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Standard Test Method for Kinematic Viscosity of Asphalts (Bitumens)¹

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1. Scope

1.1 This test method covers procedures for the determination of kinematic viscosity of liquid asphalts (bitumens), road oils and distillation residues of liquid asphalts (bitumens) all at 60°C [140°F] and of asphalt cements at 135°C [275°F] (Note 1) in the range from 6 to 100 000 mm²/s [cSt].

1.2 Results of this test method can be used to calculate viscosity when the density of the test material at the test temperature is known or can be determined. See Annex A1 for the method of calculation.

NOTE 1—This test method is suitable for use at other temperatures and at lower kinematic viscosities, but the precision is based on determinations on liquid asphalts and road oils at 60°C [140°F] and on asphalt cements at 135°C [275°F] only in the viscosity range from 30 to 6000 mm²/s [cSt].

1.3 **Warning**—Mercury has been designated by United States Environmental Protection Agency (EPA) and many state agencies as a hazardous material that can cause central nervous system, kidney and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Material Safety Data Sheet (MSDS) for details and EPA's website—<http://www.epa.gov/mercury/faq.htm>—for additional information. Users should be aware that selling mercury, mercury containing products, or both, in your state may be prohibited by state law.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

¹ This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.44 on Rheological Tests. In the IP this test method is under the jurisdiction of the Standardization Committee.

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responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:²

- C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- D341 Practice for Viscosity-Temperature Charts for Liquid Petroleum Products
- 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
- D2162 Practice for Basic Calibration of Master Viscometers and Viscosity Oil Standards
- D2493 Standard Viscosity-Temperature Chart for Asphalts
- E1 Specification for ASTM Liquid-in-Glass Thermometers
- E77 Test Method for Inspection and Verification of Thermometers

3. Terminology

3.1 Definitions:

3.1.1 *density*—the mass per unit volume of liquid. The SI unit of density is 1 kg/m³. The cgs unit of density is 1 g/cm³.

3.1.2 *kinematic viscosity*—the ratio of the viscosity to the density of a liquid. It is a measure of the resistance to flow of a liquid under gravity. The SI unit of kinematic viscosity is m²/s; for practical use, a submultiple (mm²/s) is more convenient. The cgs unit of kinematic viscosity is 1 cm²/s and is called a stoke (symbol St). The centistoke (1 cSt = 10⁻² St) is 1 mm²/s and is often used.

3.1.3 *Newtonian liquid*—a liquid in which the rate of shear is proportional to the shearing stress. The constant ratio of the

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.

shearing stress to the rate of shear is the viscosity of the liquid. If the ratio is not constant, the liquid is non-Newtonian.

3.1.4 *viscosity*—the ratio between the applied shear stress and rate of shear is called the coefficient of viscosity. This coefficient is a measure of the resistance to flow of a liquid. It is commonly called the viscosity of the liquid. The cgs unit of viscosity is 1 g/cm·s (1 dyne·s/cm²) and is called a poise (P). The SI unit of viscosity is 1 Pa·s (1 N·s/m²) and is equivalent to 10 P.

4. Summary of Test Method

4.1 The time is measured for a fixed volume of the liquid to flow through the capillary of a calibrated glass capillary viscometer under an accurately reproducible head and at a closely controlled temperature. The kinematic viscosity is then calculated by multiplying the efflux time in seconds by the viscometer calibration factor.

5. Significance and Use

5.1 The kinematic viscosity characterizes flow behavior. The method is used to determine the consistency of bitumen as one element in establishing the uniformity of shipments or sources of supply. The specifications are usually at temperatures of 60 and 135°C.

6. Apparatus

6.1 *Viscometers*, capillary-type, made of borosilicate glass, annealed, suitable for this test are described in [Annex A2](#) and include the following:

- 6.1.1 *Cannon-Fenske viscometer for opaque liquids*,
- 6.1.2 *Zeitfuchs cross-arm viscometer*,
- 6.1.3 *Lantz-Zeitfuchs viscometer*,
- 6.1.4 *BS U-Tube modified reverse flow viscometer*.

6.1.5 Calibrated viscometers are available from commercial suppliers. Details regarding calibration of viscometers are given in [Annex A3](#).

6.2 *Thermometers*—Calibrated liquid-in-glass thermometers of an accuracy after correction of 0.02°C [0.04°F] can be used or any other thermometric device of equal accuracy. ASTM Kinematic Viscosity Thermometers 47C and 47F conforming to Specification [E1](#), and IP 35C and 35F are suitable for use at 60°C [140°F] and ASTM Kinematic Viscosity Thermometers 110C and 110F are suitable for use at 135°C [275°F].

6.2.1 The specified thermometers are standardized at “total immersion,” which means immersion to the top of the liquid column with the remainder of the stem and the expansion chamber at the top of the thermometer exposed to room temperature. The practice of completely submerging the thermometer is not recommended. When thermometers are completely submerged, corrections for each individual thermometer based on calibration under conditions of complete submergence must be determined and applied. If the thermometer is completely submerged in the bath during use, the pressure of the gas in the expansion chamber will be higher or lower than during standardization, and may cause high or low readings on the thermometer. Thermometric devices for this test method must be standardized at least every 6 months.

TABLE 1 Acceptability of Test Results for Kinematic Viscosity

NOTE 1—The values given in column 2 are the coefficients of variation that have been found to be appropriate for the materials and conditions of test described in column 1. The values given in column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

Material and Type Index	Coefficient of Variation (% of mean) ^A	Acceptable Range of Two Results (% of mean) ^A
Single-operator precision:		
Asphalt cements at 135°C [275°F]	0.64	1.8
Liquid asphalts at 60°C [140°F]:		
below 3000 mm ² /s [cSt]	0.53	1.5
3000 to 6000 mm ² /s [cSt]	0.71	2.0
6000 mm ² /s [cSt] and above	3.2	8.9
Multilaboratory precision:		
Asphalt cements at 135°C [275°F]	3.1	8.8
Liquid asphalts at 60°C [140°F]:		
below 3000 mm ² /s [cSt]	1.06	3.0
3000 to 6000 mm ² /s [cSt] ^B	3.11	9.0
above 6000 mm ² /s [cSt] ^B	3.6	10.0

^A These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice [C670](#).

^B Based on less than 30 degrees of freedom.

6.2.2 It is essential that liquid-in-glass thermometers be calibrated periodically using the technique given in Test Method [E77](#) (see [Appendix X1](#)).

6.3 *Bath*—A bath suitable for immersion of the viscometer so that the liquid reservoir or the top of the capillary, whichever is uppermost, is at least 20 mm below the upper bath level, and with provisions for visibility of the viscometer and the thermometer. Firm supports for the viscometer shall be provided, or the viscometer may be an integral part of the bath. The efficiency of the stirring and the balance between heat losses and heat input must be such that the temperature of the bath medium does not vary by more than ±0.03°C [±0.05°F] over the length of the viscometer, or from viscometer to viscometer in the various bath positions at 60°C [140°F].

NOTE 2—Distilled water is a suitable bath liquid for determinations at 60°C [140°F]. USP White Oil with a flash point above 215°C [420°F] has been found suitable for determinations at 135°C [275°F]. The flash point is determined in accordance with Test Method [D92](#).

6.4 *Timer*—A stop watch or other timing device graduated in divisions of 0.1 s or less and accurate to within 0.05 % when tested over intervals of not less than 15 min. Timing devices for this test method must be calibrated at least every 6 months.

6.4.1 *Electrical Timing Devices* may be used only on electrical circuits the frequencies of which are controlled to an accuracy of 0.05 % or better.

6.4.1.1 Alternating currents, the frequencies of which are intermittently and not continuously controlled, as provided by some public power systems, can cause large errors, particularly over short timing intervals, when used to actuate electrical timing devices.

7. Preparation of Sample

7.1 To minimize loss of volatile constituents and to obtain reproducible results, proceed as follows:

7.1.1 Procedure for Liquid Asphalt (Bitumen) and Road Oil:

7.1.1.1 Allow sealed samples, as received, to reach room temperature.

7.1.1.2 Open the sample container and mix the sample thoroughly by stirring for 30 s taking care to avoid the entrapment of air. If the sample is too viscous for such stirring, place the sample in the tightly sealed container in a bath or oven maintained at $63 \pm 3^\circ\text{C}$ [$145 \pm 5^\circ\text{F}$] until it becomes sufficiently liquid for stirring.

7.1.1.3 Immediately charge the viscometer, or, if the test is to be made at a later time, pour approximately 20 mL into one or more clean, dry containers having a capacity of approximately 30 mL and immediately seal with an airtight closure.

7.1.1.4 For materials with kinematic viscosities at 60°C [140°F] above $800 \text{ mm}^2/\text{s}$ [cSt], heat the 20-mL sample in the sealed container in an oven or bath maintained at $63 \pm 3^\circ\text{C}$ [$145 \pm 5^\circ\text{F}$] until it is sufficiently liquid for a convenient transfer into the viscometer. Such heating should not exceed 30 min.

7.1.2 Procedure for Asphalt Cement:

7.1.2.1 Heat the sample with care to prevent local overheating until it has become sufficiently fluid to pour, occasionally stirring the sample to aid heat transfer and to assure uniformity.

7.1.2.2 Transfer a minimum of 20 mL into a suitable container and heat to $135 \pm 5.5^\circ\text{C}$ [$275 \pm 10^\circ\text{F}$], stirring occasionally to prevent local overheating and taking care to avoid the entrapment of air.

8. Procedure

8.1 The specific details of operation vary somewhat for the various types of viscometers. See the detailed descriptions of viscometers in [Annex A2](#) for instructions for using the type of viscometer selected. In all cases, however, follow the general procedure described in [8.2](#) to [8.8](#).

8.2 Maintain the bath at the test temperature within $\pm 0.01^\circ\text{C}$ [$\pm 0.02^\circ\text{F}$]. Apply the necessary corrections, if any, to all thermometer readings.

8.3 Select a clean, dry viscometer which will give an efflux time greater than 60 s and preheat to test temperature.

8.4 Charge the viscometer in the manner dictated by the design of the instrument, as prescribed in [Annex A2](#).

8.5 Allow the charged viscometer to remain in the bath long enough to reach the test temperature, as prescribed in [Annex A2](#).

8.6 Start the flow of asphalt in the viscometer as prescribed in [Annex A2](#).

8.7 Measure to within 0.1 s, the time required for the leading edge of the meniscus to pass from the first timing mark to the second. If this efflux time is less than 60 s, select a viscometer of smaller capillary diameter and repeat the operation.

8.8 Upon completion of the test, clean the viscometer thoroughly by several rinsings with an appropriate solvent completely miscible with the sample, followed by a completely volatile solvent. Dry the tube by passing a slow stream of filtered dried air through the capillary for 2 min, or until the last trace of solvent is removed. Alternatively, the viscometer may be cleaned in a glass cleaning oven, at a temperature not to exceed 500°C [932°F], followed by rinses with distilled or deionized water, residue-free acetone, and filtered dry air. Periodically, if deposits are observed, clean the instrument with a strong acid cleaning solution to remove organic deposits, rinse thoroughly with distilled water and residue-free acetone, and dry with filtered dry air.

NOTE 3—The cleaning oven may burn off the glue that connects the viscometer tube to the holder.

8.8.1 Chromic acid cleaning solution may be prepared by adding, with the usual precautions, 800 mL of concentrated sulphuric acid to a solution of 92 g of sodium dichromate in 458 mL of water. The use of similar commercially available sulphuric acid cleaning solutions is acceptable. Nonchromium-containing, strongly oxidizing acid cleaning solutions may be substituted so as to avoid the disposal problems of chromium-containing solutions.

8.8.2 Use of alkaline glass cleaning solutions may result in a change of viscometer calibration, and is not recommended.

9. Calculation

9.1 Calculate the kinematic viscosity to three significant figures using the following equation:

$$\text{Kinematic viscosity, mm}^2/\text{s [cSt]} = Ct \quad (1)$$

where:

C = calibration constant of the viscometer, mm^2/s^2 [cSt/s], and

t = efflux time, s.

NOTE 4—Other ASTM publications on viscosity that may be used in conjunction with results determined in accordance with this test method are Test Methods [D445](#) and [D341](#), Standard [D2493](#), and Specifications [D446](#).

10. Report

10.1 Always report the test temperature with the result, for example:

$$\text{Kinematic viscosity at } 60^\circ\text{C} = 75.6 \text{ mm}^2/\text{s [cSt]} \quad (2)$$

11. Precision and Bias

11.1 Criteria for judging the acceptability of viscosity test results obtained by this method are given in [Table 1](#).

11.2 The bias of the procedure in this test method cannot be determined because no material having an accepted reference value is available.

12. Keywords

12.1 asphalt; capillary; kinematic; viscometer; viscosity