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Standard Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer[1]

This standard is issued under the fixed designation D 2983; 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 test method describes the use of the Brookfield viscometer for the determination of the low-shear-rate viscosity of automotive fluid lubricants in the temperature range from − 5 to − 40°C. The viscosity range is 1000 to 1 000 000 cP (mPa·s).

1.2 The test method uses the centipoise (cP) as the unit of viscosity. For information the equivalent SI unit, the millipascal, is shown in parentheses.

1.3 *This standard does not purport to address all of the safety problems, 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:*

D 341 Viscosity-Temperature Charts for Liquid Petroleum Products[2]

3. Descriptions of Terms Specific to This Standard

3.1 *Brookfield viscosity*—the viscosity determined by this test method. It is expressed in centipoises (1 cP = 1 mPa·s). Its value may vary with the spindle speed (shear rate) of the Brookfield viscometer because many automotive fluid lubricants are non-Newtonian at low temperatures. See Appendix X1 for a brief explanation.

3.2 *reference viscosity*—the viscosity of Newtonian standard reference fluids specified at each of several temperatures by the supplier.[3] Reference viscosities of typical standard reference fluids are listed in Appendix X2.

4. Summary of Test Method

4.1 A lubricant fluid sample is cooled in an air bath at test temperature for 16 h. It is carried in an insulated container to a nearby Brookfield viscometer where its Brookfield viscosity is measured at any test temperature in the range from − 5 to − 40°C.[3]

5. Significance and Use

5.1 The low-temperature, low-shear-rate viscosity of gear oils, automatic transmission fluids, torque and tractor fluids, and industrial and automotive hydraulic oils are frequently specified by Brookfield viscosities.

5.2 If Brookfield viscosity versus temperature plots are required in specifications, they can be made by the procedure outlined in Annex A1.

6. Apparatus

6.1 *Brookfield Viscometer and Stand*—Model LVT or LVTD (Fig. 1 and Fig. 2).[4]

6.2 *No. 4 LV Spindle for LVT Model*—The insulated shaft spindle 4B2 is preferred. Several are needed for multiple determinations. See Fig. 2 for diagram.

6.3 *Spindle Clip* is a device that supports the spindle at proper immersion depth during cool-down. A suitable clip can be made from a bobby pin, paper clip, or similar device.

6.4 *Test Cell*—A glass test tube 22 to 22.5-mm in inside diameter and 115 ± 5 mm in overall length.[5]

6.5 *Cell Stopper* (Fig. 3).[5]

6.6 *Insulated Cell Carrier* (Fig. 3).[5]

6.7 *Cold Cabinet*[5]—A top-opening cold cabinet with an air-circulation device is required. The cold cabinet must cool the sample to a constant test temperature and hold that temperature within ±0.3°C in a range from − 5°C to − 40°C. A switch is needed to shut off the air-circulation device before the top is opened. In some models this is done automatically as the top opens.

NOTE 1—Mechanically refrigerated liquid baths have been used for Brookfield viscosity determinations. A European procedure, CEC L18-A-80, describes the use of some. However, a liquid bath should not be used for sample conditioning in Test Method D 2983 unless it can duplicate the sample cooling rates outlined in Appendix X3. The main advantage of a

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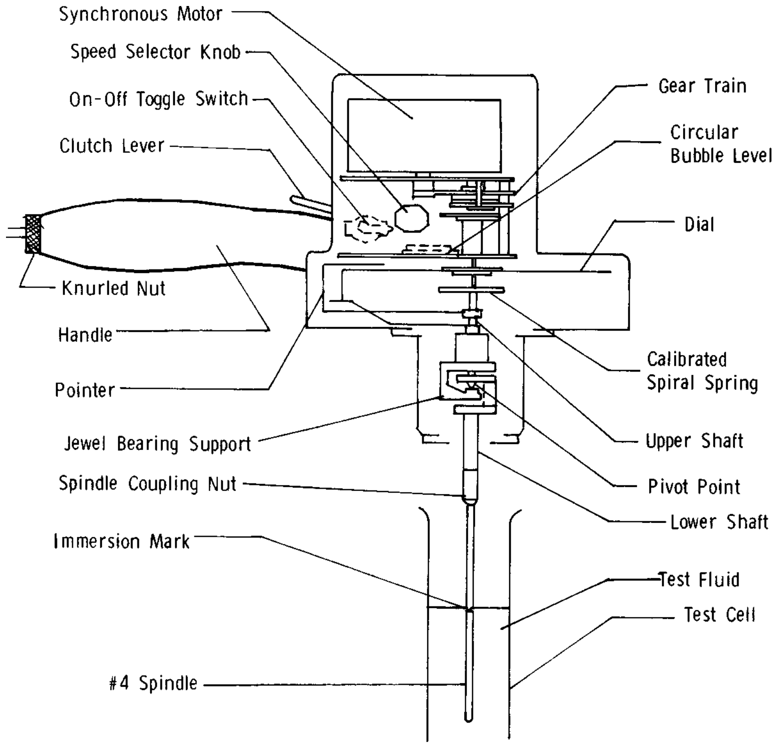
[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] Standard Newtonian Brookfield viscosity reference fluids are available from Cannon Instrument Co., Post Office Box 16, State College, PA 16801.

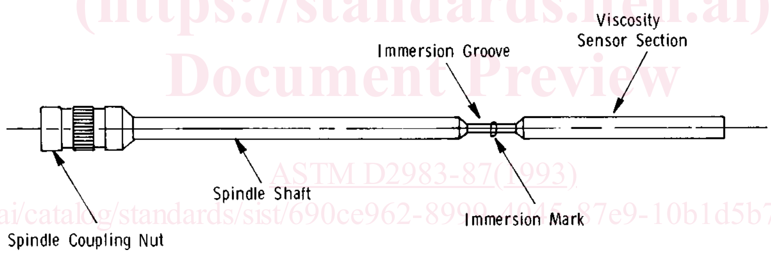
[4] The Brookfield viscometer and accessories are available from the Brookfield Engineering Laboratories, Inc., Stoughton, MA 02072.

[5] These items are available from Lawler Manufacturing, Inc., 7 Kilmer Ct., Eddison, NJ 08817.



NOTE 1—Adapted from drawings of Brookfield Engineering Laboratories.

FIG. 1 Schematic Drawing of Brookfield Synchro-Lectric Viscometer



NOTE 1—Adapted from drawings of Brookfield Engineering Laboratories.

FIG. 2 Diagram of #4 LV Cylindrical Spindle

liquid bath over an air bath is more precise temperature control. Liquid baths are available that maintain the selected test temperature within 0.1°C of the set point for the 16-h-soak period.

6.8 *Cell Rack and Turntable*—The turntable should rotate at a speed of 3 to 5 rpm. This item is often supplied with the cold cabinet.[5]

6.9 *Complete Immersion Thermometers*, carefully calibrated, or other calibrated thermometric devices that cover the range from − 5 to − 40°C. IP Brookfield Viscometer Thermometers IP 94C (−45 to − 35C), IP 95C (−35 to − 25C), IP 96C (−25 to − 15C), IP 97C (−15 to − 5C) cover this range. ASTM numbers for these thermometers are being obtained.

NOTE 2—**Caution:** Store thermometers in an upright position to help maintain calibration. Mercury-thallium amalgam used in IP 97C is toxic.

7. Use of Reference Fluids

7.1 The use of standard reference fluids, detailed in Appendix X4 and Appendix X5, was developed to assure the precise control that is essential to reliable Brookfield viscosity measurements. The procedure to calculate expected reference fluid dial readings and interpret observed reference fluid dial readings is given in Appendix X4. Although the dial reading limits listed in Appendix X4 are typical of the data received from several extensive round robins, more precise control is both desirable and possible with present equipment.

7.2 Reference fluid data can indicate the sample temperature change that results from frequent opening of the air bath when many samples are run in sequence. The temperature change during a run sequence is determined from data on the reference sample run at the beginning and at the end of each sequence. Appendix X5 details the calculation of the apparent run temperature from reference fluid dial reading and rpm data. The change in apparent run temperature from beginning to end should not exceed 0.4°C. The apparent run temperature itself should be within ± 0.3°C of the set test temperature.

NOTE 3—**Caution:** Great care should be taken to assure proper spindle immersion with all reference oil runs. Improper immersion may be reflected as an apparent temperature variation when the methods in

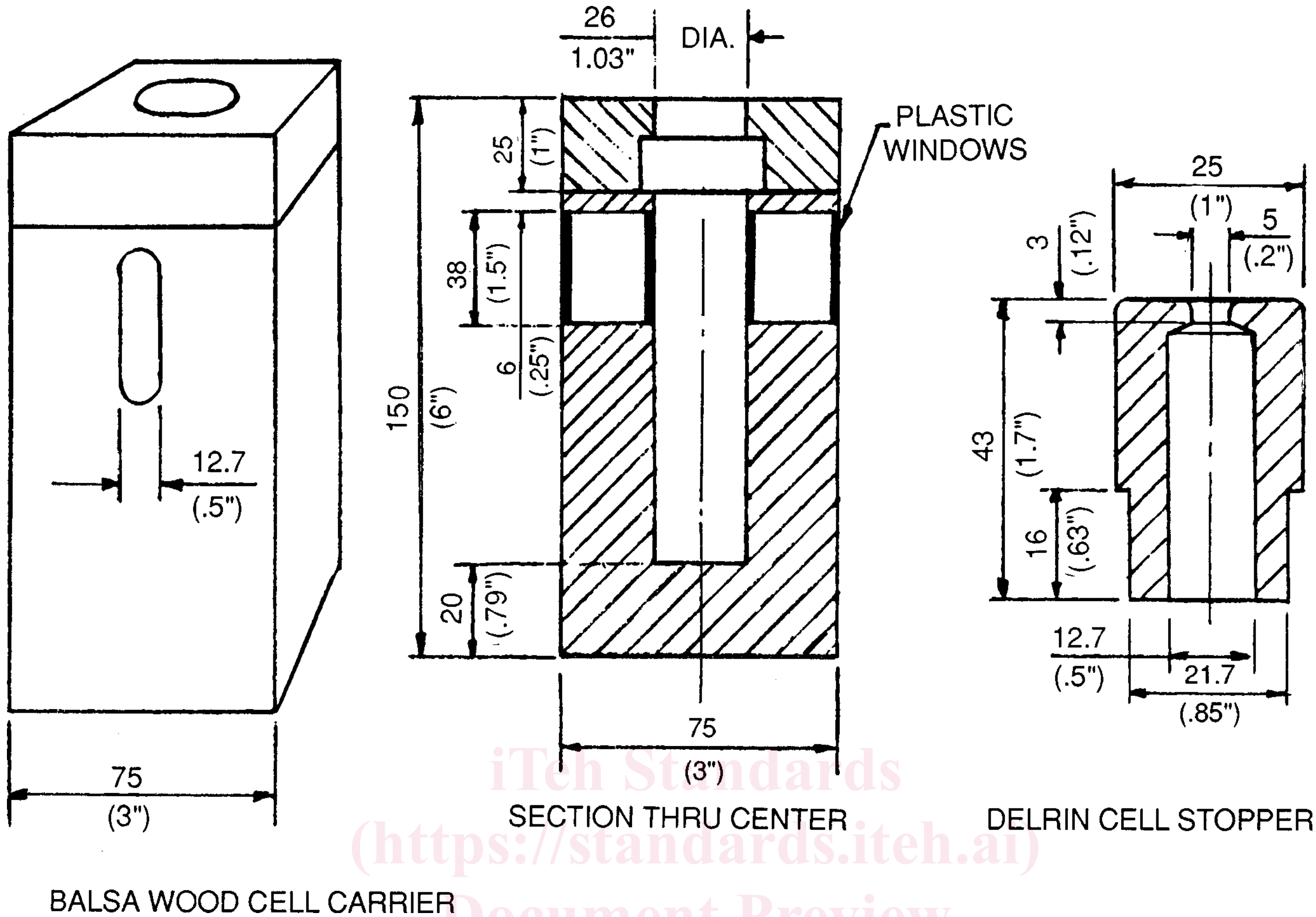


FIG. 3 Cell Carrier and Stopper

Appendix X4 and Appendix X5 are followed.

8. Rpm Selection

8.1 Because many automotive lubricant fluids are non-Newtonian at low temperatures, the rpm selected for a measurement can strongly influence the resultant Brookfield viscosity (see Appendix X1). For this reason, Table 1 lists the viscosity range for each rpm.

8.2 *Rpm Selection Chart*—See Table 1.

8.3 *If* an expected *viscosity is known*, Table 1 will give the highest rpm for a dial reading in the acceptable range.

8.4 *If* the *highest rpm* that will give an acceptable viscometer reading *is known* or can be selected from Table 1, only one sample cell need be prepared. *If* the *highest rpm* for a measurement *is not known* or cannot be estimated from Table 1, prepare two sample cells as in 10.2. Use one to determine the highest rpm that gives an acceptable viscometer reading and the other to obtain a measurement at that rpm.

8.5 The highest rpm for an oil is found by increasing speed in steps from 0.6 to 60 rpm. The highest speed is the rpm setting just below the one where the reading goes off scale. Use the observation times in 9.2 to determine the maximum rpm.

TABLE 1 RPM Selection Chart

Spindle Speed, rpm	Viscosity Calculation Factor	Acceptable Dial Reading Range	Viscosity Range, cP (mPa·s)[A]
0.6	10 000	40–100	400 000 to 1 000 000
1.5	4 000	50–100	200 000 to 400 000
3.0	2 000	50–100	100 000 to 200 000
6.0	1 000	50–100	50 000 to 100 000
12.0	500	40–100	20 000 to 50 000
30.0	200	49–100	9 800 to 20 000
60.0	100	10–98[B]	1 000 to 9 800

[A] If determined viscosity is below range indicated for rpm, use next higher rpm.

[B] Some low-viscosity automotive fluid lubricants such as brake fluids require the extended 60-rpm acceptable dial reading range. For precise viscosity determinations, dial readings below ten units are not recommended by the viscometer manufacturer.

9. Observation Times for a Dial Reading

9.1 Because the low-temperature gel structure of many fluid lubricants is easily broken down by shear, the Brookfield dial reading is often a function of observation time. Therefore, standardized observation times and recording procedures are listed in Table 2.

9.2 *Standardized Observation Times*—See Table 2.

10. Procedure

10.1 Set the test temperature of the air bath and allow it to cool before putting samples in the rotating rack. After equilibration, check the bath temperature by the thermometer or thermometric device immersed in a dummy sample of oil held by the rotating rack.

10.1.1 Allow 1 h after temperature adjustment for temperature equilibration in the dummy sample. Depending on specific

TABLE 2 Standardized Observation Times

rpm	Maximum Observation Time, min	Maximum Spindle Rotations	Record
0.6	5	3	Highest dial reading seen as the
1.5	3	4.5	scale pointer passes instrument
3.0	3	9	window during observation time.
6.0	2	12	Highest dial reading seen during
12.0	1	12	observation time.
30.0	30 s	15	Observe dial reading at end of 30 s.
60.0	30 s	30	Do this twice and record the higher reading.

bath characteristics, longer times may be required after major temperature changes.

NOTE 4—**Caution:** Do not adjust bath temperature late in the sample conditioning period because the viscosity of the sample may be significantly changed.

10.2 Use a fresh sample of each test fluid for each measurement. Fill the test cell so that the immersion mark in the center of the spindle immersion groove (Fig. 2) is just at the liquid surface when the test cell in its carrier is set up with the viscometer and spindle in measurement position. About 30 mL of oil is needed. Stopper the test cell and use the spindle clip to support the spindle with the immersion mark at the liquid surface.

NOTE 5—Maintenance of proper immersion depth is essential to good reproducibility and repeatability. Data show that an immersion variation of as little as 1.2 mm from the dimple can produce a 2 % viscosity error.

10.2.1 Handle and store the spindles and instrument with care at all times. Check the calibration of each spindle periodically with a reference oil. Discard any damaged, bent, or divergent spindle. Refer to Brookfield Engineering Co. literature for more detailed instructions on viscometer care and calibration.

10.3 Place the filled test cells in a 50°C oven for ½ h. Remove and allow to cool at room temperature for ½ h. Transfer to a preset, cooled air bath. Put the insulated test cell carriers into the air bath with the samples. After a 16-h soak time, begin to run the test series. The test series should be completed within 2 h so that a maximum soak time does not exceed 18 h for any sample (see Note 6 for an optional soak time that applies only to automatic transmission fluids at − 17.8°C).

NOTE 6—Experience has shown that 6 h is a sufficient soak time for automatic transmission fluids at − 17.8°C. Since this shorter soak time speeds data production and is used in some automatic transmission fluids specifications, it is the only exception to the 16-h soak time allowed by this test method.

10.4 Level and prepare the Brookfield viscometer for a test. Open the air bath and put one temperature-conditioned test cell in a temperature-conditioned test cell carrier. Immediately transfer the unit to the Brookfield viscometer, quickly attach the spindle to the viscometer, remove the spindle clip, and adjust the assembly until the oil level is even with the immersion mark on the immersion cut of the spindle shaft. A flashlight held behind one window of the test cell carrier is a cool light source that can help with this adjustment. Center the spindle in the hole at the top of the cell stopper. Prepare the viscometer and sample for testing within 30 s after the sample is removed from the air bath, because the test cell and test cell carrier begin to warm up immediately on removal from the cold cabinet.

10.5 Take dial readings as follows:

10.5.1 Depress the clutch on the Brookfield viscometer.

10.5.2 Turn on the viscometer motor and release clutch.

10.5.3 Take the dial readings within the observation times indicated in Table 2.

10.5.4 Record dial reading, rpm, and test temperature.

10.5.5 To take dial readings at higher speeds it may be necessary to depress the clutch and turn off the motor at the same time to keep the pointer visible through the viscometer window.

10.6 Frequent opening of the cold box during a long series of runs may cause a temperature rise in the oil. To minimize this effect, turn the air-circulation device off when the top is open and do not leave the top open unnecessarily. Allow some time for the temperature in the cabinet to come to equilibrium after closure and before withdrawing another sample.

NOTE 7—If the laboratory is equipped with a low-temperature liquid bath capable of maintaining test temperature within ±0.06°C and on which the Brookfield viscometer can be conveniently mounted, a cell may be removed from the cold cabinet after 15½ h and placed in the liquid bath at test temperature for 30 min. The Brookfield viscosity can then be measured directly on the sample in the cell in the liquid bath without haste and without fear that the sample will warm up as it does in the cell carrier. An insulated spindle is needed if this procedure is used.

11. Calculation

11.1 Calculate the Brookfield viscosity at the test temperature of the test oil or reference oil as shown in Table 3.

11.2 The shear stress and shear rate at the surface of the Brookfield spindle may be estimated by the procedure in Appendix X6.

12. Report

12.1 A routine report includes the Brookfield viscosity calculated in Section 11, the test temperature, and the test rpm. Rpm data are needed to assure that different laboratories use the same shear rates.

12.2 In cases where this test method is used for reference testing, a full report of the Newtonian reference fluid, its reference viscosity, its Brookfield viscosity, and its test rpm must accompany the test fluid data of 10.1. Reference fluid data are needed to assure that different laboratories run at the same temperature and viscometric conditions.

TABLE 3 Calculation of Brookfield Viscosity at Test Temperature of Test Oil

Brookfield Viscosity (Centipoises) = Dial Reading (0 to 100 Scale) × Factor

Spindle Speed, rpm	Factor
0.6	10 000
1.5	4 000
3	2 000
6	1 000
12	500
30	200
60[A]	100

[A] Subtract 0.4 from the dial reading at 60 rpm to correct for air resistance.