Designation: D3350 – 21

Standard Specification for Polyethylene Plastics Pipe and Fittings Materials[1]

This standard is issued under the fixed designation D3350; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the identification of polyethylene plastic pipe and fittings materials in accordance with a cell classification system. It is not the function of this specification to provide specific engineering data for design purposes, to specify manufacturing tolerances, or to determine suitability for use for a specific application.

1.1.1 Some plastic pipe and fitting PE compounds classified by this standard are sold as a base material and then combined with other material(s) (for example, color or additive concentrate) by the pipe or fitting manufacturer into a final classified compound either prior to or during production of the final article. This standard, excluding the requirements of Table 1, properties 5 and 6, and 6.1.1, can be used for property verification of the incoming base material(s) in accordance with 8.1.

1.1.2 In the case of PE compounds sold as the compound classified by the standard, see 8.1 regarding property verification of the incoming classified compound.

1.1.3 Compounds with a cell classification value other than '0' for the Hydrostatic Strength Classification (property 6) rely on a defined formulation. The composition of the defined formulation can be obtained from the owner of the formulation.

NOTE 1—Deviations from the defined formulation may affect the Hydrostatic Strength Classification.

1.2 Polyethylene plastic materials, being thermoplastic, are reprocessable and recyclable (Note 3). This specification allows for the use of those polyethylene materials, provided that all specific requirements of this specification are met.

NOTE 2—The notes in this specification are for information only and shall not be considered part of this specification.

NOTE 3—See Guide D5033 for information and definitions related to recycled plastics.

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

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 4—There is no known ISO equivalent to this standard.

1.5 For information regarding molding and extrusion materials see Specification D4976. For information regarding wire and cable materials see Specification D1248.

1.6 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

D638 Test Method for Tensile Properties of Plastics

D746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact

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

D1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

D1505 Test Method for Density of Plastics by the Density-Gradient Technique

D1603 Test Method for Carbon Black Content in Olefin Plastics

D1693 Test Method for Environmental Stress-Cracking of Ethylene Plastics

D1898 Practice for Sampling of Plastics (Withdrawn 1998)[3]

[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.

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

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

TABLE 1 Primary Properties[A] —Cell Classification Limits

Property	Test Method	0	1	2	3	4	5	6	7	8
1. Density, g/cm^3	D1505	Unspecified	0.925 or lower	>0.925-0.940	>0.940-0.947	>0.947-0.955	>0.955	. . .	Specify Value	
2. Melt index	D1238	Unspecified	>1.0	1.0 to 0.4	<0.4 to 0.15	<0.15[B]	[C]		Specify Value	
3. Flexural modulus, MPa (psi)	D790	Unspecified	<138 (<20 000)	138-<276 (20 000 to <40 000)	276-<552 (40 000 to 80 000)	552-<758 (80 000 to 110 000)	758-<1103 (110 000 to <160 000)	>1103 (>160 000)	Specify Value	
4. Tensile strength at yield, MPa (psi)	D638	Unspecified	<15 (<2200)	15-<18 (2200-<2600)	18-<21 (2600-<3000)	21-<24 (3000-<3500)	24-<28 (3500-<4000)	>28 (>4000)	Specify Value	
5. Slow Crack Growth Resistance										
I. ESCR	D1693	Unspecified								
a. Test condition (100% Igepal.)[D]			A	B	C	C	. . .	. . .	. . .	Specify Value
b. Test duration, h			48	24	192	600				
c. Failure, max, %		Unspecified	50	50	20	20				
II. PENT (hours)	F1473									
Molded plaque, 80°C, 2.4 MPa		Unspecified	. . .	. . .	. . .	10	30	100	500	Specify Value
Notch depth, F1473, Table 1		Unspecified								
6. Hydrostatic Strength Classification										
I. Hydrostatic design basis, MPa (psi), (23°C)	D2837	NPR[E]	5.52 (800)	6.89 (1000)	8.62 (1250)	11.03 (1600)	. . .	. . .		
II. Minimum required strength, MPa (psi), (20°C)	ISO 12162	. . .	. . .	. . .	. . .	. . .	8 (1160)	10 (1450)		

[A]Compliance with physical properties in accordance with Section 8 is required including requirements for cell classification, color, and ultraviolet (UV) stabilizer, thermal stability, brittleness temperature, density, tensile strength at yield, and elongation at break.
[B]Refer to 10.1.4.1.
[C]Refer to 10.1.4.2.
[D]There are environmental concerns regarding the disposal of Nonylphenoxy poly(ethyleneoxy) ethanol (CAS 68412-54-4) for example, Igepal CO-630. Users are advised to consult their supplier or local environmental office and follow the guidelines provided for the proper disposal of this chemical.
[E]NPR = Not Pressure Rated.

D2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
D2839 Practice for Use of a Melt Index Strand for Determining Density of Polyethylene
D3035 Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter
D3892 Practice for Packaging/Packing of Plastics
D4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D4703 Practice for Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
D4883 Test Method for Density of Polyethylene by the Ultrasound Technique
D4976 Specification for Polyethylene Plastics Molding and Extrusion Materials
D5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics (Withdrawn 2007)[3]
F1473 Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins
F2263 Test Method for Evaluating the Oxidative Resistance of Polyethylene (PE) Pipe to Chlorinated Water

2.2 *ISO Standard:*
ISO 12162 Thermoplastic Materials for Pipes and Fittings for Pressure Applications—Classification and Designation—Overall Service (Design) Coefficient

3. Terminology

3.1 *Definitions:*

3.1.1 Terms as described in Terminology D883 shall apply in this specification.

3.1.2 *polyethylene plastics, n*—as defined by this specification, plastics or resins prepared by the polymerization of no less than 85 % ethylene and no less than 95 % of total olefins with additional compounding ingredients.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *base materials, n*—PE material without non-black or black pigment, supplied to industry, that is either a PE compound classified by this Standard or a component of a PE compound classified by this standard.

3.2.2 *PE compounds, n*—has the same meaning as PE plastics materials, compounds, and plastics.

3.3 Historical usage and user group conventions have resulted in inconsistent terminology used to categorize and describe polyethylene resins and compounds. The following terminology is in use in ASTM specifications pertaining to polyethylene:

3.3.1 *Specification D1248:*

3.3.1.1 Type (0, I, II, III, IV) = density ranges (same, respectively, as Class in Specification D4976).

3.3.1.2 Class (A, B, C, D) = composition and use.

3.3.1.3 Category (1, 2, 3, 4, 5) = melt index ranges (same as Grade in Specification D4976).

3.3.1.4 Grade (E, J, D, or W followed by one or two digits) = specific requirements from tables.

3.3.2 *Specification D3350:*

3.3.2.1 Type (I, II, III) = density ranges (same as Types I, II, and III in Specification D1248 and Classes 1, 2, and 3 in Specification D4976).

3.3.2.2 Class = a line callout system consisting of "PE" followed by six cell numbers from Table 1 plus a letter (A, B, C, D, E) denoting color and UV stabilizer.

3.3.2.3 Grade = simplified line callout system using "PE" followed by density and slow crack growth cell numbers from Table 1.

3.3.3 *Specification D4976:*

3.3.3.1 Group (1, 2) = branched or linear polyethylene.

3.3.3.2 Class (0, 1, 2, 3, 4) = density ranges (same, respectively, as Type in Specification D1248).

3.3.3.3 Grade (1, 2, 3, 4, 5) = melt index ranges (same as Category in Specification D1248).

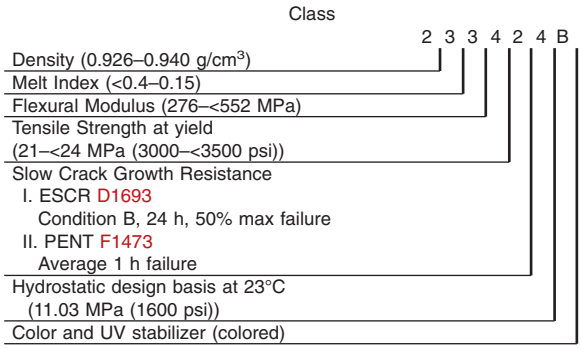
4. Classification

4.1 Polyethylene plastic pipe and fittings compounds are classified in accordance with density, melt index, flexural modulus, tensile strength at yield, slow crack growth resistance, and hydrostatic strength classification in Table 1.

NOTE 5—It has been a long-standing practice to use the following terms in describing polyethylene plastics:

Type I (0.910 to 0.925) = Low Density
Type II (0.926 to 0.940) = Medium Density
Type III (0.941 to 0.965) = High Density

NOTE 6—The manner in which materials are identified in the cell classification is illustrated for Class PE233424B as follows (refer also to Table 1 and 6.2):



4.2 Materials used in polyethylene plastic pipe and fittings shall use a cell-type format for the identification, close characterization, and specification of material properties. The information from the format is to be used alone or in combination.

NOTE 7—This type format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available materials. The manufacturer should be consulted. Additionally, the appropriate ASTM standard specification should be reviewed to assure materials utilized will meet all the material and piping requirements as specified in the standard.

4.3 *Grade*—A code for polyethylene pipe and fittings materials that consists of the two letter abbreviation for polyethylene (PE) followed by two numbers that designate the density cell (Property 1) and the slow crack growth resistance cell (Property 5), as defined by either Test Method F1473 or Test Method D1693, of the thermoplastic, as specified in Table 1. For the requirements of Property 5 (slow crack growth resistance), consult the materials section of the appropriate ASTM standard specification for the end-use application.

NOTE 8—Grade designations were adapted from Specification D1248 – 84 prior to the removal of pipe material from D1248 - 84. Former Specification D1248 – 84 grades for PE pipe materials were P14, P23, P24, P33, and P34. Equivalent Specification D3350 grade designations for these materials are PE11, PE20, PE23, PE30, and PE33, respectively.

5. Materials and Manufacture

5.1 The molding and extrusion material shall be polyethylene plastic in the form of powder, granules, or pellets.

5.2 The molding and extrusion materials shall be as uniform in composition and size and as free of contamination as is achieved by good manufacturing practice. If necessary, the level of contamination may be agreed upon between the manufacturer and the purchaser.

5.3 When specified, the color and translucence of molded or extruded pieces formed, under the conditions specified by the manufacturer of the materials, shall be comparable within commercial match tolerances to the color and translucence of standard samples supplied in advance by the manufacturer of the material.

6. Physical Properties

6.1 *Cell Classification*—Test values for specimens of the PE material prepared as specified in Section 9 and tested in accordance with Section 10 shall conform to the requirements given in Table 1. A typical property value for a PE material is to be the average value from testing numerous lots or batches and determines the cell number. When, due to manufacturing tolerances and testing bias, individual lot or batch values fall into the adjoining cell, the individual value shall not be considered acceptable unless the user, or both the user and the producer, determine that the individual lot or batch is suitable for its intended purpose.

6.1.1 For PE compounds with a code letter designation of A, all properties shall be determined, for classification purposes, on the non-pigmented (natural) material. For PE compounds with any other code letter designation, all properties other than density, in accordance with 6.5, shall, for classification purposes, be determined on the PE compound represented by that code letter (for example, black [C], colored with UV stabilizer [E], etc.)

6.2 *Color and Ultraviolet (UV) Stabilizer*—The color and UV stabilization shall be indicated at the end of the cell classification by means of a letter designation in accordance with the following code:

Code Letter	Color and UV Stabilizer
A	Natural
B	Colored
C	Black with a carbon black in the range as noted in 6.2.1 and 6.2.2
D	Natural with UV stabilizer
E	Colored with UV stabilizer

6.2.1 For PE compounds with a hydrostatic strength classification cell class 0 (not pressure-rated), the carbon black content shall be in the range of 2.0 % to 4.0 %.

6.2.2 For PE compounds with a hydrostatic strength classification other than cell class 0, the carbon black content shall be in the range of 2.0 % to 3.0 %.

6.3 *Thermal Stability*—The PE material shall contain sufficient antioxidant so that the minimum induction temperature shall be 220°C when tested in accordance with 10.1.9.

6.4 *Brittleness Temperature*—The brittleness temperature shall not be warmer than −60°C when tested in accordance with Test Method D746.

6.5 *Density*—The density used to classify the material shall be the density of the PE base material (non-pigmented PE) determined in accordance with 10.1.3. When the average density of any lot or shipment falls within ±0.002 g/cm^3 of the nominal value, it shall be considered as conforming to the nominal value and to all classifications based on the nominal value.

6.5.1 For black compounds, containing carbon black, determine the density, *Dp*, and calculate the resin density, *Dr*, as follows:

$$Dr = Dp - 0.0044C$$

where:

C = weight percent of carbon black.

6.5.2 For colored compounds, the nominal density of the base material shall be provided by the manufacturer, on request.

6.6 *Tensile Strength at Yield*—The tensile strength at yield used to classify the material shall be the tensile strength at yield of the PE resin determined in accordance with 10.1.6. When the average tensile strength at yield of any lot or shipment falls within ±3.45 MPa (±500 psi) of the nominal value, it shall be considered as conforming to the nominal value and to all classifications based on the nominal value.

6.7 *Elongation at Break*—As tested in accordance with 10.1.6, all pressure rated materials shall have a minimum extension at break of 400 %.

6.8 *Oxidative Resistance Classification:*

6.8.1 The Oxidative Resistance Classification is a classification of a PE compound's resistance to the oxidative effects of chlorinated potable water. The classification is only for PE compounds intended for potable water pressure piping applications as noted in the materials requirement section of the appropriate ASTM standard specification. In addition to the class specified in 3.3.2.2, the user shall specify an oxidative resistance requirement by appending the category designation requirement (Table 2) to the line call out.

TABLE 2 Minimum Log Average Test Times for Oxidative Resistance Classification

Categorization	90°C (194°F) Test Temperature		
	Test Stress 2.48 MPa (360 psi) Time (h)	Test Stress 2.76 MPa (400 psi) Time (h)	Test Stress 3.10 MPa (450 psi) Time (h)
CC0	Unspecified	Unspecified	Unspecified
CC1	2700	1900	1200
CC2	7400	5100	3400
CC3	16 200	11 100	7400

6.8.2 The oxidative resistance time used to classify the PE compound shall be determined in accordance with 10.1.11 and be classified in accordance with Table 2.

7. Sampling

7.1 A batch or lot shall be considered as a unit of manufacture and shall consist of one production run or as a blend of two or more production runs of material.

7.2 Unless otherwise agreed upon between the manufacturer and the purchaser, the material shall be sampled in accordance with the procedure described in Sections 9 through 12 of Practice D1898. Adequate statistical sampling prior to packaging shall be considered an acceptable alternative.

NOTE 9—A sample taken from finished product may not necessarily represent the original batch or lot.

8. Number of Tests

8.1 The requirements identified by the material designation and otherwise specified in the purchase order shall be verified by tests made in accordance with 11.1. For routine inspection, only those tests necessary to identify the material to the satisfaction of the purchaser shall be required. One sample shall be sufficient for testing each batch or lot provided that the average values for all of the tests made on that batch or lot comply with the specified requirements.

9. Specimen Preparation

9.1 Unless otherwise specified in Section 10, the test specimens shall be molded in accordance with Procedure C of Annex A1 of Practice D4703.

9.2 When pipe or fitting test specimens are required, they shall be extruded or molded in accordance with the specifications of the material manufacturer.

10. Test Methods

10.1 The properties enumerated in this specification shall be determined in accordance with the following test methods:

10.1.1 *Conditioning*—Unless otherwise specified in the test methods or in this specification, for those tests where conditioning is required, condition the molded test specimens in accordance with Procedure A of Practice D618.

10.1.2 *Test Conditions*—Unless otherwise specified in the test methods or in this specification, conduct tests at the standard laboratory temperature of 23 ± 2°C (73.4 ± 3.6°F).

10.1.3 *Density*—Test Method D1505 or alternative methods referenced in 2.1 (see D792, D2839, and D4883) providing equivalent accuracy. Make duplicate determinations using two separate portions of the same molding or from two moldings. The molded specimen thickness portions shall be 1.9 ± 0.2 mm (0.075 ± 0.008 in.). Calculate the average value.

10.1.4 *Melt Index*—Test Method D1238, using Condition 190/2.16. Make duplicate determinations on the material in the form of powder, granules, or pellets, and calculate the average; no conditioning is required.

10.1.4.1 For materials having a melt index less than 0.15 (Cell 4), the manufacturer shall report a flow rate not greater than 20 g/10 min and not less than 4.0 g/10 min when tested in accordance with Test Method D1238, Condition 190/21.6.

10.1.4.2 Classify materials having a melt index less than 0.15 (Cell 4) as Cell 5 only if they have a flow rate not greater than 4.0 g/10 min when tested in accordance with Test Method D1238, Condition 190/21.6.

NOTE 10—For materials having a melt index less than 0.40 to 0.15 g/10 min (Cell 3), the manufacturer may report a flow rate value when tested in accordance with Test Method D1238, Condition 190/21.6. For non-pressure applications, if agreed upon between the manufacturer and the purchaser, the manufacturer may report only the melt index.

NOTE 11—Flow rate is the general term used for all results obtained with Test Method D1238. Although the flow rate of polyethylene plastics may be measured under any of the conditions listed for it under 7.2 of Test Method D1238, only measurements made at Condition 190/2.16 may be identified as "Melt Index."

10.1.5 *Flexural Modulus*—Test Methods D790, using Method 1, Procedure B, and a 50-mm (2-in.) test span. Test five specimens, each 3.2 by 12.7 mm (⅛ by ½ in.) flatwise at a crosshead speed of 12.7 mm/min (0.5 in./min) and the average value of the secant modulus calculated at 2 % strain in the outer fibers.

10.1.5.1 The deflection of the test specimen corresponding to 2 % strain (0.02 mm/mm or in./in.) is calculated as follows:

$$D = rL^2/6d$$

where:

D = deflection of the center of the beam test specimen at 2 % strain, in.,
r = strain in the outer fibers = 0.02 mm/mm (0.02 in./in.),
L = test span = 50 mm (2 in.), and
d = specimen depth = 3.2 mm (⅛ in.).

10.1.5.2 The stress corresponding to 2 % strain is calculated as follows:

$$S = 3\,PL/2\,bd^2$$

where:

S = stress in the outer fiber at 2 % strain,
P = load corresponding to 2 % strain, N (lbf),
L = test span = 50 mm (2 in.),
d = specimen depth = 3.2 mm (⅛ in.), and
b = specimen width = 12.7 mm (½ in.).

The secant modulus at 2 % strain is the ratio of stress to strain or S/0.02.

10.1.6 *Tensile Strength at Yield*—The tensile strength at yield and elongation at break shall be determined in accordance with Test Method D638. The speed of testing shall be 500 mm/min (20 in./min for materials in the density range from 0.910 to 0.925 g/cm^3) and 50 mm/min (2 in./min for all others). Specimens shall conform to the dimensions given for Type IV in Test Method D638 with a thickness of 1.9 ± 0.2 mm (0.075 ± 0.008 in.). Specimen shall be either die cut or machined.

10.1.7 *Slow Crack Growth Resistance*—One method shall be used to classify this material property.

10.1.7.1 *Slow Crack Growth Resistance*—The material's resistance shall meet the minimum requirement shown for the appropriate cell classification when tested in accordance with Test Method D1693.

10.1.7.2 *Slow Crack Growth Resistance*—The average failure time from two test specimens shall meet the minimum requirement shown for the appropriate cell classification when tested in accordance with Test Method F1473. Test at least four specimens in case of a dispute.

10.1.8 *Hydrostatic Strength Classification*—One method shall be used to classify this material property.

10.1.8.1 *Hydrostatic Design Basis*—Determine the hydrostatic design basis in accordance with Test Method D2837, on pipe extruded from three different lots of material. Subject specimens from one lot for at least 10 000 h. Terminate the tests on the two additional lots after 2000 h. The results from each of the three lots shall be within the same or next higher cell limits.

NOTE 12—For pressure application at elevated temperatures, the hydrostatic design basis should be determined at that temperature in accordance with Test Method D2837. The 100 000-h intercept should be categorized in accordance with Table 1 of Test Method D2837.

10.1.8.2 *Minimum Required Strength*—Determine the minimum required strength in accordance with ISO 12162.

10.1.9 *Thermal Stability*—Test specimens taken from pipe or fittings made from the virgin material with a differential scanning calorimeter (DSC).[4] The directions of the instrument manufacturer regarding calibration and operation shall be followed except when in conflict with other parts of this section.

NOTE 13—This test requires accurate temperature and atmosphere control on the DSC specimen compartment. The DSC manufacturers offer choices in cell configuration and temperature control parameters that may affect this required control. For example, in some power compensation DSCs, use of the two-hole platinum specimen holder lids with a special "flow-through" swing-away block cover is required. Therefore, the user may wish to consult equipment-specific literature and with the equipment manufacturer to optimize the operation of individual DSCs for this test.

10.1.9.1 *Specimens*—Press small pieces of the pipe into films 0.127 ± 0.013 mm (0.0050 ± 0.0005 in.) thick. Cut at least three disks 6.35 ± 0.13 mm (0.250 ± 0.005 in.) in diameter from the film.

10.1.9.2 *Procedure*—Place the disk of film in a small aluminum cup used in the DSC in a stretched condition, as shown in Fig. 1(*a*). Place a small piece of indium (melting point 156.6°C) or anisic acid (melting point 183.0°C) for a temperature reference standard contained in a similar cup (see Fig. 1(*b*)) in the reference position. Use an oxidized copper

[4] Instruments are available from TA Instruments, Perkin-Elmer, and others.