Designation: D7483 – 13a

Standard Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Oscillating Piston Viscometer[1]

This standard is issued under the fixed designation D7483; 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 dynamic viscosity and derivation of kinematic viscosity of liquids, such as new and in-service lubricating oils, by means of an oscillating piston viscometer.

1.2 This test method is applicable to Newtonian and non-Newtonian liquids; however the precision statement was developed using Newtonian liquids.

1.3 The range of dynamic viscosity covered by this test method is from 0.2 mPa·s to 20 000 mPa·s (which is approximately the kinematic viscosity range of 0.2 mm^2/s to 22 000 mm^2/s for new oils) in the temperature range between –40 to 190°C; however the precision has been determined only for new and used oils in the range of 34 to 1150 mPa·s at 40°C, 5.7 to 131 mPa·s at 100°C, and 46.5 to 436 mm^2/s at 40°C.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

D2162 Practice for Basic Calibration of Master Viscometers and Viscosity Oil Standards

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D5967 Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine

D6300 Practice for Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products and Lubricants

D6708 Practice for Statistical Assessment and Improvement of Expected Agreement Between Two Test Methods that Purport to Measure the Same Property of a Material

D6792 Practice for Quality System in Petroleum Products and Lubricants Testing Laboratories

2.2 *ISO Standards:*[3]

ISO/EC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

2.3 *NIST Standard:*[4]

NIST Technical Note 1297 Guideline for Evaluating and Expressing the Uncertainty of NIST Measurement Results

3. Terminology

3.1 *Definitions:*

3.1.1 *dynamic viscosity (η), n*—the ratio between the applied shear stress and rate of shear of a liquid.

3.1.1.1 *Discussion*—It is sometimes called the coefficient of dynamic viscosity or, simply, viscosity. Thus, dynamic viscosity is a measure of the resistance to flow or to deformation of a liquid under external shear forces.

3.1.1.2 *Discussion*—The term dynamic viscosity can also be used in a different context to denote a frequency-dependant quantity in which shear stress and shear rate have a sinusoidal time dependence.

3.1.2 *kinematic viscosity (ν), n*—the ratio of the dynamic viscosity (η) to the density (ρ) of a liquid.

3.1.2.1 *Discussion*—For gravity flow under a given hydrostatic head, the pressure head of a liquid is proportional to its

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

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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 International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

[4] Available from http://physics.nist.gov/ccu/Uncertainty/index.html.

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

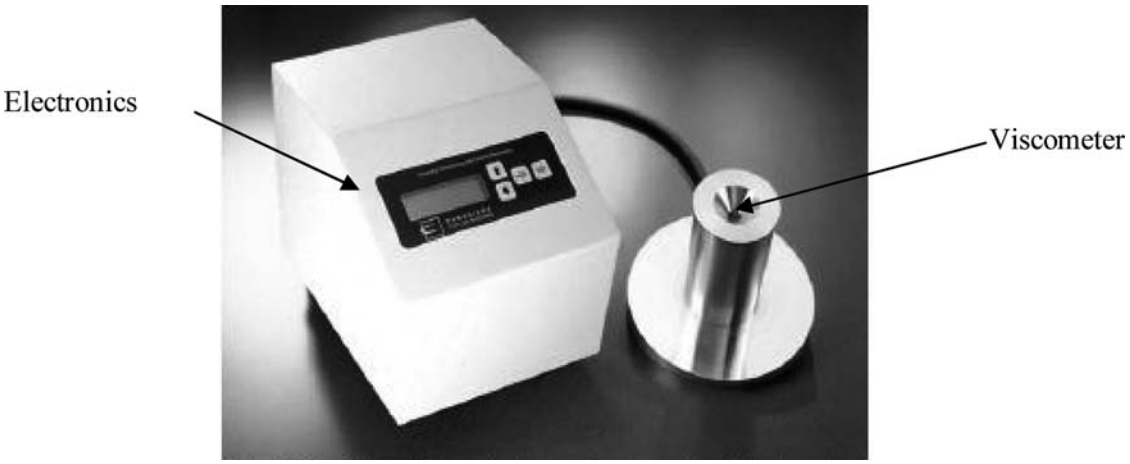

FIG. 1 Viscometer with Electronics

density, (ρ). Therefore the kinematic viscosity, (ν), is a measure of the resistance to flow of a liquid under gravity.

3.1.3 *rate of shear (shear rate), n*— in liquid flow, the velocity gradient across the liquid.

3.1.4 *shear stress, n*—the force per unit area in the direction of the flow.

3.1.4.1 *Discussion*—The SI unit for shear stress is the pascal (Pa).

3.1.5 *density (ρ), n*—mass per unit volume.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *oscillating piston viscometer, n*—a device that measures the travel time of a piston driven electromagnetically into stationary oscillating motion through a liquid at a controlled force in order to determine the dynamic viscosity of the liquid.

4. Summary of Test Method

4.1 A specimen of sample is placed in the thermally controlled measurement chamber where the piston resides. The piston is driven into oscillatory motion within the measurement chamber by a controlled magnetic field. Once the sample is at the test temperature, as determined by the temperature detector, the piston is propelled repeatedly through the liquid (by the magnetic field). A shear stress (ranging from 5 Pa to 750 Pa) is imposed on the liquid under test due to the piston travel. The dynamic viscosity is determined by measuring the average travel time of the piston. The kinematic viscosity is derived by additionally measuring the ratio between the up and down travel times. This information is then applied to a calibration curve using liquids of known viscosity to calculate the dynamic viscosity. The kinematic viscosity is derived by an externally measured density by additionally measuring the ratio between the up and down travel times. The precision and bias data for kinematic viscosity (as published in RR:D02-1755[5]) were derived by externally measured density and do not apply to the internal density measurement.

5. Significance and Use

5.1 Many petroleum products, as well as non-petroleum materials, are used as lubricants for bearings, gears, compressor cylinders, hydraulic equipment, etc. Proper operation of this equipment depends upon the viscosity of these liquids.

5.2 Oscillating piston viscometers allow viscosity measurement of a broad range of materials including transparent, translucent and opaque liquids. The measurement principle and stainless steel construction makes the Oscillating Piston Viscometer resistant to damage and suitable for portable operations. The measurement itself is automatic and does not require an operator to time the oscillation of the piston. The electromagnetically driven piston mixes the sample while under test. The instrument requires a sample volume of less than 5 mL and typical solvent volume of less than 10 mL which minimizes cleanup effort and waste.

6. Apparatus

6.1 *Oscillating Piston Viscometer:*[6,7]

6.1.1 The oscillating piston viscometer (see Fig. 1) comprises a measurement chamber and calibrated piston capable of measuring the dynamic viscosity within the limits of precision given in Section 16.

6.1.2 *Piston*—Free moving, magnetically driven body within a Oscillating Piston Viscometer which is used for measuring the viscosity of liquids. Individual pistons are sized to measure specific viscosity ranges by varying the sensor annulus. See Table 1 for the selection of the piston according to the viscosity range.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1755. Contact ASTM Customer Service at service@astm.org.

[6] The Oscillating Piston Viscometer is covered by a patent. Interested parties are invited to submit information regarding the identification of an alternative to this patented item to the ASTM International headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

[7] The sole sources of supply for the apparatus known to the committee at this time is Cambridge Viscosity Inc., 101 Station Landing, Medford, MA 02155 (www.cambridgeviscosity.com). If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

TABLE 1 Viscosity Ranges of Oscillating Viscometer Pistons

Minimum Viscosity (mPa·s)	Maximum Viscosity (mPa·s)	Piston Designation	Nominal Piston Diameter (mm)	Recommended Sample Volume (mL)
0.02	2	SP20	7.87	3.2–5
0.25	5	SP50	7.83	3.2–5
0.5	10	SP11	7.81	3.2–5
1	20	SP21	7.76	3.5–5
2.5	50	SP51	7.68	3.5–5
5	100	SP12	7.62	3.5–5
10	200	SP22	7.54	3.5–5
25	500	SP52	7.34	3.5–5
50	1000	SP13	7.21	4.0–5
100	2000	SP23	6.96	4.0–5
250	5000	SP53	6.27	4.0–5
500	10 000	SP14	6.05	4.0–5
1000	20 000	SP24	5.72	4.0–5

6.1.3 *Measurement Chamber*—Location within Oscillating Piston Viscometer where piston motion (through the liquid under test) occurs due to an imposed electromagnetic field. See Fig. 2.

6.1.4 *Electronics*—Capable of controlling the electromagnetic field to propel and detect the travel time of the piston with a discrimination of 0.01 s or better and uncertainty within ±0.07 %. The travel time is calibrated to be between 0.4 s and 60 s, at a distance of 5 mm.

6.1.5 *Temperature Controlled Jacket*—Sufficient for maintaining measurement chamber temperature within ±0.06°C.

6.1.6 *Temperature Measuring Device*—Industrial platinum resistance thermometer (IPRT) or equivalent sensor with a maximum permissible error of ±0.02°C. It is recommended, that the temperature measuring device be verified with an independent, calibrated temperature probe at the test temperature.

6.2 *Temperature Regulation System:*

6.2.1 Any liquid bath or thermoelectric means for regulating the jacket temperature.

6.2.2 The temperature control must be such that the temperature of the measurement chamber is held within ±0.06°C of the desired measurement temperature.

6.3 *Sample Introduction Mechanism*—A syringe, micropipette, or flow-through adapter for introducing between 3.2 mL and 5 mL, inclusive by pressure, into the measurement chamber.

7. Reagents and Materials

7.1 Certified viscosity reference standards shall be certified by a laboratory that has been shown to meet the requirements of ISO/EC 17025 by independent assessment. Viscosity standards shall be traceable to master viscometer procedures described in Practice D2162.

7.2 The uncertainty of the certified viscosity reference standard shall be stated for each certified value (k = 2, 95 % confidence). See ISO/EC 17025 or NIST TN 1297.

7.2.1 The certified viscosity reference should have a published viscosity in accordance with Test Method D445 or equivalent means that is close to that of the liquids being tested at the test temperature. For example, if intended measurements are to be made from 5-25 mPa·s at 100°C, then a reference oil viscosity of 15 mPa·s at 100°C would be appropriate.

7.3 Cleaning solvents miscible with the sample and chemically compatible with the wetted viscometer components (such as alcohols, toluene, etc.). These wetted components are typically 316L and 430 Stainless Steel.

7.4 Quality control (QC) liquid similar to 7.1, but with viscosity values internally certified as noted in 12.2.

8. 8. Sampling, Samples, and Test Units

8.1 Ensure that the sample is homogenous. Engine sampling is generally specified in the test method, for example Test Method D5967. When applicable, refer to Practice D4057 (manual) or Practice D4177 (automatic) for proper sampling techniques.

9. Preparation of Apparatus

9.1 Place the viscometer on a stable surface.

9.2 Select the viscosity output units. If kinematic viscosity is selected, some apparatus will internally determine density to derive kinematic viscosity. Otherwise, enter the known density and operate the unit according to the procedure in Section 13.

9.3 Verify calibration accuracy by testing a reference standard or QC liquid at the test temperature. Follow the procedure in Section 13.

10. Calibration and Standardization

10.1 Calibrate according to manufacturer's instructions to obtain a calibration curve (using two test liquids with referenced viscosity values near, but within, the extremes of the piston range being used).

10.2 Certified Viscosity Standards may be used as confirmatory checks on the procedure in the laboratory. This procedure is outlined in Section 13. If the dynamic viscosity result, at the calibration test point, does not agree with the certified value within the limits of precision in Section 16, each step in the procedure should be rechecked, as well as the temperature measuring device and viscometer calibration, to locate the source of error. If the source is not detected, consult the manufacturer.

11. Sample Conditioning

11.1 Shake all new and used oil samples using the following procedure.

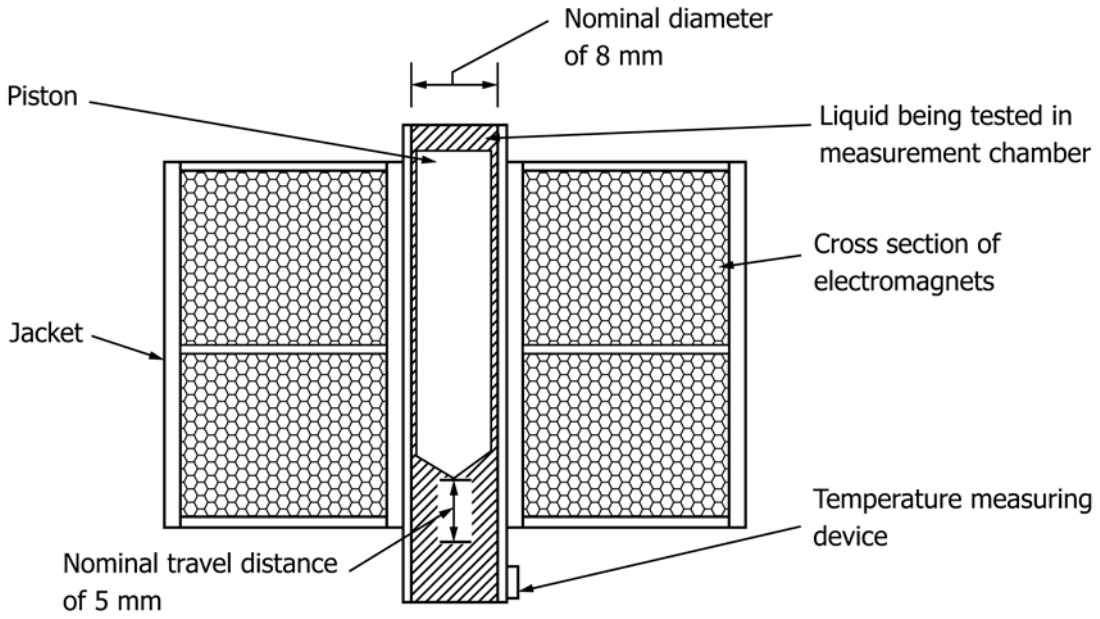

FIG. 2 Cross Sectional View of Measurement Chamber

11.1.1 Ensure cap is tight on the container.

11.1.2 Shake vigorously by hand for 30 s. Wait 10 s, or longer if needed, for air bubbles to dissipate.

11.1.3 A specimen of the sample shall be taken by pipette, pouring or pumping. Suspected nonhomogeneous samples must be conveyed for analysis promptly following the shaking and dissipation procedure of step 11.1.2.

12. Quality Control/Quality Assurance (QC/QA)

12.1 Confirm proper performance of the instrument and the test procedure by analyzing reference oil as QC sample.

12.2 If suitable reference oil is not available, prepare a QC sample by replicate analyses of a batch of oil sample. Then statistically analyze the data to assign a mean value and uncertainty limit to the sample.

12.3 When QC/QA protocols are already established in the testing facility, these may be used to confirm the reliability of the test result.

12.4 When there is no QC/QA protocol established in the testing facility, guidance may be obtained from Practice D6792.

13. Procedure

13.1 Verify or set the temperature control settings, as tested with the control standard, so the viscometer temperature reads the desired set point ±0.06°C while the piston is in motion.

13.2 Remove the piston and clean the specimen from the measurement chamber as described in the viscometer manual.

13.3 Load the measurement chamber with sample using the volume listed in Table 1 related to the piston size being used for the viscosity range anticipated. To minimize contamination, and if sample volume allows, pre-wet the chamber and piston with the sample material and dry wipe with a lint free cloth.

13.4 Load the measurement chamber with a clean piston. The piston size should be selected such that the measured viscosity is between the minimum and maximum viscosity values listed in Table 1. If the reported result is outside of this range, the measurement shall be repeated using the appropriate piston size.

13.5 Start the reporting software in accordance with manufacturer's instructions, which in turn will:

13.5.1 Allow the sample to equilibrate in the measurement chamber for at least 2 min while the piston is oscillating.

13.5.2 Ensure that temperature stability is within the criterion set in 6.2.

13.5.3 Measure the upward and downward piston travel times for each cycle and compute viscosity until the standard deviation as percent of mean, over the previous 20 dynamic viscosity computations, is less than 0.6%.

13.6 Record the average result from the last 20 computations.

14. Calculation and Interpretation

14.1 The calculation of dynamic viscosity and kinematic viscosity are computed and displayed automatically by the apparatus.

14.2 Alternatively, the kinematic viscosity can be calculated externally using the dynamic viscosity and the known density.

15. Report

15.1 Dynamic Viscosity result in mPa·s to three significant figures.

15.2 Kinematic Viscosity result in mm^2/s, to three significant figures.

15.3 Temperature in degrees Celsius, to the second decimal place.

16. Precision and Bias[8]

16.1 *Precision*—The precision of this test method as determined by the statistical examination of the interlaboratory test results[5] is as follows:

16.1.1 *Repeatability*—The difference between successive test results, obtained by the same operator using the same apparatus under constant operating conditions on identical test material, would in the long run, in the normal and correct operation of this test method, exceed the following only in one case in twenty.

$0.04747 * X^{1.1132}$ mPa·s	40°C	34 to 1150 mPa·s
$0.06351(Y + 20)$ mm²/s	40°C	46.5 to 436 mm²/s
$0.08184 * X^{0.9311}$ mPa·s	100°C	5.7 to 131 mPa·s

where:
X = result in mPa·s at specified temperature
Y = result in mm²/s at specified temperature

16.1.2 *Reproducibility*—The difference between two single and independent test results, obtained by different operators working in different laboratories on identical test material, would in the long run, in normal and correct operation of this test method, exceed the following only in one case in twenty.

$0.08995 * X^{1.1132}$ mPa·s	40°C	34 to 1150 mPa·s
$0.1267(Y + 20)$ mm²/s	40°C	46.5 to 436 mm²/s
$0.2271 * X^{0.9311}$ mPa·s	100°C	5.7 to 131 mPa·s

where:
X = result in mPa·s at specified temperature
Y = result in mm²/s at specified temperature

NOTE 1—The degrees of freedom associated with the reproducibility estimate from this interlaboratory study for D7483 derived kinematic viscosity at 40°C are 20. Since the minimum requirement of 30 (in accordance with Practice D6300) is not met, users are cautioned that the actual reproducibility may be significantly different than these estimates.

NOTE 2—The degrees of freedom associated with the reproducibility estimate from this interlaboratory study for dynamic viscosity at 100°C are 13. Although Practice D6300 does not recommend publication of precision with degrees of freedom less than 15 due to its questionable reliability, Subcommittee D02.07 decided to publish this precision. Users are cautioned that the actual reproducibility may be significantly different than these estimates.

16.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this Test Method, bias has not been determined.

16.3 *Relative Bias*—A relative bias assessment versus Test Method D445 at 40°C was performed using Practice D6708. Because Test Method D7483 measures dynamic viscosity in mPa·s, and Test Method D445 measures kinematic viscosity in mm²/s, the 40°C dynamic viscosity (mPa·s) was converted to 40°C kinematic viscosity (mm²/s) using statistically established density means. Bias-corrected results from Test Method D7483, as per the bias correction equation (Eq), may be considered as practically equivalent to results from Test Method D445, for sample types and property ranges studied. No sample-specific bias, as defined in Practice D6708, was observed for the materials studied.

$$\text{bias-corrected } X = \text{predicted } Y = 1.01\,X, \text{range } 46.5 \text{ to } 436\ \text{mm}^2/\text{s}$$

where:

X = result obtained by Test Method D7483,
bias-corrected X = predicted Y result that would have been obtained by Test Method D445 on the same sample.

16.4 The precision statements were derived from a 2011 interlaboratory cooperative test program. Participants analyzed 10 sample sets comprised of 3 base oils, 3 formulated oils, 3 used oils and 1 additive. The range of viscosity was 5.7 to 1150 mPa·s at temperatures of 40 and 100°C. There were 8 laboratories that participated with Test Method D7483 and 6 laboratories participated with Test Method D445. Information on the type of samples and their average dynamic viscosity are in the research report.[5]

17. Keywords

17.1 dynamic viscosity; kinematic viscosity; oscillating piston; oscillating piston viscometer; viscosity

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1657. Contact ASTM Customer Service at service@astm.org.

SUMMARY OF CHANGES

Subcommittee D02.07 has identified the location of selected changes to this standard since the last issue (D7483 – 13) that may impact the use of this standard. (Approved June 15, 2013.)

(1) Updated subsections 4.1 and 9.2; updated Section 15.

(2) Added new 14.2.

Subcommittee D02.07 has identified the location of selected changes to this standard since the last issue (D7483 – 08) that may impact the use of this standard. (Approved March 1, 2013.)

(1) Updated 1.3 to reflect viscosity range of materials tested in research report.

(2) Updated Section 16 to reflect results published in the new research report.