Designation: D2857 – 22

Standard Practice for Dilute Solution Viscosity of Polymers[1]

This standard is issued under the fixed designation D2857; 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 practice covers the determination of the dilute solution viscosity of polymers. There are several ASTM standards (Test Methods D789, D1243, D1601, and D4603, and Practice D3591) that describe dilute solution viscosity procedures for specific polymers, such as nylon, poly(vinyl chloride), polyethylene, and poly(ethylene terephthalate). This practice is written to augment these standards when problems arise with which the specific procedure is not concerned, or when no standard is available for the polymer under investigation.

1.2 This practice is applicable to all polymers that dissolve completely without chemical reaction or degradation to form solutions that are stable with time at a temperature between ambient and 150°C. Results are usually expressed as relative viscosity (viscosity ratio), inherent viscosity (logarithmic viscosity number), or intrinsic viscosity (limiting viscosity number) (see 3.1).

1.3 For polyamides, relative viscosity values by this procedure are not equivalent to those determined by Test Methods D789.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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 1—This standard and ISO 1628, "Plastics—Determination of Viscosity Number and Limiting Viscosity Number," are technically equivalent.

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]

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D446 Specifications and Operating Instructions for Glass Capillary Kinematic Viscometers

D789 Test Method for Determination of Relative Viscosity of Concentrated Polyamide (PA) Solutions

D883 Terminology Relating to Plastics

D1243 Test Method for Dilute Solution Viscosity of Vinyl Chloride Polymers

D1600 Terminology for Abbreviated Terms Relating to Plastics

D1601 Test Method for Dilute Solution Viscosity of Ethylene Polymers

D3591 Test Method for Determining Logarithmic Viscosity Number of Poly(Vinyl Chloride) (PVC) in Formulated Compounds

D4603 Test Method for Determining Inherent Viscosity of Poly(Ethylene Terephthalate) (PET) by Glass Capillary Viscometer

D5226 Practice for Dissolving Polymer Materials

E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

2.2 *ISO Standard:*

1628/1 Guidelines for the Standardization of Methods for the Determination of Viscosity Number and Limiting Viscosity Number of Polymers in Dilute Solution[3]

2.3 *National Institute of Standards and Technology Document:*

Circular No. C602 Testing of Glass Volumetric Apparatus[4]

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.70 on Analytical Methods.

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

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

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

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms pertaining to plastics used in this test method, refer to Terminology D883. For abbreviations used in this test method, refer to Terminology D1600, unless otherwise indicated.

3.1.2 *inherent viscosity, η_{inh} , n*—the ratio of the natural logarithm of the relative viscosity to the mass concentration of the polymer, *c*: $\eta_{inh} = (\ln \eta_r)/c$.

3.1.2.1 *Discussion*—Also known as the logarithmic viscosity number, η_{ln}. See also 3.1.4.

3.1.3 *intrinsic viscosity, [η], n*—the limiting value of the reduced viscosity or the inherent viscosity at infinite dilution of the polymer:

$$[\eta] = \lim_{c \to 0} (\eta_i / c) = \lim_{c \to 0} \eta_{inh}.$$

3.1.3.1 *Discussion*—Also known as the limiting viscosity number and in the literature as the Staudinger index. See also 3.1.4.

3.1.4 *reduced viscosity, n*—the ratio of the relative viscosity increment to the mass concentration of the polymer, *c*, that is, η_i / c.

3.1.4.1 *Discussion*—Also known as the viscosity number. The unit must be specified; cm^3 /g is recommended.

3.1.4.2 *Discussion*—This quantity and those defined in 3.1.2 and 3.1.3 are neither viscosities nor pure numbers. The terms are to be looked upon as traditional names. Any replacement by consistent terminology would produce unnecessary confusion in the polymer literature.

3.1.5 *relative viscosity, η_r , n*—the ratio of the viscosity of the solution, η, to the viscosity of the solvent, η_s, that is, $\eta_r = \eta / \eta_s$.

3.1.5.1 *Discussion*—Also known as the viscosity ratio.

3.1.6 *relative viscosity increment, η_i , n*—the ratio of the difference between the viscosities of solution and solvent to the viscosity of the solvent, that is, $\eta_i = (\eta - \eta_s)/\eta_s$.

3.1.6.1 *Discussion*—The use of the term specific viscosity for this quantity is discouraged, since the relative viscosity increment does not have the attributes of a specific quantity.

4. Summary of Practice

4.1 General procedures are given for the determination of the dilute solution viscosity of polymers, including descriptions of apparatus, reagents and materials, and sample preparation, as well as measurement procedures and calculations.

4.2 If detailed test methods are available for the polymers of interest, such as those mentioned in 1.1, this practice provides information of a general nature to augment the detailed treatments in the relevant test methods.

5. Significance and Use

5.1 The determination of dilute solution viscosity provides one item of information towards the molecular characterization of polymers. When viscosity data are used in conjunction with other molecular parameters, the properties of polymers depending on their molecular structure may be predicted.

5.2 Viscosity is dependent on molecular weight distribution, so with certain restrictions, satisfactory correlations can be obtained between dilute-solution viscosity and molecular parameters such as molecular weight or chain length. The most limiting restrictions that must be observed are as follows:

5.2.1 It must be known that the polymers used to establish the correlations and those to which they are applied do not consist of or contain branched species. Basically a measure of molecular size and not molecular weight, the dilute solution viscosity can be correlated appropriately with molecular weight or chain length only if there is a unique relationship between the mass and the size of the dissolved polymer molecules. This is the case for linear, but not for most branched, polymers.

5.2.2 For reasons similar to those outlined in 5.2.1, it must be required that the polymers to which the correlations are applied have the same chemical composition as those used in establishing the relationships.

5.3 For polymers meeting the restrictions of 5.2, empirical relationships can be developed between the dilute solution viscosity of a polymer and its hydrodynamic volume or average chain dimension (radius of gyration or end-to-end distance). Such relationships depend upon any variables influencing this molecular size of the dissolved polymer. The most important of these variables are solvent type and temperature. Thus, the solution viscosity of a given polymer specimen depends on the choice of these variables, and they must always be specified with the viscosity for complete identification.

5.4 The solution viscosity of a polymer of sufficiently high molecular weight may depend on rate of shear in the viscometer, and the viscosity of a polyelectrolyte (polymer containing ionizable chemical groupings) will depend on the composition and ionic strength of the solvent. Special precautions beyond the scope of this practice are required when measuring such polymers.

5.5 Finally, the viscosity of polymer solutions may be affected drastically by the presence of recognized or unrecognized additives in the sample, including but not limited to colorants, fillers, or low-molecular-weight species.

6. Apparatus

6.1 *Volumetric Flasks,*[5] 100-mL or other size found convenient.

6.2 *Transfer Pipets,*[5] sizes between 1 and 25 mL, as required. Transfer pipets for use with polymer solutions should have about 2 mm cut from their lower tips to permit more rapid transfer of the solution to the viscometer.

6.3 *Constant-Temperature Bath,* capable of maintaining ±0.01°C at the desired temperature (usually between 25 and 150°C). Less stringent temperature control (±0.02°C) is satisfactory upon demonstration that the precision of results is not affected.

6.4 *Viscometer,* glass capillary type, as described in Specifications D446. Efflux time for the solvent and temperature

[5] Glassware should conform to the standards of accuracy in National Institute of Standards and Technology Circular No. C602.