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Standard Specification for Polypropylene Injection and Extrusion Materials[1]

This standard is issued under the fixed designation D4101; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

ε[1] NOTE—Editorially adjusted Table X1.1 in April 2016.
ε[2] NOTE—Editorially updated SAE standards in October 2016.

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 D7209.)

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 known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
D149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
D257 Test Methods for DC Resistance or Conductance of Insulating Materials
D495 Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation
D523 Test Method for Specular Gloss
D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D570 Test Method for Water Absorption of Plastics
D618 Practice for Conditioning Plastics for Testing

[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

D635 Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
D638 Test Method for Tensile Properties of Plastics
D648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
D695 Test Method for Compressive Properties of Rigid Plastics
D696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C with a Vitreous Silica Dilatometer
D732 Test Method for Shear Strength of Plastics by Punch Tool
D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact
D785 Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D1238 Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
D1435 Practice for Outdoor Weathering of Plastics
D1505 Test Method for Density of Plastics by the Density-Gradient Technique
D1525 Test Method for Vicat Softening Temperature of Plastics
D1531 Test Methods for Relative Permittivity (Dielectric Constant) and Dissipation Factor by Fluid Displacement Procedures (Withdrawn 2012)[3]
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
D2117 Test Methods for Carbon Black—Surface Area by Nitrogen Adsorption (Withdrawn 1999)[3]
D2240 Test Method for Rubber Property—Durometer Hardness
D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D3012 Test Method for Thermal-Oxidative Stability of Polypropylene Using a Specimen Rotator Within an Oven
D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
D3641 Practice for Injection Molding Test Specimens of Thermoplastic Molding and Extrusion Materials
D3763 Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors
D3801 Test Method for Measuring the Comparative Burning Characteristics of Solid Plastics in a Vertical Position
D3835 Test Method for Determination of Properties of Polymeric Materials by Means of a Capillary Rheometer
D3892 Practice for Packaging/Packing of Plastics
D4000 Classification System for Specifying Plastic Materials
D4329 Practice for Fluorescent Ultraviolet (UV) Lamp Apparatus Exposure of Plastics
D4364 Practice for Performing Outdoor Accelerated Weathering Tests of Plastics Using Concentrated Sunlight
D4805 Terminology for Plastics Standards (Withdrawn 2002)[3]
D4812 Test Method for Unnotched Cantilever Beam Impact Resistance of Plastics
D5279 Test Method for Plastics: Dynamic Mechanical Properties: In Torsion
D5420 Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)
D5630 Test Method for Ash Content in Plastics
D5740 Guide for Writing Material Standards in the Classification Format
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
D6110 Test Method for Determining the Charpy Impact Resistance of Notched Specimens of Plastics
D6290 Test Method for Color Determination of Plastic Pellets
D7209 Guide for Waste Reduction, Resource Recovery, and Use of Recycled Polymeric Materials and Products (Withdrawn 2015)[3]
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E313 Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates
E831 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[4]

2.3 *DOT Standard:*
MVSS-302 Federal Motor Vehicle Safety Standard 302 Flammability of Interior Materials[5]

2.4 *UL Standard:*
UL 94 Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances[6]

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094.

[5] 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.

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

2.5 *SAE Standards:*[7]

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 J2412 Accelerated Exposure of Automotive Interior Trim Components Using a Controlled Irradiance Xenon-Arc Apparatus

SAE J2527 Performance Based Standard for Accelerated Exposure of Automotive Exterior Materials Using a Controlled Irradiance Xenon-Arc Apparatus

SAE J1976 Outdoor Weathering of Exterior Materials

3. Terminology

3.1 *Definitions*— See Terminologies D883 and D4805 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 D1600, 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, 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
	>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

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

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 D4000. 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 D4000 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 D4000 suffix with the following requirements:

W = Weather resistant,
A = Practice D1435,
5 = Elongation properties, and
10 = 10 % change.

A designation of W110 would indicate that it is a Specification D4101 suffix with the following requirements:

W = Weatherability,
1 = Practice D2565, 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:

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 D1531 or D150	2.30
Dissipation factor, max	Test Methods D1531	0.0005
Insulation resistance, min, Ω	Test Methods D257	1×10^{15}
Water immersion stability	Test Methods D1531 or D150	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 D2565 using Test Cycle 1 for exterior applications.
2 = Specimens exposed in a fluorescent UV/condensation accelerated test apparatus that conforms to Practice D4329 using Test Cycle A for exterior applications.
3 = Specimens exposed in a xenon-arc accelerated test apparatus that conforms to SAE J2527 or equivalent for exterior applications.
4 = Specimens exposed in a xenon-arc accelerated test apparatus that conforms to SAE J2412 or equivalent for interior applications.
5 = Specimens exposed to concentrated natural sunlight in accordance with Practice D4364 without water spray.
6 = Specimens exposed to concentrated natural sunlight in accordance with Practice D4364 with water spray (Table 1, Cycle 1).
7 = Specimens exposed to natural sunlight in accordance with Practice D1435 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^2.nm) at 340 nm.
6 = 2500 kJ/(m^2.nm) at 340 nm.
7 = 1000 MJ/m^2 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^2.nm) at 340 nm
D = 601.6 kJ/(m^2.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:

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

Thus, at an irradiance level of 0.55 W/(m^2.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^2.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 D65, specular included, ΔE = 2.5 max.
6 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 2.0 max.
7 = Colorfastness by SAE J1545, for exterior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 3.0 max.
8 = Colorfastness by SAE J1767, for interior materials, CIELAB color difference, 10° observer, Illuminant D65, specular included, ΔE = 2.5 max.
9 = Colorfastness by SAE J1767, for interior materials, CIELAB color difference, 10° observer, Illuminant D65, 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 E29 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 Sampling shall be statistically adequate to satisfy the requirements of 14.4. 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.

NOTE 12—Limited data have shown that, for Polypropylenes, mechanical test values can be significantly affected by the cross sectional area of the runner. Specimens molded using the specified minimum runner size of 5 mm D (~20 mm^2) exhibited lower values of most mechanical properties than specimens molded using runners with cross-sectional areas of 50 and 80 mm^2. Higher viscosity (lower MFR) materials appear to be more sensitive. This effect needs to be considered when comparing data obtained from different sources.

11.1.1 *Specimen Mold*—Molds designed in compliance with Practice D3641 to mold the following test specimens:

11.1.1.1 A Test Method D638, Type I tension test specimen with a thickness of 3.2 ± 0.1 mm.

11.1.1.2 A rectangular bar, with dimensions of 127 mm by 12.7 mm by 3.2 ± 0.1 mm.

11.1.1.3 Plate, with minimum dimensions of 100 mm^2 or 100-mm diameter with a thickness of 3.2 ± 0.2 mm.

11.1.2 *Mold Temperature*—The temperature of the mold shall be 60 ± 3°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 ±2°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 D1238, 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 ±3°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 13—For materials with melt flows less than 1 g/10 min, the temperature of the melt should be raised in 5°C increments from 250°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°C. If unable to obtain the weight at 270°C, make slight adjustments in the injection pressure to achieve the proper weight. The melt temperature shall be 190°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 ±1°F or ±1°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 (±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 ±2 %.

NOTE 14—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 15—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 D3641.

11.2 Prepare test specimens for heat stability testing in accordance with Test Method D3012.

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 ± 2°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 ± 2°C and 50 ± 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 D618, 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 16—When the temperature in the molding area exceeds 28°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.

NOTE 17—Data have shown that, for some polypropylene impact copolymers with higher xylene solubles or higher rubber content, Izod impact values can vary significantly over time.

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 18—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 ± 2°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 ± 2°C and 50 ± 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 [8]

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 D1238. Make two determinations on the material in the form that it is to be molded (such as powder, pellets, or granules).

NOTE 19—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 ± 0.025 mm in diameter. Specimens shall be measured in accordance with Test Methods D5947.

13.1.3 *Tensile Stress*—Test Type I specimens using Test Method D638. 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 D790, Method I, Procedure A, with a 50-mm span, a 5.0 ± 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 D638, 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 20—If the Test Method D638 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
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:

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

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

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 D256 (A) shall be used for notched specimens tested at 23°C. Specimens shall be cut from the center section of the Test Method D638, 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 D256 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 21—Although the 57.2 mm length of specimen does not comply with the minimum specimen length of 61.5 mm specified by Test Method D256, 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 D256, Method A.

NOTE 22—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 D256, 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 D648 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 D3763 shall be used to test specimens equal to or greater in dimensions than 100 mm^2 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 shall 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. The transition region of the curve shall be established using either 5°C or 10°C increments, but -5°C increments must be used when testing 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 23—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 D2584.
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 Inspection and certification of the material supplied with reference to a specification based on this classification system shall be for conformance to the requirements specified herein.

14.2 Lot-acceptance inspection shall be the basis on which acceptance or rejection of the lot is made. The lot-acceptance inspection shall consist of:
14.2.1 *Melt Flow*

14.3 Periodic check inspection with reference to a specification based upon this classification system shall consist of the tests for all requirements of the material under the specification. Inspection frequency shall be adequate to ensure the material is certifiable in accordance with 14.4.

14.4 Certification shall be that the material was manufactured by a process in statistical control, sampled, tested, and inspected in accordance with this classification system, and that the average values for the lot meet the requirements of the specification (line callout).

14.5 A report of test results shall be furnished when requested. The report shall consist of results of the lot-acceptance

inspection for the shipment; the percent by weight of recycled plastic, as defined in 3.1.47 of Guide D7209, if requested; and the result of the most recent periodic-check inspection.

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 D3892 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,[A] Test Method D1238, Condition 230/2.16, g/10 min	Tensile Stress[B] at Yield, Test Method D638, min,[C] MPa	Flexural Modulus[D] (1 % Secant), Test Methods D790, Procedure A, min,[C] MPa	Izod Impact,[E] Resistance at 23°C, Test Method D256, min,[F] J/m	Deflection Temperature at 455-KPa Stress,[G] Test Method D648[H], 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	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.				

[A] Nominal flow rate is as supplied by the manufacturer of the material. Maximum allowable tolerance = ±30 % per individual lot.
[B] Test specimens are unannealed Test Method D638, 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 %.
[C] MPa × 145 = psi.
[D] Test specimens are the center of the unannealed Test Method D638,, 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.
[E] Test specimens are nominal 3.2 mm in width and are at the center section of unannealed Test Method D638, Type I tensile bar.
[F] J/m = ft·lbf/in. × 53.38.
[G] Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.
[H] Minimum values are based on testing the material by Test Method D648, Method A (test span 101.6 mm).

TABLE A Detail Requirements[A] of Polypropylene Not Called Out by Tables B, C, G, and T

Designation or Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile stress at yield,[B] Test Method D638, min, MPa[C]	Unspecified	20	35	50	65	80	95	110	125	Specify value[D]
2	Flexural modulus (1 % secant),[E] Test Methods D790 (A), min, MPa[C]	Unspecified	1000	2000	3000	4000	5000	6000	7000	8000	Specify value[D]
3	Izod impact resistance[F] at 23°C, Test Method D256, min, J/m[G]	Unspecified	15	30	45	60	90	135	190	250	Specify value[D]
4	Deflection temperature at 455 kPa,[H] Test Method D648, min, °C	Unspecified	80	95	110	130	150	170	90	210	Specify value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B]Test specimens are unannealed Test Method D638, 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 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant based on strain.
[F]Test specimens are nominal 3.2 mm in thickness and are at the center section of Test Method D638, Type I tensile bar.
[G]J/m × (1.873×10^{-2}) = ft · lb/in. or J/m = ft · lb/in. × 53.38.
[H]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.

TABLE B Detail Requirements[A] of Unfilled and Unreinforced Polypropylene

Designation or Order No.	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile stress at yield,[B] Test Method D638, min, MPa[C]	Unspecified	5	10	15	20	25	30	35	40	Specify value[D]
2	Flexural modulus (1 % secant),[E] Test Methods D790, (A), min, MPa[C]	Unspecified	100	250	500	750	1000	1250	1500	1750	Specify value[D]
3	Izod impact resistance[F] at 23°C, Test Method D256, min, J/m[G]	Unspecified	10	50	100	200	300	400	500	700	Specify value[D]
4	Deflection temperature at 455 kPa,[H] Test Method D648, min, °C	Unspecified	50	60	70	80	90	100	110	120	Specify value[D]
5	Flow rate,[I] Test Method D1238, Condition 230/2.16, g/10 min	Unspecified	≤0.3	>0.3-1.0	>1.0-3.0	>3.0-10	>10-20	>20-40	>40-100	>100	Specify value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B]Test specimens are unannealed Test Method D638, 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 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant based on strain.
[F]Test specimens are nominal 3.2 mm in thickness and are at the center section of Test Method D638, Type I tensile bar.
[G]J/m × (1.873×10^{-2}) = ft · lb/in. or J/m = ft · lb/in. × 53.38.
[H]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.
[I]Nominal flow rate is as supplied by the manufacturer of the material. Allowable tolerance ±30 % per individual lot.

TABLE C Detail Requirements[A] of Calcium Carbonate Filled Polypropylene

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile Stress at Yield[B] Test Method D638, min, MPa[C]	Unspecified	10	14	17	21	24	27	31	34	Specify Value[D]
2	Flexural Modulus (1 % secant)[E] Test Method D790 (A), min, MPa[C]	Unspecified	800	1100	1400	1700	1900	2200	2500	2700	Specify Value[D]
3	Izod impact resistance[F] at +23°C Test Method D256, min, J/m[G]	Unspecified	15	35	55	75	90	110	135	255	Specify Value[D]
4	Deflection Temperature at 455 kPa[H] Test Method D648, min, °C	Unspecified	75	80	85	90	95	100	105	110	Specify Value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Specify Value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of molded parts.
[B]Test specimens are unannealed Test Method D638, 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 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[F]Test specimens are a nominal 3.2 mm in thickness and are cut from the center of a Test Method D638, Type I tensile bar.
[G]J/m × (1.873×10^{-2}) = ft- lb/in. or J/m = ft-lb/in. × 53.38.
[H]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.

TABLE G Detail Requirements[A] of Glass Reinforced Polypropylene

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile Stress at Yield[B] Test Method D638, min, MPa[C]	Unspecified	24	32	40	48	57	65	74	82	Specify Value[D]
2	Flexural Modulus (1 % secant)[E] Test Method D790 (A), min, MPa[C]	Unspecified	1000	1900	2800	3700	4600	5500	6400	7300	Specify Value[D]
3	Izod impact resistance[F] at +23°C Test Method D256, min, J/m[G]	Unspecified	15	35	55	80	100	130	150	170	Specify Value[D]
4	Deflection Temperature at 455 kPa[H] Test Method D648, min, °C	Unspecified	80	90	100	110	120	130	140	150	Specify Value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Specify Value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of molded parts.
[B]Test specimens are unannealed Test Method D638, 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 %.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638 Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[F]Test specimens are a nominal 3.2 mm in thickness and are cut from center section of Test Method D638, Type I tensile bar.
[G]J/m × (1.873×10^{-2}) = ft- lb/in. or J/m = ft-lb/in. × 53.38.
[H]Test specimens are a nominal 3.2 by 12.7 mm cross section and shall be unannealed.

TABLE H Detail Requirements[A] of Unfilled and Unreinforced Polypropylene Copolymers

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Flexural Modulus (1 % secant)[B] Test Method D790 (A), min, MPa[C]	Unspecified	100	300	600	900	1200	1500	1800	2100	Specify Value[D]
2	Izod impact resistance[E] at 23°C Test Method D256, min, J/m[F]	Unspecified	20	40	70	120	180	260	400	Non Break[G]	Specify Value[D]
3	Multiaxial Impact Ductile-Brittle Transition Temperature, °C[H]	Unspecified	<10	<0	<-10	<-20	<-30	<-40	<-50	<-60	Specify Value[D]

[A]It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of parts molded of these materials.
[B]Test specimens are nominal 3.2 by 12.7-mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[C]MPa × 145 = psi or kPa × 0.145 = psi.
[D]If a specific value is required, it must appear on the drawing or contract, or both.
[E]Test specimens are nominal 3.2 mm in thickness and are cut from center section of unannealed Test Method D638, Type I tensile bar.
[F]J/m × (1.873×10^{-2}) = ft • lb/in. or J/m = ft • lb/in. × 53.38.
[G]Izod impact resistance, non-break failure mode, no value reported
[H]Plate with thickness 3.2 ± 0.2 mm.

TABLE T Detail Requirements[A] of Talc Filled Polypropylene

Designation or Order Number	Property	0	1	2	3	4	5	6	7	8	9
1	Tensile stress at Yield[B] Test Method D638, min, MPa[C]	Unspecified	12	16	20	24	28	32	36	40	Specify Value[D]
2	Flexural Modulus (1 % secant)[E] Test Method D790 (A), min, MPa[C]	Unspecified	650	1000	1350	1700	2050	2400	2750	3100	Specify Value[D]
3	Izod impact resistance[F] at +23°C Test Method D256, min, J/m[G]	Unspecified	15	35	55	75	95	115	135	155	Specify Value[D]
4	Deflection Temperature at 455 kPa[H] Test Method D648, min, °C	Unspecified	70	80	90	100	110	120	130	140	Specify Value[D]
5	To be determined	Unspecified	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Specify Value[D]

[A] It is recognized that detailed test values, particularly Izod impact, may not predict nor even correlate with performance of molded parts.
[B] Test specimens are unannealed Test Method D638, 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 %.
[C] MPa × 145 = psi or kPa × 0.145 = psi.
[D] If a specific value is required, it must appear on the drawing or contract, or both.
[E] Test specimens are nominal 3.2 by 12.7 mm cross section and are at the center of unannealed Test Method D638, Type I tensile bar. Span is a nominal 50 mm. Rate of crosshead is 1.3 mm/min using Method I. Report 1 % secant modulus based on strain.
[F] Test specimens are a nominal 3.2 mm in thickness and are at the center of a Test Method D638, Type I tensile bar.
[G] J/m × (1.873×10^{-2}) = ft- lb/in. or J/m = ft-lb/in. × 53.38.
[H] Test specimens are nominal 3.2 by 12.7 mm cross section and shall be unannealed.

TABLE 1 Melt Temperature Requirements for Molding

Flow Rate, g/10 min	Melt Temperature, °C
1.0–1.5	250
1.6–2.5	240
2.6–4.0	230
4.1–6.5	220
6.6–10.5	210
10.6–17.5	200
17.6-30.0	190

SUPPLEMENTARY REQUIREMENTS

The following supplementary items may become part of this specification, when applicable, as agreed upon between the user and the supplier.

S1. Approval

S1.1 Material submitted by a new supplier must be approved by the user. Material or test specimens submitted by the supplier and intended for evaluation shall be accompanied by the supplier's laboratory test report.

S2. New Sources

S2.1 The user may elect to temporarily accept shipment on the supplier's certification.

S3. Infrared Spectrophotometry or Thermal Analysis, or Both

S3.1 At the option of the user, infrared or thermal analysis, or both, may be conducted on material/parts supplied to this specification. The curves established for initial approval shall constitute the reference standard and shall be kept on file at the user's laboratory. All samples shall produce curves that correspond to the reference standard within agreed upon tolerances when tested under the same conditions as those specified on the master set of curves.

S3.2 In the event such tests are to be designated as requirements to be tested by the supplier, this must appear on the part drawing or purchase contract, or both.

S4. Quality Assurance Provisions for Government/Military Procurement

S4.1 Selection of Acceptable Quality Level (AQL) and of Inspection Level (IL) shall be made with consideration of the specific use requirements. This is discussed in Sections 7 and 8 of Practice D1898, with reference to MIL-STD-105. In the absence of contrary requirements, the following values shall apply:

	IL	AQL
Testing (Polymer, Unfabricated)	S–1[A]	. . .

[A] Samples shall be drawn from the required number of units and pooled for preparation of molded samples for property evaluation.

S5. Government/Military Packaging

S5.1 (Text of this section will be the same as presently being balloted by Subcommittee D20.94.)

APPENDIXES

(Nonmandatory Information)

X1. ADDITIONAL TEST METHODS AND CONDITIONS

X1.1 Table X1.1 specifies the other test methods and conditions, other than the five standard test methods, that can be used to characterize polypropylene.

TABLE X1.1 Test Methods and Conditions[A]

Number	Property	Standard Test Method	Specimen Type Dimensions, mm	Processing Method	Units	Suffix from D4000 or D4101, Section 5	Test Conditions and Supplementary Instructions
1.	Rheological properties						
1.1	Melt flow rate	D1238	Granules or powder		g/10 min	VC2	Test temperature 230°C, 2.16 kg load
1.2	Melt rheology	D3835	Granules or powder		Pa-s		Test temperatures 190, 210, and 230°C
2.	Mechanical properties						
2.1	Tensile stress at yield	D638	Type I, thickness = 3.2	Injection	MPa	KY	Test 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 %
2.2	Tensile elongation at yield				%	LY	
2.3	Tensile modulus				MPa		Speed of 5 mm/min with Class B-2 or better extensometer
2.4	Tensile creep modulus	D2990	Type I, thickness = 3.2	Injection	MPa		At room temperature and at least two elevated temperatures for 1000 h at three stress levels
2.5	Flexural modulus	D790	Center of Type I bar, 63.5 by 12.7 by 3.2	Injection	MPa	UC	1 % secant, 50 mm span, 1.3 mm/min speed 5 ± 0.1 mm radius support rods and loading nose at yield if yield occurs at less than 5 % strain, otherwise report value at 5 %
2.6	Flexural strength				MPa	NA	
2.7	Flexural creep modulus	D2990	Center of Type I bar, 63.5 by 12.7 by 3.2	Injection	MPa		At room temperature and at least two elevated temperatures for 1000 h at three stress levels
2.8	Compressive strength	D695	12.7 by 12.7 by 25.4 prism or 12.7 mm diameter by 25.4 mm long right cylinder	Injection	MPa	QA	Speed 1.3 mm/min (strain rate 0.05 mm/mm/min)
2.9	Compressive modulus		12.7 by 12.7 by 50.8 prism or 12.7 mm diameter by 50.8 mm long right cylinder		MPa		Slenderness ratio 11 to 16 to 1, speed 1.3 mm/min (strain rate 0.025 mm/mm/min)
2.10	Compressive creep modulus	D2990	12.7 by 12.7 prism or 12.7 mm diameter length (must be sufficient to meet slenderness ratio or 11 to 15)	Injection			At room temperature and at least two elevated temperatures for 100 h at three stress levels
2.11	Shear strength	D732	50 disk or 50 by 50 by 50 square with thickness of 3.2	Injection	MPa		Speed 1.3 mm/min
2.12	Shear modulus	D5279	76 by 13 by 3.2	Injection	Pa		–150°C to Tg+20°C or Tm+10°C @ 1 Hz
					Pa	SM	
2.13	Izod impact resistance	D256	Center of Type I bar, 57.2 by 12.7 by 3.2	Injection	J/m	PA	Use a 2.7 J pendulum for all materials, unless at 2.7 J non-break behavior is observed.
2.14	Charpy impact resistance	D6110	127 by 12.7 by 3.2	Injection	J/m	PB	
2.15	Cantilever beam impact	D4812	Center of Type I bar, 63.5 by 12.7 by 3.2		J/m		
2.16	Tensile impact resistance	D1822	Type S, thickness = 3.2	Injection	kJ/m^2		

TABLE X1.1 *Continued*

Number	Property	Standard Test Method	Specimen Type Dimensions, mm	Processing Method	Units	Suffix from D4000 or D4101, Section 5	Test Conditions and Supplementary Instructions
2.17	Gardner impact	D5420	Minimum 50 by 50 by 3.2 square or 50 diameter by 3.2 disk[B]	Injection	J	PG3	Geometry GC at +23°C, or –30°C, or both
2.18	Puncture properties	D3763	Minimum 100 by 100 by 3.2 square or 100 diameter by 3.2	Injection	J		Test speed 2.2 m/s. Report energy at peak load and total energy at 50 % of the peak load. Primary test temperature +23°C. If the temperature at which the material transitions from ductile to brittle failure is required, recommended test temperatures for initial evaluation are +0°C, -15°C, -30°C and -40°C.
2.19	Rockwell hardness	D785	Minimum 25 by 25 square by 6 or 25 diameter disk by 6 thick	Injection compression	HRR		Rockwell R scale (thickness of specimen may be achieved by plying specimens or thinner specimens may be used if hardness is shown not to be changed)
2.20	Shore A or D hardness	D2240	Minimum 25 by 25 square by 6 or 25 diameter disk by 6 thick	Injection compression	Shore A or D		Shore A or D scale (thickness of specimen may be achieved by plying specimens or thinner specimens may be used if hardness is shown not to be changed). Values at 1 s.
3.	Thermal properties						
3.1	Melting temperature	D2117	Any material form		°C	CE	Fisher-Johns
		D3418				CD	DSC/DTA
3.2	Heat deflection temperature	D648	127 by 13 by 3.2	Injection	°C	YA	Unannealed specimen, 1820 kPa stress.
						YD	Unannealed specimen, 455 kPa stress.
3.3	Vicat softening temperature	D1525	Minimum 12 by 12 by 3 square or 12 diameter disk	Injection	°C	CB	Rate A, 50°C/h
3.4	Coefficient of linear thermal expansion	D696	Between 50 and 120 length, other dimensions depend on test apparatus	Injection	µm/(m·°C)		Dilatometer, between –30° and +30°C (use E228 for temperatures other than –30 and +30°C)
		E831	Between 2 and 10 length and less than 10 lateral dimension	Injection	µm/(m·°C)		Report over ranges from –30 to 0°C, 0 to +30°C, and +30 to +60°C
3.5	Thermal conductivity	C177	Depends on test apparatus	Injection	cal/s/cm^2/°C/cm		
3.6	Brittleness temperature	D746	Length minimum 20 + minimum 5 in clamp by 6.35 by 1.91	Injection	°C	PL	Procedure A
3.7	Flammability	D635	127 by 12.7 by 3.2	Injection	mm/min	FA	
		D2863	127 by 6.5 by 3.2	Injection	%	FB	
		D3801	127 by 12.7 by 3.2	Injection	s	FC	Generate rating based on burning time and glow time
		MVSS-302	355 by 102 by 1.25	Injection	mm/min		
4.	Electrical properties						
4.1	Volume resistivity	D257	100 by 100 by 3.2 square or 100 diameter disk by 3.2	Compression	Ohm·cm	EG	Electrification for 60 s with applied voltage of 500 V
4.2	Dielectric strength	D149	100 by 100 by 3.2 square or 100 diameter disk by 3.2	Compression	kV/mm	EA	Method A—short time
						ED	Method B—step by step
4.3	Dielectric constant	D150	100 by 100 by 3.2 square or 100 diameter disk by 3.2	Compression		ED	Test at 1 MHz
4.4	Dissipation factor					EE	
4.5	Arc resistance	D495	Dependent on test apparatus, thickness 3.2	Compression	s	EF	
5.	Optical						
5.1	Yellowness index[A]	E313	Minimum 63.5 by 63.5 by 3.2 or minimum 63.5 diameter disk by 3.2	Injection	YI		Reflectance with specular light included
5.2	Yellowness index	D6290	Pellets		YI		Reflectance, specular light excluded, Illuminant C, 2° observer calculate YI with E313 equation
5.3	Gloss	D523	150 by 75 by 3.2	Injection			At 45 and 60°

TABLE X1.1 *Continued*

Number	Property	Standard Test Method	Specimen Type Dimensions, mm	Processing Method	Units	Suffix from D4000 or D4101, Section 5	Test Conditions and Supplementary Instructions
6.							
6.1	Natural weathering	D1435	Type I tensile bar for physical testing and minimum 65.5 by 63.5 square or 63.5 diameter disk by 3.2 for color change.	Injection		W7	Angle of exposure 45°, report exposure time, % retention of physical properties and total solar radiant energy. See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		SAE J1976	Type I tensile bar for physical testing and minimum 65.5 by 63.5 square or 63.5 diameter disk by 3.2 for color change.	Injection		W8	Angle of exposure 5°, report exposure time, % retention of physical properties and total solar radiant energy. See Third Alphanumeric Suffixes for evaluations and failure criteria.[C]
6.2	Accelerated weathering	D2565	same as for 6.1	Injection		W1	Xenon-arc test as described in First Digit 1. Exposure for 720 h.[D] See Third Digit Alphanumeric for evaluations of exposure and failure criteria.[C]
		D4329	same as for 6.1	Injection		W2	Fluorescent UV/condensation test as described in First Digit 2.[D] See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		SAE J2412	same as for 6.1	Injection		W4	Xenon-arc test as described in First Digit 4. Radiant exposure of 1240.8 kJ/(m^2.nm) at 340 nm.[D] See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		SAE J2527	same as for 6.1	Injection		W3	Xenon-arc test as described in First Digit 3. Radiant exposure of 2500 kJ/(m^2.nm) at 340 nm.[D] See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
		D4364	same as for 6.1	Injection		W5, W6	UV radiant exposure below 385 nm of 1000 MJ/m^2 (approximately 3 years).[D] Specify whether First Digit is 5 or 6. See Third Alphanumeric Suffixes for evaluations of exposure and failure criteria.[C]
6.3	Oven aging	D3012	50 by 10 by 1.0	Compression or Injection	Days	SA	Test temperature = 150°C
7.	Other						
7.1	Water absorption	D570	50.8 by 3.2 disk	Injection	%		24 h immersion at ambient temperature
7.2	Water absorption	D570	50.8 by 3.2 disk	Injection	%		Long-term immersion to saturation
7.3	Chemical resistance	D543	50.8 by 3.2 thick disk or Type I bar, 3.2 thickness	Injection	%		Disk for weight and dimensional changes
				Injection	%		Type I for mechanical properties retention, 7 day immersion
7.4	Density	D792	37 by 12.7 by 3.2	Injection	kg/m^3	GC	
		D1505	Pellet or section of molded or extruded sample		kg/m^3	GD	
7.5	Ash	D5630	Granules or pellets		%		

[A]The measurement of yellowness index of molded flat specimens for comparison between other laboratories is not as reproducible as with pellets due to the difference in molding techniques to make the specimen; the additional heat history applied to the material; differences in design of the colorant measurement systems; the level of specimen transparence, translucence, or opaqueness; and the color of the background backing up the specimen.
[B]The Gardner impact resistance of a material is dependent on the size and shape of the specimen, gating of the mold, and the material flow pattern in the mold during injection molding. When the impact failure mode is ductile the specimen dimensions do not make a significant difference, but when the impact failure mode is brittle, larger specimens of the same thickness will yield higher impact results. In cases of non-agreement, customer and supplier shall agree on specimen and dimensions used.
[C]Failure shall be when the material loses tensile strength or Izod impact properties. If color change is critical, ΔE cannot exceed 3.0.
[D]The minimum exposure time shall be that necessary to produce a statistically significant change in the property measured, that is, tensile strength, impact resistance or color, in the least stable material being evaluated.

X2. TABLE PP REQUIREMENTS FOR UNREINFORCED POLYPROPYLENE GROUPS 02 AND 03 (NATURAL COLOR ONLY)

X2.1 Table X2.1 is the former Table PP for the line call out of random copolymers (Group 2) and copolymers and impact modified materials (Group 03). Groups 02 and 03 have been replaced by Group 05 in the main document. A material previously classified with these groupings may continue to be used. All new materials shall be called out with the Group 5 classification.

TABLE X2.1 PP Requirements for Unreinforced Polypropylene (Natural Color Only)

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] Test Method D1238, Condition 230/2.16, g/10 min	Density, max Test Methods D1505 or D792, kg/m³	Tensile Stress[B] at Yield, Test Method D638, min,[C] MPa	Flexural Modulus[D] (1 % Secant), Test Methods D790, Procedure A, min,[C] MPa	Izod Impact,[E] Resistance at 23°C, Test Method D256, min,[F] J/m	Deflection Temperature at 455-KPa Stress,[G] Test Method D648[H], min, °C
02	Random copolymer	1	General purpose	1	. . .	. . .	910	24	1000	30	78
				2	. . .	. . .	910	24	800	30	67
				3	. . .	. . .	910	22	700	30	67
				4	. . .	. . .	910	20	600	40	62
				5	. . .	. . .	910	17	500	45	62
				6	. . .	. . .	910	16	400	50	60
				7	. . .	. . .	910	15	350	50	60
				0	Other						
		2	Nucleated	1	. . .	. . .	915	26	975	35	87
				2	. . .	. . .	915	24	675	40	77
				3	. . .	. . .	915	22	575	40	73
				4	. . .	. . .	915	21	375	50	67
				0	Other						
		0	Other	0	Other						
03	Copolymers or impact modified	1	Low impact	1	. . .	. . .	905	26	1000	10	80
				2	. . .	. . .	905	21	850	10	65
				3	. . .	. . .	905	23	850	30	70
				4	. . .	. . .	905	18	650	30	65
				5	. . .	. . .	905	17	450	30	60
				6	. . .	. . .	905	24	800	50	75
				7	. . .	. . .	905	22	750	50	70
				8	. . .	. . .	905	20	750	50	70
				9	. . .	. . .	905	18	650	50	65
				0	Other						
		2	Moderate impact	1	. . .	. . .	905	27	1000	60	85
				2	. . .	. . .	905	25	850	70	80
				3	. . .	. . .	905	23	850	70	75
				4	. . .	. . .	905	21	750	70	70
				5	. . .	. . .	905	19	550	70	70
				6	. . .	. . .	905	19	550	70	60
				7	. . .	. . .	905	22	700	90	75
				8	. . .	. . .	905	17	650	90	65
				9	. . .	. . .	905	15	550	90	60
				0	Other						
		3	Medium impact	1	. . .	. . .	905	25	1000	100	75
				2	. . .	. . .	905	23	900	120	70
				3	. . .	. . .	905	19	700	120	65
				4	. . .	. . .	905	17	500	120	60
				5	. . .	. . .	905	17	600	150	65
				6	. . .	. . .	905	25	850	200	70
				7	. . .	. . .	905	20	850	200	70
				8	. . .	. . .	905	20	700	200	70
				9	. . .	. . .	905	16	500	200	60
				0	Other						
		4	High impact	1	. . .	. . .	905	24	800	300	80
				2	. . .	. . .	905	21	800	300	75
				3	. . .	. . .	905	21	550	300	70
				4	. . .	. . .	905	17	500	300	65
				5	. . .	. . .	905	15	450	300	60
				6	. . .	. . .	905	16	500	400	65
				7	. . .	. . .	905	24	750	600	70
				8	. . .	. . .	905	20	700	600	65
				9	. . .	. . .	905	19	500	600	60
				0	Other						
		5	Nucleated	1	. . .	. . .	905	29	1000	10	77
				2	. . .	. . .	905	27	1300	30	95

TABLE X2.1 *Continued*

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] Test Method D1238, Condition 230/2.16, g/10 min	Density, max Test Methods D1505 or D792, kg/m^3	Tensile Stress[B] at Yield, Test Method D638, min,[C] MPa	Flexural Modulus[D] (1 % Secant), Test Methods D790, Procedure A, min,[C] MPa	Izod Impact,[E] Resistance at 23°C, Test Method D256, min,[F] J/m	Deflection Temperature at 455-KPa Stress,[G] Test Method D648[H], min, °C
				3	. . .	. . .	905	23	950	30	90
				4	. . .	. . .	905	21	850	30	85
				5	. . .	. . .	905	23	1050	50	85
				6	. . . .	. . .	905	19	800	50	85
				7	. . .	. . .	905	26	1150	80	85
				8	. . .	. . .	905	22	850	80	80
				9	. . .	. . .	905	19	550	100	80
				0	Other						
		0	Other	0	Other						

[A]Nominal flow rate is as supplied by the manufacturer of the material. Maximum allowable tolerance = ±30 % per individual lot.
[B]Test specimens are unannealed Test Method D638, 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 %.
[C]MPa × 145 = psi.
[D]Test specimens are the center of the unannealed Test Method D638, 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.
[E]Test specimens are nominal 3.2 mm in width and are at the center section of unannealed Test Method D638, Type I tensile bar.
[F]J/m = ft·lbf/in. × 53.38.
[G]Test specimens are nominal 3.2 by 12.7-mm cross section and shall be unannealed.
[H]Minimum values are based on testing the material by Test Method D648, Method A (test span 101.6 mm).

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D4101 - 11) that may impact the use of this standard. (March 1, 2014)

(1) Revised 9.1.
(2) Revised Section 14.
(3) Removed Practice D1898 from 2.1.