test instrument with the lowest capacity pendulum recognized by Test Method D 256, which is the 2.7 J (2 ft-lb) pendulum. This pendulum shall be used for all Izod impact resistance measurements where the specimen exhibits a complete, hinge, or partial break. For specimens showing non-break behavior, progressively increase the hammer capacity to move the type of break from non-break with the 2.7 J hammer to complete, hinge, or partial break so that an impact value may be reported. Conformance or nonconformance with the specifications detailed in the Tables shall be based on a material having a complete, hinge, or partial break.

13.1.6 *Deflection Temperature*—Test Method D 648 shall be used to test a rectangular specimen 3.2 by 12.7 by 127 mm with a load applied at the center to give maximum fiber stresses of 455 kPa.

13.1.7 *Multiaxial Impact Ductile-Brittle Transition Temperature*—Test Method D 3763 shall be used to test specimens equal to or greater in dimensions than 100 mm<sup>2</sup> or 100 mm in diameter and 3.2 ± 0.2 mm in thickness. The test speed shall be 2.2 m/s with the 12.7-mm diameter impact dart and 76-mm support ring. The temperature at which 80 % of the specimens exhibit ductile failure shall be determined based on the definitions listed in Section 3. This temperature may be determined by either a standard graphical method or through a probability graphical method. When using the standard graphic method to determine the 80 % passing temperature, it is necessary to repeat this procedure of testing ten specimens at a series of temperatures differing by uniform increments of 5°C. Ten degree increments may be used initially to establish the transition region of the curve but 5°C increments must be used in the transition temperature region. When using probability graph paper, it is not necessary to obtain the lowest no-failure temperatures, at which no failure is obtained, or the highest failure temperature. Draw a straight line through a minimum of four points, two above and two below the 50 % failure point. The temperature indicated at the intersection of the data line with the 20 % failure line shall be reported as the ductile-brittle temperature or 80 % passing temperature.

NOTE 21—In addition to visually examining the plaques for ductile failure, review the load versus time or load versus displacement curve for the impact for signs of ductility.

13.1.8 *Reinforcement and Additive Concentrations:*

13.1.8.1 *Glass Percentage*— Use Test Method D 2584.

13.1.8.2 *All Others*—Method to be specified.

13.1.8.3 Additional testing methods and conditions, refer to Appendix X1.

#### 14. Inspection and Certification

14.1 Certification and inspection of the material supplied under this specification shall conform to the requirements specified herein and in Classification D 4000, Section 15.

#### 15. Rejection and Rehearing

15.1 Material that fails to conform to the requirements of this specification may be rejected. If any failure occurs, the materials may be retested to establish conformity. Rejection shall be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of the test, a claim for a rehearing may be made.

#### 16. Packaging and Package Marking

16.1 Provisions of Practice D 3892 apply for packaging, packing, and marking of plastic materials.

#### 17. Keywords

17.1 injection and extrusion materials; materials specification; polypropylene; polypropylene test methods; recycled plastics

**TABLE PP Requirements for Unreinforced Polypropylene (Natural Color Only)**

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate, <sup>A</sup> Test Method D 1238, Condition 230/2.16, g/10 min	Tensile Stress <sup>B</sup> at Yield, Test Method D 638, min, <sup>C</sup> MPa	Flexural Modulus <sup>D</sup> (1 % Secant), Test Methods D 790, Procedure A, min, <sup>C</sup> MPa	Izod Impact, <sup>E</sup> Resistance at 23°C, Test Method D 256, min, <sup>F</sup> J/m	Deflection Temperature at 455-KPa Stress, <sup>G</sup> Test Method D 648 <sup>H</sup> , min, °C
01	Homopolymer	1	General purpose	1	...	<0.3	27.5	1050	32	81
				2	...	>0.2 to ≤1.0	27.5	1000	27	81
				3	...	>1.0 to ≤3.0	27.5	1000	25	74
				4	...	>3.0 to ≤10	27.5	950	20	71
				5	...	>10 to ≤20	26	850	16	71
				6	...	>20 to ≤40	25	800	14	64
				7	...	>40 to ≤100	24	800	12	64
				8	...	>100 to ≤200	23	850	12	64
				9	...	>200	21	850	8	74
		0	Other	...	...	...	...	...	...	...
		2	Nucleated	1	...	>1.0 to ≤3.0	33.5	1350	27	100
				2	...	>1.0 to ≤3.0	30.5	1150	27	90
				3	...	>3.0 to ≤10	30.5	1150	22	100
				4	...	>3.0 to ≤10	30.5	1150	21	90
				5	...	>10 to ≤30	30	1150	20	95
				6	...	>10 to ≤30	30	1150	16	85
				7	...	>30	28.5	1050	16	80
		0	Other	...	...	...	...	...	...	...
		3	High-crystallinity	1	...	<1.0	38	2000	21	100
				2	...	>1.0 to ≤5.0	36	1800	21	100
				3	...	>5.0 to ≤10	36	1600	21	100
4	...			>10 to ≤20	33	1400	22	95		
5	...			>20 to ≤40	30	1300	24	90		
6	...			>40	26	1300	26	90		
0	Other			...	...	...	...	...	...	...
0	Other	...	...	...	...	...	...	...		
02	Random Copolymers		Refer to Appendix X2							
03	Copolymers or Impact-Modified		Refer to Appendix X2							
05	Copolymers or impact modified	0	Other	0	Other	Use Table H for a reduced line callout of materials where only the ratio of stiffness to impact is important. Use Table B when a full line callout is required.				

<sup>A</sup>Nominal flow rate is as supplied by the manufacturer of the material. Maximum allowable tolerance = ±30 % per individual lot.

<sup>B</sup>Test specimens are unannealed Test Method D 638, Type I tensile bars and shall be tested at 50 mm/min when the material is one that shows a breaking strain greater than 10 %, or at 5 mm/min when the material breaks at a strain equal to or less than 10 %.

<sup>C</sup>MPa × 145 = psi.

<sup>D</sup>Test specimens are the center of the unannealed Test Method D 638, Type I tensile bars with a nominal 3.2 by 12.7-mm cross section. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant based on strain.

<sup>E</sup>Test specimens are nominal 3.2 mm in width and are cut from the center section of unannealed Test Method D 638, Type I tensile bar.