



Designation: D 4020 – 00a

Standard Specification for Ultra-High-Molecular-Weight Polyethylene Molding and Extrusion Materials¹

This standard is issued under the fixed designation D 4020; 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 Department of Defense.

1. Scope *

1.1 This specification provides for the identification of virgin, unmodified ultra-high-molecular-weight polyethylene (UHMW-PE) plastics molding and extrusion materials. This identification is made in such a manner that the seller and purchaser can agree on the acceptability of different commercial lots or shipments.

1.2 It is not intended to differentiate between various molecular weight grades of ultra-high-molecular-weight polyethylene commercially available.

1.3 It is not the function of this specification to provide specific engineering data for design purposes.

1.4 Ultra-high-molecular-weight polyethylenes, as defined in this specification, are those linear polymers of ethylene which have a relative viscosity of 1.44 or greater, in accordance with the test procedures described herein.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 The following precautionary caveat pertains only to the test method portion. Section 7, 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 1—There is no ISO equivalent specification. However, in ISO 11542-1, a range of viscosity numbers defines the viscosity of UHMW-PE grades. The viscosity numbers are determined in accordance with ISO 1628-3.

2. Referenced Documents

2.1 ASTM Standards:

D 883 Terminology Relating to Plastics²

D 1601 Test Method for Dilute Solution Viscosity of Ethylene Polymers²

D 1898 Practice for Sampling of Plastics³

2.2 ISO Standards:⁴

ISO 11542-1 Plastics—Ultra High Molecular-Weight Polyethylene (PE-UHMW) Moulding and Extrusion Materials—Part 1: Designation System and Basis for Specification

ISO 1628-3 Plastics—Determination of Viscosity Number and Limiting Viscosity Number—Part 3: Polyethylenes and Polypropylenes

3. Terminology

3.1 *Definitions*—Definitions of terms used in this specification are in accordance with Terminology D 883.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *ultra-high-molecular-weight polyethylene molding and extrusion materials*—as defined by this specification, those substantially linear polyethylenes which have a relative viscosity of 1.44 or greater, at a concentration of 0.02 %, at 135°C, in decahydronaphthalene.

3.2.1.1 *Discussion*—It has been common practice to refer to the “molecular weight” of UHMW-PE resins. The following calculations shall be used to approximate the specific viscosity (η_{sp}), reduced viscosity (η_{red} or R.S.V.), intrinsic viscosity (η or I.V.), and the approximate viscosity average molecular weight of virgin resin. The solution viscosity test on thermally processed material is invalid due to inadequate solubility and possible crosslinking.

$$\text{Relative viscosity} = \eta_r = \frac{t_s - \frac{k}{t_s}}{t_o - \frac{k}{t_o}} \quad (1)$$

$$\text{Specific viscosity} = \eta_{sp} = \eta_r - 1$$

$$\text{Reduced viscosity} = \eta_{red} = \frac{\eta_{sp}}{C}$$

$$\text{Intrinsic viscosity} = [\eta] = (2\eta_{sp} - 2 \ln \eta_{rel})^{1/2} \div c$$

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.

Current edition approved Nov. 10, 2000. Published January 2001. Originally published as D 4020 – 81. Last previous edition D 4020 – 00.

² *Annual Book of ASTM Standards*, Vol 08.01.

³ Discontinued; see *1997 Annual Book of ASTM Standards*, Vol 08.01.

⁴ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

limiting viscosity number at 0 % concentration
 Nominal viscosity molecular weight = $5.37 \times 10^4 [\eta]^{1.37}$

where:

- k = kinetic energy correction constant for the particular viscometer used,
- t_s = flow time of solution at 135°C, s,
- t_o = flow time of pure solvent at 135°C, s, and
- C = concentration.

NOTE 2—There are other equations being used in industry to calculate the viscosity average molecular weights. Refer to Appendix X3 for the other equations and their relationship to the viscosity average molecular weight equation in 3.2.1.1. The equation in 3.2.1.1 is the only equation that shall be used for reporting of viscosity average molecular weight.

4. Classification

4.1 It is recognized that dilute solution viscosity measurements can only be made on virgin resin. Therefore, the following test and limits shall be used to determine the properties of virgin polymer only.

5. Materials and Manufacture

5.1 The molding and extrusion material shall be UHMW polyethylene 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 can be achieved by good manufacturing practice. If necessary, the level of contamination may be agreed upon between the seller and the purchaser.

5.3 Unless controlled by requirements specified elsewhere

in this specification, the color and translucence of molded or extruded pieces, formed under conditions recommended by the manufacturer of the material, will be comparable within commercial match tolerances to the color and translucence of standard molded or extruded samples of the same thickness supplied in advance by the manufacturer of the material.

6. Sampling

6.1 A batch or lot shall be considered as a unit of manufacture and may consist of a blend of two or more production runs of the same material.

6.2 Unless otherwise agreed upon between the seller and the purchaser, the material shall be sampled in accordance with the procedure described in the general and specific sampling procedures of Practice D 1898. Adequate statistical sampling prior to packaging shall be considered an acceptable alternative.

7. Test Method

7.1 *Dilute Solution Viscosity*—Use Test Method D 1601, as modified in Annex A1.

8. Keywords

8.1 extrusion materials; molding materials; plastics; polyethylene; ultra-high-molecular-weight; UHMW-PE; viscosity

Document Preview

ANNEX

(Mandatory Information)

<https://standards.iteh.ai/catalog/standards/sist/ec1beb0c-ccc6-4f73-962f-3a3692279912/astm-d4020-00a>

A1. DILUTE SOLUTION VISCOSITY

A1.1 General Description

A1.1.1 The test sequence consists of dissolving UHMW-PE in decahydronaphthalene (0.02 g/100 mL) at 150°C and then measuring the relative viscosity at 135°C in an Ubbelohde No. 1 viscometer. The relative solution viscosity may be calculated from these experimental data.

A1.2 Apparatus

- A1.2.1 *Analytical Balance*.
- A1.2.2 *Microscope Slide Cover Slip*.
- A1.2.3 *Hot Plate*, with magnetic stirrer.
- A1.2.4 *Erlenmeyer Flask*, 250-mL, with glass stopper.
- A1.2.5 *Vacuum Drying Oven*.
- A1.2.6 *Vacuum Aspirator*.
- A1.2.7 *Viscometer*, Ubbelohde No. 1.
- A1.2.8 *Constant-Temperature Bath*, 135 ± 0.1°C, with a 305-mm diameter by 460 mm (12 by 18-in.) tall glass jar as a container, and having a suitable support for the viscometer.
- A1.2.9 *Buret*, 100-mL capacity, 0.1-mL subdivisions.
- A1.2.10 *Stopwatch*, 0.2-s reading.
- A1.2.11 *Still*, for decahydronaphthalene.
- A1.2.12 *Glass Funnel*, with heating mantle.

A1.3 Reagents

- A1.3.1 *Decahydronaphthalene*, freshly distilled.
- A1.3.2 *Tetrakis* [methylene 3-(3',5'-di-*tert*-butyl-4'-hydroxyphenyl) propionate] methane.⁵
- A1.3.3 *Xylene*, industrial-grade.
- A1.3.4 *Sulfuric Acid-Potassium Dichromate Cleaning Solution*—To 35 mL of a saturated solution of potassium dichromate (K₂Cr₂O₇), carefully add 1 L of concentrated sulfuric acid (H₂SO₄).
- A1.3.5 *Acetone*, reagent grade.

A1.4 Procedure

- A1.4.1 *Decahydronaphthalene Preparation*—Distill in accordance with Test Method D 1061 and add 0.2 % tetrakis [methylene 3-(3',5'-di-*tert*-butyl-4'-hydroxyphenyl) propionate] methane.
- A1.4.2 *Cleaning the Viscometer*—Clean the viscometer thoroughly with the cleaning solution, wash several times with distilled water, rinse with acetone, and purge with dry nitrogen.

⁵ The antioxidant (Irganox® 1010) is available from Ciba-Geigy, Ardsley, NY.

A1.4.3 *Solution Preparation*—Dry the UHMW-PE in a vacuum oven for 2 h at 60°C. Weigh 14 to 17 mg of the dry UHMW-PE onto a slide cover slip. Use the buret to transfer the decahydronaphthalene at room temperature into the Erlenmeyer flask, measuring, in millilitres, a volume equal to 4.5 times the UHMW-PE weight in milligrams, for example, 15 mg of UHMW-PE and 67.5 mL of decahydronaphthalene. Heat the decahydronaphthalene, with stirring, to 150°C, and drop in the UHMW-PE and its slide cover slip. Continue stirring at 150°C for 1 h, with the flask lightly stoppered.

A1.4.4 *Viscosity Measurement:*

A1.4.4.1 Place the clean viscometer into the constant-temperature bath, fill with decahydronaphthalene, and allow the viscometer and solvent to come to thermal equilibrium at 135 ± 0.1°C. Determine the viscosity of the solvent. Remove the decahydronaphthalene with vacuum and wash the viscometer with 200 mL of warm (110 to 120°C) xylene. Remove with vacuum and aspirate dry air or nitrogen to dry the viscometer (2 or 3 min). It is essential that the whole viscometer be dry.

A1.4.4.2 Meanwhile, place the flask of polymer solution into the 135°C bath and allow it to equilibrate. Transfer

sufficient solution to fill the viscometer to the mark (see Note A1.1) and determine the viscosity of the solution.

A1.4.4.3 Between uses, clean the viscometer as described in A1.4.2. Prolonged waits between uses (overnight, etc.) will require the use of the H₂SO₄ – K₂Cr₂O₇ cleaning solution.

NOTE A1.1—Filling of the viscometer is made easier by the use of a glass funnel warmed with a heating mantle. This helps to prevent the UHMW-PE from precipitating.

A1.5 Calculation

A1.5.1 Calculate the relative solution viscosity as follows:

$$\eta_r = \frac{k}{t_s - \frac{k}{t_o}} \quad (A1.1)$$

where:

k = kinetic energy correction constant for the particular viscometer used,

t_s = flow time of solution at 135°C, and

t_o = flow time of pure solvent at 135°C.

APPENDIXES

(Nonmandatory Information)

X1. IMPACT TEST METHOD FOR ULTRA-HIGH-MOLECULAR-WEIGHT POLYETHYLENE

X1.1 Scope

X1.1.1 This test method covers determination of the impact strength of UHMW-PE, which is extremely impact resistant. When tested in accordance with Test Method D 256, Method A, UHMW-PE generally gives the NBF type of failure, rendering the test result invalid. This test method specifies the same type of pendulum impact test machine as that given in Test Method D 256 but introduces a much higher degree of stress concentration into the specimen by double notching with a razor blade. Application of this test method shall be limited to the characterization of virgin, unmodified UHMW-PE resins, not commercially processed products. It is advised that the user be familiar with Test Method D 256 before attempting to use this test method.

X1.1.2 The values stated in SI units are to be regarded as the standard.

X1.1.3 *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 X1.1—There is currently no ISO standard that duplicates this test method. The impact strength of UHMW-PE is measured by a double-notched Charpy impact test in the pending ISO/CD 11542-2.

X1.2 Referenced Documents

X1.2.1 *ASTM Standards:*

D 256 Test Method for Determining the Pendulum Impact Resistance of Notched Specimens of Plastics²

X1.2.2 *ISO Standards:*⁴

ISO 180-1982 (E) Determination of Izod Impact Strength of Rigid Materials

ISO/CD 11542-2 Plastics—Ultra-High Molecular Weight Polyethylene (PE-UHMW) Moulding and Extrusion Materials—Part 2: Preparation of Test Specimens and Determination of Properties

X1.3 Apparatus

X1.3.1 The Izod-type impact machine that conforms to the requirements of Test Method D 256, including the calibration and checking methods, shall be used.

X1.4 Test Specimen

X1.4.1 The geometry and dimensions of the specimen are given in Fig. X1.1.

X1.4.2 The specimens shall be cut from a sheet compression molded under the following conditions:

Molding pressure	6.9 to 10.3 MPa
Platen temperature	196 to 210°C
Heating time	20 min at 196 to 210°C
Platen cooling rate	15 ± 2°C/min from 150 to 90°C
Platen temperature for demolding	<30°C

X1.4.3 The width of the specimen shall be the thickness of the sheet if the sheet thickness is within 6.00 to 6.75 mm. Sheet material thicker than 6.75 mm shall be machined down to 6.35 ± 0.25 mm. Sheet material thicker than 7.65 mm shall not be used.

X1.4.4 Each specimen shall be free of twist and shall be bounded by mutually perpendicular pairs of plane parallel