Designation: D5857 – 17

Standard Specification for Polypropylene Injection and Extrusion Materials Using ISO Protocol and Methodology[1]

This standard is issued under the fixed designation D5857; 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.

INTRODUCTION

This material specification is intended to provide a call out system for polypropylene utilizing specimen preparation procedures and test method based on ISO standards.

This specification is not intended for the determination of the suitability of performance of materials in the final application. Selection of these materials is to be made by personnel with expertise in the plastics field in which the environment, inherent properties of the materials, performance of the parts, 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 polypropylene homopolymers, polypropylene copolymers, and polypropylene-elastomer compounds produced with or without the addition of impact modifiers (ethylene-propylene rubber, polyisobutylene rubber, and butyl rubber, and so forth), colorants, stabilizers, lubricants, fillers, or reinforcements.

1.2 This specification allows for the use of those polypropylene materials that can be recycled, reconstituted, and reground, provided that the following conditions are met:

1.2.1 The requirements as stated in this specification and other ISO guidelines pertaining to these types of materials are met, and

1.2.2 The material has not been modified in any way to alter its conformance to food contact regulations or similar requirements.

1.3 The proportions of recycled, reconstituted, and regrind 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 buyer of recycled, reconstituted, and regrind materials to ensure compliance.

1.4 The properties included in this classification system are those required to identify the compositions covered. Other requirements necessary to identify particular characteristics important to specialized applications can be specified by using the suffixes as given in Section 5 and those in Classification System D4000.

1.5 This classification system and specification are intended to provide a means of calling out polypropylene materials used in the fabrication of end items or parts. It is not intended for the selection of materials. Material selection can be made by those having expertise in the plastic field only after careful consideration of the design and the performance required of the part, the environment to which it will be exposed, the fabrication process to be employed, the costs involved, and the inherent properties of the material other than those covered by this specification.

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

1.7 The following precautionary caveat pertains only to the test methods portion, Section 13, of this specification: *This specification 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 specification to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This specification is similar to both ISO 1873-1 and ISO 1873-2, but to different degrees. This specification resembles ISO 1873-1 in title only. The content is significantly different. This specification and ISO 1873-2 differ in approach or detail; data obtained using either are technically equivalent.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D1600 Terminology for Abbreviated Terms Relating to Plastics
D1999 Guide for Selection of Specimens and Test Parameters from ISO/IEC Standards (Withdrawn 2000)[3]
D3763 Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors
D3892 Practice for Packaging/Packing of Plastics
D4000 Classification System for Specifying Plastic Materials
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

2.2 *ISO Standards:*[4]

ISO 62 Plastics—Determination of Water Absorption
ISO 75-1 Plastics—Determination of Temperature of Deflection Under Load, Part 1: General Test Method
ISO 75-2 Plastics—Determination of Temperature of Deflection Under Load, Part 2: Plastics and Ebonite
ISO 105 Textiles—Tests for Color Fastness
ISO 178 Plastics—Determination of Flexural Properties of Rigid Plastics
ISO 179 Plastics—Determination of Charpy Impact Strength of Rigid Materials
ISO 180 Plastics—Determination of Izod Impact Strength of Rigid Materials
ISO 293 Plastics—Compression Moulding Test Specimens of Thermoplastic Material
ISO 294 Plastics—Injection Moulding of Test Specimens of Thermoplastic Material
ISO 306 Plastics—Thermoplastic Materials—Determination of Vicat Softening Temperature
ISO 527-1 Plastics—Determination of Tensile Properties, Part 1: General Principles
ISO 527-2 Plastics—Determination of Tensile Properties, Part 2: Test Conditions for Molding and Extrusion Plastics
ISO 537 Plastics—Testing with Torsional Pendulum
ISO 604 Plastics—Determination of Compressive Properties
ISO 868 Plastics and Ebonite—Determination of Indention Hardness by Means of a Durometer (Shore Hardness)
ISO 877 Plastics—Methods of Exposure to direct Weathering, to Weathering Using Glass-Filtered Daylight, and to Intensified Weathering by Daylight Using Fresnel Mirrors
ISO 899 Plastics—Determination of Tensile Creep
ISO 974 Plastics—Determination of the Brittleness Temperature by Impact
ISO 1133 Plastics—Determination of Melt Flow Rate of Thermoplastics
ISO 1183A Plastics—Methods for Determining the Density and Relative Density of Non-Cellular Plastics
ISO 1191 Plastics—Polyethylene and Polypropylenes in Dilute Solutions—Determination of Viscosity Number and of Limiting Viscosity Number
ISO 1628-3 Plastics—Determination of Viscosity Number and Limiting Viscosity Number, Part 3: Polyethylene and Polypropylene Resins
ISO 1873-1 Plastics—Propylene and Propylene-Copolymer Thermoplastics, Part 1: Designation
ISO 1873-2 Plastics—Polypropylene (PP) and Propylene-Copolymer Thermoplastics, Part 2: Preparation of Test Specimens and Determination of Properties
ISO 2039-1 Plastics—Determination of Hardness, Part 1: Ball Indention Method
ISO 2039-2 Plastics—Determination of Hardness, Part 2: Rockwell Hardness
ISO 2818 Plastics—Preparation of Test Specimens by Machining
ISO 3451-1 Plastics—Determination of Ash, Part 1: General Methods
ISO 3795 Road Vehicles, and Tractors and Machinery for Agriculture and Forestry—Determination of Burning Behavior of Interior Materials
ISO 4582 Plastics—Determination of Changes in Colour and Variations in Properties after Exposure to Daylight Under Glass, Natural Weathering or Artificial Light
ISO 4589 Plastics—Determination of Flammability by Oxygen Index
ISO 4892-1 Methods of Exposure to Laboratory Light Sources, Part 1: General Guidance
ISO 4892-2 Plastics—Methods of Exposure to Laboratory Light, Part 2: Xenon Arc Exposure
ISO 4892-3 Plastics—Methods of Exposure to Laboratory Light, Part 3: Fluorescent UV Lamps
ISO 6427 Plastics—Determination of Matter Extractable by Organic Solvents (Conventional Methods)
ISO 6602 Plastics—Determination of Flexural Creep by Three-Point Loading
ISO 6603-1 Plastics—Determination of Multiaxial Impact Behavior of Rigid Plastics, Part 1: Falling Dart Method
ISO 6603-2 Plastics—Determination of Multiaxial Impact Behavior of Rigid Plastics, Part 2: Instrumented Puncture Test
ISO 8256 Plastics—Determination of Tensile Impact Properties
ISO 9113 Plastics—Polypropylene (PP) and Propylene-Copolymer Thermoplastics—Determination of Isotactic Index
ISO 10350 Plastics—Acquisition and Presentation of Comparable Single-Point Data
ISO 11357–3 Plastics—Differential Scanning Calorimetry (DSC), Part 3: Determination of Temperature and Enthalpy of Melting and Crystallization

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

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

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

ISO 11403-1 Plastics—Acquisition and Presentation of Comparable Multi-Point Data, Part 1: Mechanical Properties
ISO 11403-2 Plastics—Acquisition and Presentation of Comparable Multi-point Data—Part 3: Environmental Influences on Properties
ISO 20753 Plastics—Test Specimens

2.3 *IEC Standards:*[4]
IEC 93 Recommended Methods of Test for Volume and Surface Resistivities of Electrical Insulation Materials
IEC 112 Recommended Method for Determining the Comparative Tracking Index of Solid Insulation Materials Under Moist Conditions
IEC 243-1 Recommended Methods of Test for Electric Strength of Solid Insulating Materials at Power Frequencies
IEC 250 Recommended Methods for the Determination of the Permittivity and Dielectric Dissipation Factor of Electrical Insulation Materials at Power, Audio, and Radio Frequencies Including Metre Wavelengths
IEC 296 Specification for Unused Mineral Insulating Oils for Transformers and Switchgear
IEC 60695–11–10 Fire Hazard Testing-Part 11–10: Test Flames-50 W Horizontal and Vertical Test Methods

2.4 *SAE Standards:*[5]
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 J1976 Outdoor Weathering of Exterior 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

3. Terminology

3.1 *Definitions*—Definitions of terms and abbreviations applying to this specification appear in Terminologies D883 and D1600 and Guide D7209.

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 during 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 minimum of 80 % of the specimens exhibit ductile failure.

3.2.6 *ductile failure, n*—one where the specimen deforms plastically before fracturing such that the cracks do not radiate 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.

3.2.7.1 *Discussion*—The injection pressure along with the injection speed determines the volumetric fill rate of the mold.

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

3.2.9 *injection velocity, n*—the average velocity of the melt as it passes through the cross-sectional area of a cavity of a single- or multi-cavity mold at the position that forms the critical portion of the test specimen.

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-H, PP-R, and PP-B*).

3.2.14 *polypropylene heterophasic copolymers (PP-B)*—a propylene plastic consisting of two or more separate phases. These include PP+EPR, PP+EPDM, PP+IIR, PP+BR, and so forth.

3.2.14.1 *Discussion*—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.

3.2.16.1 *Discussion*—Polypropylene random copolymers containing more than one additional monomer are often called terpolymers.

4. Classification

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

NOTE 2—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.

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

4.1.1 The values in Table PP are based on testing that was conducted 40 to 96 h after molding. Testing was conducted in a standard laboratory atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity

4.1.2 To facilitate the incorporation of future or special materials not covered by Table PP, the other/unspecified category (0) for group, class, and grade is indicated on the table with the basic properties to be obtained from Table B or Table H, as it applies.

4.1.3 Specific requirements for unreinforced polypropylene homopolymers not covered by Table PP shall be shown by a six-character designation. The designation shall consist of the letter B and the five digits comprising the cell numbers for the property requirements in the order in which they appear in Table B.

NOTE 3—An example of a special material using this classification system is as follows. The designation PP0110B55143 would indicate the following with the material requirements from Table B:

PP0110	=	General purpose polypropylene homopolymer,
B	=	Table B property requirements,
5	=	25 MPa tensile strength, min,
5	=	1000 MPa flexural modulus (1 % secant, min),
1	=	1.6 kJ/m^2 Charpy impact, min,
4	=	80°C deflection temperature, min, and
3	=	>1.0 to 3.0 nominal flow rate.

4.1.4 Specific requirements for unreinforced impact-modified polypropylene and polypropylene copolymers are shown in Table H. The designation will consist of the letter H and five digits comprising the cell numbers for the property requirements in the order in which they appear in Table H. Table H has been incorporated into this specification to improve the call-out of random copolymers and impact copolymers. Though Table H uses five digits, one digit is unspecified, so it has a reduced number of property callouts based on flexural modulus, Charpy impact, and two multiaxial impact ductile-brittle transition temperatures. If more properties are required to properly call out a material, use Table B.

NOTE 4—An example of a polypropylene copolymer material using Table H would be as follows. The designation PP0600H58540 would indicate the material with the following requirements:

PP0600	=	Copolymer or impact modified,
H	=	Table H property requirements,
5	=	950 MPa flexural modulus, min,
8	=	Non-break failure mode, no value reported Charpy impact resistance, min,
5	=	<–30°C ductile-brittle transition temperature at 2.2 m/s,
4	=	<–20°C ductile-brittle transition temperature at 6.6 m/s,
0	=	Unspecified.

4.1.5 Table PP was developed using data generated from natural color materials. However, Table PP can be used to specify black or other color polypropylenes if the compounded materials meet the requirements found in the table.

4.2 Reinforced versions of the polypropylene materials are classified in accordance with Tables PP, A, C, G, and T, Tables C, G, and T are used when the filler or reinforcement is known to be either calcium carbonate, talc, or glass. Table A is used when the material cannot be classified by Tables PP, C, G, or T. These tables specify the properties after the addition of reinforcements, or fillers for mechanical properties improvement, at the nominal level indicated (see 4.2.1).

4.2.1 *Fillers and Reinforcing Materials*—A symbol (single letter) shall be used for the major reinforcement or combinations thereof (see Table 1), along with two numbers that indicate the nominal percentage of addition by mass (see Table 2).

NOTE 5—This part of the system uses the type and percentage of additive to designate modification of the base material. To facilitate this designation, the type and percentage of additive may 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, or filled polypropylene materials shall be shown by a six-character designation. The designation shall consist of the letter A, C, G, or T and the five digits comprising the cell numbers for the property requirements in the order in which they appear in Tables A, C, G, or T.

4.2.3 When the grade of the basic materials is not known or is not important, the use of 0 grade classification shall be used for reinforced materials in this system (see Note 6).

NOTE 6—An example of this classification system for a reinforced polypropylene material is as follows. The designation PP0110T20T65150 would indicate the following, with the material requirements for Table T:

PP0110	=	general purpose polypropylene homopolymer from Table PP,
T20	=	Talc filled, 20 %,
T	=	Table T property requirements,
6	=	30 MPa tensile strength, min,
5	=	2100 MPa flexural modulus, min,
1	=	2.0 kJ/m^2, Charpy Impact, min,
5	=	56°C deflection temperature, min,
0	=	Unspecified.

If no properties are specified, the designation would be PP0110T20T00000.

4.3 Although the values listed for both filled, reinforced, and unfilled polypropylenes are necessary to include the range of properties available in existing materials, not every possible combination of the properties exists or can be obtained

5. Suffixes

5.1 When additional requirements are needed for the materials covered in this specification that are not covered in Tables PP, A, B, C, G, H, or T those requirements shall be designated through the use of suffixes. The primary suffix list can be found in Classification System D4000, Section 7, Suffix Requirements. Other suffixes that pertain only to the material requirements in this specification are listed below. 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 7—Suffixes from Classification System D4000 contain two letters followed by three numbers, while suffixes from Specification D5857 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 System D4000 suffix.

Suffixes:

E = electrical requirements as designated by the following digits:

First Digit

0 = to be specified.
1 = specimens preconditioned 40 h at 23°C and 50 % relative humidity, then 14 days in distilled water at 23 ± 1°C.
2 = specimens preconditioned 88 h at 23°C and 50 % relative humidity, then 14 days in distilled water at 23 ± 1°C.

Second Digit

0 = to be specified.
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. Specimen size and thickness shall be in accordance with Guide D1999.

Electrical Properties:		
Dielectric constant, max	IEC 250	2.3
Dissipation factor, max	IEC 250	0.0005
Volume resistance, min, ohm-cm	IEC 93	1×10^{15}
Water immersion stability	IEC 250	[A]

[A] Shall meet the dielectric constant and dissipation factor requirements.

W = weatherability requirements as designated by the following digits:

First Digit

1 = specimens exposed in a xenon arc test apparatus to conditions specified in SAE J2527 for exterior applications.
2 = specimens exposed in a xenon arc test apparatus to conditions specified in SAE J2412 for interior applications.
3 = Natural weathering in accordance with ISO 877, for interior applications.
4 = Natural weathering in accordance with ISO 877 for exterior applications.
5 = Specimens exposed in a xenon arc test apparatus to conditions specified in ISO 4892-2 for interior applications.
6 = Specimens exposed in a xenon arc test apparatus to conditions specified in ISO 4892-2 for exterior applications.
7 = Specimens exposed in a fluorescent UV/condensation test apparatus to conditions specified in ISO 4892-3.
8 = Natural weathering in accordance with SAE J1976 for exterior applications.

Second Digit

0 = to be specified.
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 = 225.6 kJ/(m^2.nm) at 340 nm.
8 = 601.6 kJ/(m^2.nm) at 340 nm.

NOTE 8—Conversion from hours to kilojoules (kJ) varies with irradiance and the light/dark cycle. Conversion to kJ from actual light hours is based on the following relation:

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

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 Digit

0 = to be specified.
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 shall be no less than 50 % of the original.
3 = the tensile strength after exposure shall be no less than 90 % of the original.
4 = ISO 105 grey scale rating.
5 = colorfastness by SAE J1545 for exterior materials, CIELAB color difference, 10 degrees observer, illuminant D65, specular included. ΔE = 2.5 max.
6 = colorfastness by SAE J1545 for exterior materials, CIELAB color difference, 10 degrees observer, illuminant D65, specular included. ΔE = 3.0 max.
7 = colorfastness by SAE J1767 for interior materials, CIELAB color difference, 10 degrees observer, illuminant D65, specular included. ΔE = 3.0 max.
Z = Other special requirements characteristics (see 5.2).

5.2 Category "Z" shall be used, as necessary, to designate other special requirements (for example, internal mold release, UV stabilization, etc.) not covered by existing call out capabilities. These shall be spelled out in detail and identified in sequence, that is, 01 ultraviolet (UV)-stabilized, 02 special color, and 03, etc.

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

6. Basic Requirements

6.1 The 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 callout.

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

8. Detail Requirements

8.1 Test samples for the various materials shall conform to the requirements prescribed in Tables PP, A, B, C, G, and 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 lot of material shall be considered as a

unit of manufacture as prepared for shipment, and is permitted to consist of a blend of two or more "production runs" or batches.

10. Number of Tests

10.1 The number of tests conducted shall be consistent with the requirements of the specific ISO test method.

11. Sample Preparation

11.1 The method of sample preparation and type of specimen used for each test is specified in Table 3.

11.2 *Injection Molding:*

11.2.1 *Specimen Mold*—Specimens shall be injection molded using a mold design specified in ISO 294. A mold of the same design as ISO 294, but with shutoff valves to allow balanced molding of single types of specimens without making a complete mold change, can be used if it can be shown that it provides specimens of the same quality with mechanical properties equivalent to specimens molded in the ISO 294 design.

NOTE 9—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.

11.2.2 *Cavity Gate Dimensions*—The gate height and width shall be a minimum of two-thirds of the height and width of the specimen.

11.2.3 *Injection Velocity*—The following calculations shall be used to determine the injection velocity:

$$V_I = (pi \times D^2 \times v_s)/(4 \times n \times A_c) \quad (1)$$

or

$$v_{av} = V_s/(t_I \times A_c \times n) \quad (2)$$

where:

V_{AV} = average injection velocity, mm/s
V_I = injection velocity, mm/s,
D = screw diameter, mm,
v_s = screw speed, mm/s,
n = number of cavities,
A_c = cross section at the position that forms the critical portion of the test specimen,
V_s = shot volume, mm^3, and
t_I = injection time, s.

NOTE 10—Eq 1 and 2 may give slightly different values to some extent due to different contributions of the compression of the whole melt in front of the screw and from different amounts of back flow.

11.2.4 For a given molding machine and given mold, the injection pressure and injection velocity shall be set to produce equal part weights, including sprue and runners, within 1 % regardless of the material's melt flow rate.

11.2.5 *Melt Temperature Determination:*

11.2.5.1 *Needle-type Pyrometer*—The melt temperature shall be measured on cycle by taking the temperature of several successive free shots with a needle-type pyrometer to an accuracy of ±3°C. The needle shall 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 the measurement, collect the mass in a heated container, or in one made from material of low thermal conductivity. Control the quantity of plastic in the free shot so that it is 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.

11.2.5.2 *Infrared Pyrometer*—The melt temperature can also be measured using an infrared pyrometer with 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 to 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 and shall be re-established each time either pyrometer is recalibrated.

11.2.5.3 If other temperatures have to be used because of the nature of the polymer, they shall be reported, together with the reasons for use.

11.2.5.4 An increase in the MFR during molding to 1.5 times the original value shall be avoided. If the MFR increases by more than 1.5 times the original value, the melt temperature shall be lowered, 10°C at a time, until the increase in MFR is <1.5 times the original value.

11.2.6 *Mold Temperature*—Mold 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.

11.2.7 *Specimen Weight*—For a given molding machine and mold combination, the injection pressure and injection velocity shall be set to produce equal part weights, including sprue and runners, within 1 % regardless of the material melt flow rate.

11.2.8 *Injection and Hold Pressures*—The injection pressure and hold pressure shall be set at a level that does not produce flash, sink marks, or voids in the specimens. The maximum amount of flash shall not exceed 1 mm and shall be acceptable only in the non-testing areas of the specimen.

11.2.9 *Reporting*—Report the injection molding conditions in accordance with ISO 294 and ISO 1873-2.

11.3 *Compression Molding:*

11.3.1 *Specimens*—For electrical testing or when the specimens cannot be injection molded, specimens shall be prepared by stamping or machining (see ISO 2818) from a compression-molded sheet. Compression molding of sheet shall be conducted in accordance with ISO 293, with the following additional points specified in ISO 1873-2:

11.3.1.1 *Mold*—A simple three-plate frame.

11.3.1.2 *Predrying*—No drying is normally necessary.

11.3.1.3 *Molding Temperature*—210 ± 5°C.

11.3.1.4 *Average Cooling Rate*—Method B; 15 ± 5°C/min.

11.3.1.5 *Molding Procedure*—The contact pressure time shall be 5 to 10 min, and the full-pressure time shall be 2 to 5 min. The demolding temperature shall be less than or equal to 40°C.

NOTE 11—The method of sample preparation may affect the level of crystallinity or orientation in the test specimen. As a consequence, test specimens may yield different test results. Thus, the method of preparation shall be taken into account when comparing results. In cases of disagreement, injection-molded specimens shall be the referee standard.

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. It is recommended that specimens be allowed to cool individually for about 30 min on a bench, or in a rack, or on the injection molded runner 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 the 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 procedure.

NOTE 12—When the temperature in the molding area exceeds 28°C or the humidity level exceeds 60 % (applies only to filled material) specimens shall be moved as quickly as possible to the controlled or standard laboratory atmosphere.

NOTE 13—Acceptable storage mediums include boxes, paper bags or envelopes, plastic bags, or racks, whichever is most practical for the laboratory storing the specimens.

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

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

NOTE 14—Extending the conditioning time may result in increased or decreased test results. Polypropylene properties change with time as a result of amorphous densification and, in some cases, due to a small degree of secondary crystallization in the rubbery phase.

12.2 *Test Conditions:*

12.2.1 Natural unfilled polypropylene shall be tested in a controlled laboratory atmosphere of 23 ± 2°C. For filled and reinforced polypropylene or polypropylene blends that 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 material type's properties are not affected by humidity. For all materials to be tested for electrical properties, the laboratory shall comply with the requirements of the standard test methods for electrical testing. In all cases the laboratory shall report both the temperature and humidity conditions during testing.

13. Test Methods

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

NOTE 15—It is recognized that detailed test values, particularly Charpy Impact, may not predict nor even correlate with performance of parts molded of these materials.

13.1.1 *Flow Rate*—Condition 12 (230°C with 2.16 kg load) of ISO 1133. Make two determinations on the material in the form that it is to be molded (such as powder, pellets, or granules).

NOTE 16—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 *Tensile Stress at Yield*—Test an unannealed ISO 20753 Type A1 specimen using ISO 527. For materials that show a breaking strain greater than 10 %, use a test speed of 50 mm/min. For materials that break at a strain less than 10 %, use a test speed of 5 mm/min.

13.1.3 *Flexural Modulus (Chord Modulus)*—Using ISO 178, determine a chord modulus between 0.0005 and 0.0025 mm/mm strain using a rectangular 80 by 10 by 4-mm specimen cut from the center of an unannealed ISO 20753 Type A1 multipurpose specimen. Set the test span at 64 mm and test speed to 2 mm/min. The support rods and loading nose shall be 5 ± 0.1 mm in radius. Test results shall be corrected for machine compliance.

NOTE 17—If the ISO 20753 Type A1 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 *Charpy Impact Resistance*—The center section of an unannealed ISO 20753 Type A1 multipurpose bar shall be tested in accordance with ISO 179, Method 1A, with the V-notch having 0.25-mm radius at bottom. The test temperature is 23°C.

13.1.5 *Falling Mass Impact Resistance*—Testing shall be conducted in accordance with ISO 6603-2, with a 60-mm diameter by 2-mm thick specimen or a 60-mm square by 2-mm thick supported by a 40-mm diameter ring and impacted with a 20-mm diameter dart utilizing either the variable height or variable weight method. Determine the total energy to failure.

NOTE 18—The square specimen is preferred as this specimen may also be used to measure mold shrinkage properties.

13.1.6 *Temperature of Deflection Under Load*—Using ISO 75-1 and 75-2, test a rectangular 80 by 10 by 4-mm specimen cut from the center of an unannealed ISO 20753, Type A1

multipurpose specimen in the flatwise position. A load is applied at the center of the specimen to give a fiber stress of 1.8 MPa.

13.1.7 *Multiaxial Impact Ductile-Brittle Transition Temperature*—Test Method D3763 shall be used to test specimens 3.2 mm thick and equal to or greater than 100 mm in diameter. The test speeds shall be 2.2 m/s and 6.6 m/s with the 12.7-mm diameter impact dart and 76-mm support ring. The temperature at which a minimum of 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 graph method. When using the standard graphical method to determine the 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, nor the highest failure temperature. Draw a straight line through a minimum of four points, two above and two below the 20 % 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 19—Additional test methods for characterization can be found in Table 4, ISO 10350, and ISO 11403-2.

14. Inspection and Certification

14.1 Inspection and certification of the material supplied under 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 those tests that ensure process control during manufacture as well as those necessary to ensure certifiability. Tests are melt flow rate, percent of reinforcement or filler, tensile stress at yield, flexural modulus, Charpy impact, and temperature of deflection under load (HDT).

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

14.4 Certification shall be that the material was manufactured, sampled, tested, and inspected in accordance with this specification and that the average values meet the requirements at a confidence level of 95 %.

14.5 A report of the test results shall be furnished when requested. The report shall consist of results of the lot-acceptance inspection for the shipment and results of the most recent periodic-check inspection.

15. Packaging and Package Marking

15.1 The provision of Practices D3892 apply for packaging, packing, and marking of plastic materials.

16. Keywords

16.1 injection and extrusion materials; polypropylene; recycled

TABLE PP Requirements for Unreinforced, Reinforced, and Filled Polypropylene

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] ISO 1133, Condition 230/2.16, g/10 min	Density, Maximum, ISO 1183, kg/m^3,[B] (for reference only)	Tensile Stress at Yield, ISO 527, minimum, MPa	Flexural Modulus (Chord), ISO 178, minimum, MPa	Charpy Impact Resistance at 23°C, ISO 179, minimum, kJ/m^2	Deflection Temperature at 1.8 MPa Stress, ISO 75-2 Flatwise, minimum, °C
01	Homopolymer	1	general purpose	1	unfilled	≤0.3		26	1075	3.5	48
				2	unfilled	>0.3 ≤1.0		26	1025	3.1	48
				3	unfilled	>1.0 ≤3.0		26	1025	2.9	46
				4	unfilled	>3.0 ≤7.0		26	975	2.5	45
				5	unfilled	>7.0 ≤20		24.5	875	2.1	45
				6	unfilled	>20 ≤40		23.5	825	1.9	43
				7	unfilled	>40 ≤100		22.5	825	1.7	43
				8	unfilled	>100 ≤200		21.5	875	1.7	43
				9	unfilled	>200		20	875	1.4	46
				0	other						
		2	nucleated	1	unfilled	>1.0 ≤3.0		31.5	1375	3.1	53
				2	unfilled	>1.0 ≤3.0		29	1175	3.1	50
				3	unfilled	>3.0 ≤7.0		29	1175	2.6	53
				4	unfilled	>3.0 ≤7.0		29	1175	2.5	50
				5	unfilled	>7.0 ≤20		28.5	1175	2.4	52
				6	unfilled	>7.0 ≤20		27	1175	2.1	49
				7	unfilled	>20		27	1075	2.1	47
				0	other						
		3	high crystallinity	1	unfilled	≤1.0		36	2050	2.5	53
				2	unfilled	>1.0 ≤3.0		34	1850	2.5	53
				3	unfilled	>3.0 ≤7.0		34	1650	2.5	53
				4	unfilled	>7.0 ≤20		31	1425	2.6	52
				5	unfilled	>20 ≤40		28.5	1325	2.8	50
				6	unfilled	>40		24.5	1325	3.0	50

TABLE PP Requirements for Unreinforced, Reinforced, and Filled Polypropylene

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] ISO 1133, Condition 230/2.16, g/10 min	Density, Maximum, ISO 1183, kg/m^3,[B] (for reference only)	Tensile Stress at Yield, ISO 527, minimum, MPa	Flexural Modulus (Chord), ISO 178, minimum, MPa	Charpy Impact Resistance at 23°C, ISO 179, minimum, kJ/m^2	Deflection Temperature at 1.8 MPa Stress, ISO 75-2 Flatwise, minimum, °C
				0	other						
		0	other	0	other						
02	Refer to Appendix Appendix X1.										
03	Refer to Appendix Appendix X1.										
04	Refer to Appendix Appendix X1.										
05	Homopolymer, Heat-stabilized	1	general purpose	1	unfilled	≤0.3		26	1075	3.5	48
				2	unfilled	>0.3 ≤1.0		26	1025	3.1	48
				3	unfilled	>1.0 ≤3.0		26	1025	2.9	46
				4	unfilled	>3.0 ≤7.0		26	975	2.5	45
				5	unfilled	>7.0 ≤20		24.5	875	2.1	45
				6	unfilled	>20 ≤40		23.5	825	1.9	43
				7	unfilled	>40 ≤100		22.5	825	1.7	43
				8	unfilled	>100 ≤200		21.5	875	1.7	43
				9	unfilled	>200		20	875	1.4	46
				0	other						
		2	nucleated	1	unfilled	>1.0 ≤3.0		31.5	1375	3.1	53
				2	unfilled	>1.0 ≤3.0		29	1175	3.1	50
				3	unfilled	>3.0 ≤7.0		29	1175	2.6	53
				4	unfilled	>3.0 ≤7.0		29	1175	2.5	50
				5	unfilled	>7.0 ≤20		28.5	1175	2.4	52
				6	unfilled	>7.0 ≤20		27	1175	2.1	49
				7	unfilled	>20		27	1075	2.1	47
				0	other						
		3	high crystallinity	1	unfilled	≤1.0		36	2050	2.5	53
				2	unfilled	>1.0 ≤3.0		34	1850	2.5	53
				3	unfilled	>3.0 ≤7.0		34	1650	2.5	53
				4	unfilled	>7.0 ≤20		31	1425	2.6	52
				5	unfilled	>20 ≤40		28.5	1325	2.8	50
				6	unfilled	>40		24.5	1325	3.0	50
				0	other						
		0	other	0	other						
06	Copolymers or impact modified	0	other	0	other	Use Table H to 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.					
07	Copolymers or impact modified, Heat-stabilized	0	other	0	other	Use Table H to 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.					
11	Glass-filled homopolymer	1	reinforced	G10	10 % glass	...	1000	35	2000	3.0	81
				G15	15 % glass	...	1010	35	2700	2.4	110
				G20	20 % glass	...	1060	50	3500	4.5	120
				G30	30 % glass	...	1150	54	5000	5.5	130
				0	other						
		2	reinforced, heat-stabilized	G15	15 % glass	...	1020	35	2700	2.4	110
				G20	20 % glass	...	1060	50	3500	4.5	120
				G30	30 % glass	...	1150	54	4100	5.5	130
				0	other						

TABLE PP Requirements for Unreinforced, Reinforced, and Filled Polypropylene

Group	Description	Class	Description	Grade	Description	Nominal Flow Rate,[A] ISO 1133, Condition 230/2.16, g/10 min	Density, Maximum, ISO 1183, kg/m^3,[B] (for reference only)	Tensile Stress at Yield, ISO 527, minimum, MPa	Flexural Modulus (Chord), ISO 178, minimum, MPa	Charpy Impact Resistance at 23°C, ISO 179, minimum, kJ/m^2	Deflection Temperature at 1.8 MPa Stress, ISO 75-2 Flatwise, minimum, °C
		3	chemically-coupled	G20	20 % glass	...	1090	54	3800	5.0	125
				G30	30 % glass	...	1160	55	5000	6.0	130
				G40	40 % glass	...	1270	70	8000	7.7	140
				0	other						
		4	chemically-coupled, heat-stabilized	G10	10 % glass	...	1000	34	1800	3.0	90
				G20	20 % glass	...	1090	54	3200	5.3	125
				G25	25 % glass	...	1090	60	4000	5.5	...
				G30	30 % glass	...	1160	55	4300	6.0	130
				G40	40 % glass	...	1270	70	8000	7.7	140
				0	other						
		5	highly-coupled	0	other						
		6	highly-coupled, heat-stabilized	G45	45 % glass	...	1310	100	10 000	9.5	145
				0	other						
12	Glass-filled copolymer	1	reinforced	G20	20 % glass	...	1060	45	2850	3.8	130
				0	other						
		2	reinforced, heat-stabilized	G10	10 % glass	...	1000	37	2600	2.5	108
				G15	15 % glass	...	1020	40	2500	2.9	112
				G20	20 % glass	...	1060	45	2850	3.8	128
				G30	30 % glass	...	1150	57	5350	6.0	135
				0	other						
		3	chemically-coupled	G15	15 % glass	...	1020	30	2000	10.0	110
				0	other						
		4	chemically-coupled, heat-stabilized	G15	15 % glass	...	1030	30	2000	10.0	110
				G20	20 % glass	...	1090	55	3800	5.7	130
				G30	30 % glass	...	1150	60	5400	6.2	134
				G45	45 % glass	...	1270	68	6200	10.0	135
				0	other						
		5	highly-coupled	0	other						
		6	highly-coupled, heat-stabilized	0	other						
21	Talc-filled homopolymer	1	general purpose	T15	15 % talc	...	1000	23	1750	2.0	47
				T20	20 % talc	...	1100	26	2010	1.8	59
				T30	30 % talc	...	1190	23	2500	1.9	64
				T40	40 % talc	...	1290	25	3000	2.2	63
		2	heat-stabilized	T20	20 % talc	...	1110	25	1750	1.6	54
				T30	30 % talc	...	1180	26	2800	1.7	65
				T40	40 % talc	...	1300	24	2900	1.7	64
				0	other						
		3	high crystallinity	0	other						
		4	high crystallinity, heat-stabilized	0	other						
		5	Extrusion Grade	T20	20 % talc	...	1050	31	2119	...	66
				0	other						
		6	Extrusion Grade, heat-stabilized	T20	20 % talc	...	1100	23	1800	2.4	60
				T40	40 % talc	...	1280	24	4000	2.5	73
				0	other						
22	Talc-filled copolymer	1	general purpose	T10	10 % talc	...	1020	23	1300	2.3	47
				T15	15 % talc	...	1030	20	1500	3.0	51
				T20	20 % talc	...	1130	19	1500	2.0	51
				T25	25 % talc	...	1130	20	2000	2.2	53
				T40	40 % talc	...	1280	19	2300	2.3	57
				0	other						