~~Designation:D4486–91 (Reapproved 2010)~~ Designation: D4486 – 10

Standard Test Method for Kinematic Viscosity of Volatile and Reactive Liquids[1]

This standard is issued under the fixed designation D4486; 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 test method covers the measurement of kinematic viscosity of transparent, Newtonian liquids which because of their reactivity, instability, or volatility cannot be used in conventional capillary kinematic viscometers. This test method is applicable up to 2×10^{-5} N/m^2(2 atm) pressure and temperature range from −53 to +135°C (−65 to +275°F).

1.1.1 For the measurement of the kinematic viscosity of other liquids, see Test Method D445.

~~1.2~~

1.2 **WARNING**—Mercury has been designated by many regulatory 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 and/or mercury containing products into your state or country may be prohibited by law.

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.* For specific warning statements, see 7.2, 7.3, 7.4, and Annex A1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

~~D2162Practice for Basic Calibration of Master Viscometers and Viscosity Oil Standards~~

E1 Specification for ASTM Liquid-in-Glass Thermometers

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *density*—the mass per unit volume of the liquid.

3.1.1.1 *Discussion*—The cgs unit of density (ρ) has the dimensions of grams per cubic centimetre. The SI unit of density has the dimensions of kilograms per cubic metre.

3.1.2 *kinematic viscosity*—The ratio of the viscosity to the density of the liquid.

3.1.2.1 *Discussion*—For gravity flow under a given hydrostatic head, the pressure head of a liquid is proportional to its density ρ. For any particular viscometer, the time of flow of a fixed volume of liquid is directly proportional to η/ρ. This ratio is the kinematic viscosity coefficient (ν). The cgs unit of kinematic viscosity is the stoke and has the dimensions of centimetre squared per second: the centistoke (0.01 St) is frequently used. The SI unit of kinematic viscosity has the dimensions of metre^2/second, and is equivalent to 10^4 St.

3.1.3 *viscosity*—the ratio between the applied shear stress and rate of shear.

3.1.3.1 *Discussion*—This ratio is called the coefficient of viscosity. The coefficient of viscosity (η) is thus a measure of the resistance to flow of the liquid. This is commonly called the viscosity of the liquid. The cgs unit of viscosity is the poise. P, which has the dimensions of dyne-seconds per square centimetre: the centipoise (0.01 poise) is frequently used. The SI unit of viscosity has the dimensions of newton second/metre^2, and is equivalent to 10 P.

3.1.4 *vulnerable liquid*—a liquid which by reason of its volatility, instability or reactivity in the presence of air or any other specific gaseous medium may undergo physical or chemical changes that may affect its viscosity.

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[1] This test method is under the jurisdiction of Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.11 on Engineering Sciences of High Performance Fluids and Solids.

Current edition approved ~~Aug.~~Oct. 1, 2010. Published ~~October~~November 2010. Originally approved in 1991. Last previous edition approved in ~~2006~~2010 as D4486–91(20~~10~~6). DOI: ~~10.1520/D4486-91R10.~~10.1520/D4486-10.

[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.

4. Summary of Test Method

4.1 The time is measured, in seconds, for a fixed volume of liquid to flow under gravity through the capillary of the viscometer under a reproducible driving head and at a closely controlled temperature. The kinematic viscosity is calculated from the measured flow time and the calibration constant of the viscometer.

5. Significance and Use

5.1 Kinematic viscosity is a physical property which is of importance in the design of systems in which flowing liquids are used or handled.

6. Apparatus

6.1 *Viscometer Thermostat*—Any transparent liquid or vapor bath of sufficient depth such that at no time during the measurement will any portion of the sample in the viscometer be less than 20 mm below the surface of the bath liquid or less than 20 mm above the bottom of the bath may be used. The temperature control must be such that for the range from 15 to 100 °C (60 to 212 °F) the temperature of the bath medium does not vary by more than 0.02 °F (0.01 °C) over the length of the viscometers, or between the position of each viscometer, or at the location of the thermometer. For temperatures outside this range, the variation must not exceed 0.05 °F (0.03 °C).

6.2 ~~*Temperature-Measuring Device*—Suitable liquid-in-glass Kinematic Viscosity Test Thermometers, covering the range of test temperatures indicated in~~ Temperature Measuring Device—A resistance thermometer (RTD) capable of measurement to ± 0.01ºC (0.02ºF) is the preferred device for temperature measurement. The use of suitable liquid-in-glass Kinematic Viscosity Test Thermometers covering the range of test temperatures indicated in Table 1~~,~~ as listed in Specification E1, ~~make certain that~~is permitted provided they have been standardized before use (see 8.2~~). Any other thermometric device is permissible provided that the same accuracy can be obtained.~~). The use of an RTD is preferred because the thermometers listed in Specification E1 contain mercury.

6.3 *Timing Device*—Any timing device may be used provided that the readings can be taken with a discrimination of 0.2 s or better, and that it has an accuracy within ±0.07 % when tested over intervals of 15 min.

6.3.1 Electrical timing devices may be used if the current frequency is controlled to an accuracy of 0.05 % or better. Alternating currents, as provided by some public power systems, are intermittently rather than continuously controlled. When used to actuate electrical timing devices, such control can cause large errors in viscosity flow measurements.

7. Reagents and Materials

7.1 *Viscosity Oil Standards*, conforming to ASTM viscosity oil standards having the approximate kinematic viscosity shown in ~~Table 2~~Table 1. Certified kinematic viscosity values are compared by annual cooperative tests by a number of laboratories and are supplied with each portion.

7.2 *Chromic Acid (Cleaning Solution)*—(**Warning—**Causes severe burns. A recognized carcinogen. Strong oxidizer, contact with organic material may cause fire. Hygroscopic. See A1.2.)

7.2.1 Other suitable cleaning solutions[3] are available. In referee testing situations, glassware shall be cleaned with a cleaning solution agreed upon by the parties involved.

7.3 *Acetone*—(**Warning—**Extremely flammable. Vapors may cause flash fire. See Annex A1.3.)

7.4 *Hydrochloric Acid (Concentrated)*—(**Warning—**Poison. Corrosive. May be fatal if swallowed. Liquid and vapor cause severe burns. Harmful if inhaled. See Annex A1.4.)

[3] Other suitable chromium free, sulfuric acid-based cleaning solutions are available.

TABLE ~~2~~ 1 Approximate Values of the ASTM Viscosity Standards

Viscosity Standard Conforming to ASTM Standards[A]	Approximate Kinematic Viscosity, cSt								
	At −53.89°C (−65°F)	At – 40°C (–40°F)	At 20°C (68°F)	At 25°C (77°F)	At[B] 37.78°C (100°F)	At 40°C (104°F)	At 50°C (122°F)	At[B] 98.89°C (210°F)	At 100°C (212°F)
S-3	300	80	4.6	4.0	3.0	2.9	...	1.2	1.2
S-6	...	...	11	8.9	6.0	5.7	...	1.8	1.8
S-20	...	...	44	34	20	18	...	4.0	3.9
S-60	...	...	170	120	60	54	...	7.4	7.2
S-200	...	...	640	450	200	180	...	17	17
S-600	...	...	2400	1600	600	520	280	33	32
S-2000	...	...	8700	5600	2000	1700	...	78	75
S-8000	...	...	37 000	23 000	8000	6700	...	...	...
S-30000	...	...	...	81 000	27 000	23 000	11 000	...	...

[A] The actual values for the standards listed above are established and annually reaffirmed by cooperative tests. In 1971, tests were made using 15 different types of viscometers in 26 laboratories located in 9 countries.

[B] Standardizations at 37.78 °C and 98.89 °C are to be discontinued Jan 1, 1977.

8. Standardization

8.1 *Viscometers*—Only calibrated viscometers standardized as described in Annex A2 shall be used.

8.2 ~~*Thermometers*~~*Temperature*~~—Liquid-in-glass thermometers~~ —Temperature measuring devices shall be checked to the nearest ~~0.01 °C (0.02 °F)~~ 0.01ºC (0.02ºF) by ~~direct~~ comparison ~~with~~to a suitable standardized ~~thermometer. Kinematic Viscosity Test Thermometers~~ instrument. Liquid-in-glass thermometers shall be standardized at "total immersion," which means immersion to the top of the ~~mercury column,~~liquid column with the remainder of the stem and the expansion chamber at the top of the thermometer exposed to room temperature; do not submerge the expansion bulb at the top of the thermometer. It is essential that the ice point of the standardized thermometers be determined periodically and the official corrections be adjusted to ~~conform to~~ reflect the change in the ice point.

8.3 *Timers*—Standard time signals available in some nations may be used in checking the accuracy of timing devices. In the United States of America, time signals, as broadcast by the National Bureau of Standards, Station WWV, Washington, DC 20234, at 2.5, 5, 10, 15, 20, 25, 30, and 35 MHz are a convenient and primary standard reference for calibrating timing devices; the signals are broadcast 24 h daily. Station CHU from Ottawa, Canada, at 3.330, 7.335, and 14.670 MHz or Station MSF at Rugby, United Kingdom, at 2.5, 5, and 10 MHz may be received better in some locations.

8.4 Viscosity standards may also be used to check the over-all kinematic viscosity procedure in a laboratory. If the measured kinematic viscosity does not agree within ±0.35 % of the certified value, each step in the procedure should be rechecked, including thermometer and viscometer calibration to locate source of error.

9. Cleaning of Viscometer

9.1 Between successive determinations, clean the viscometer thoroughly by several rinsings with an appropriate solvent completely miscible with the sample, followed by a completely volatile solvent. Dry the viscometer with vacuum attached to Tube *A* or by placing viscometer in a vacuum oven.

9.2 Periodically clean the instrument with chromic acid (**Warning—**See 7.2 and A1.2.) to remove organic deposits, rinse thoroughly with distilled water and acetone (**Warning—**See 7.3 and A1.3.), and dry with clean dry air. Inorganic deposits may be removed by hydrochloric acid (**Warning—**See 7.4 and A1.4.) treatment before use of cleaning acid, particularly if barium salts are suspected.

NOTE 1—Do not allow chromic acid or hydrochloric acid to stand in contact with the Kovar fitting on the viscometer. Use a glass pipet to introduce these acids into the viscometer in such a manner that contact with the metal fittings is kept to an absolute minimum.

NOTE 2—Viscometers used for silicone fluids, fluorocarbons, and other liquids which are difficult to remove by the use of a cleaning agent, should be reserved for the exclusive use of those fluids except when standardizing. Such viscometers should be subjected to standardization checks at frequent intervals.

10. Procedure for Kinematic Viscosity

10.1 Maintain the bath at the test temperature within the limits given in 6.1. Apply the necessary corrections, if any, to all thermometer readings.

10.2 Select a clean, dry, calibrated viscometer that will give a flow time not less than the minimum specified for the viscometer (see ~~Table 3~~Table 2), or 200 s, whichever is the greater.

10.3 Charge the viscometer through Tube *A* (see Fig. 1) until Bulb *B* is half filled.

10.4 Test samples that are not stable in the presence of air at the test temperature must have the air in the viscometer purged by a working gas that does not react with the test sample.

~~10.4.1For the vulnerable-liquid viscometer (~~

10.4.1 For the vulnerable liquid viscometer (Fig. 1), attach Tube *A* to a controlled source of a working gas. Tilt the charged viscometer until the liquid sample no longer covers the end of Tube *C*. Pressure purge the viscometer with working gas. Release the pressure and repeat the purge at least four times.

TABLE ~~3~~ 2 Dimensions for Vulnerable Liquid and Tilting Viscometers

Size No.	Approximate Constant, cSt/s	Viscosity Range, cSt	Inside Diameter of Tube D, mm (±2 %)		Volume Bulb F mL (±5%)	
			Liquid	Tilting	Liquid	Tilting
25	0.002	0.5[A] to 2	0.31	0.31	1.5	1.5
50	0.004	0.8 to 4	0.44	0.37	3.0	1.5
75	0.008	1.6 to 8	0.54	0.46	3.0	1.5
100	0.015	3 to 15	0.63	0.52	3.0	1.5
150	0.035	7 to 35	0.78	0.65	3.0	1.5
200	0.1	20 to 100	1.01	0.84	3.0	1.5
300	0.25	50 to 250	1.26	1.05	3.0	1.5

[A] 250 s minimum flow time.