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An American National Standard

Standard Test Method for Predicting the Borderline Pumping Temperature of Engine Oil[1]

This standard is issued under the fixed designation D 3829; 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 prediction of the borderline pumping temperature (BPT) of engine oils through the use of a 16-h cooling cycle over the temperature range from 0 to −40°C.

1.2 Applicability to petroleum products other than engine oils has not been determined.

~~1.3This~~1.3 This test method uses the millipascal (mPa·s), as the unit of viscosity. For information, the equivalent centipoise unit is shown in parentheses.

1.4 *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. Terminology

2.1 *Definitions:*

2.1.1 ~~*viscosity*—the ratio between the applied shear stress and rate of shear. It is sometimes called the coefficient of dynamic viscosity. This value is thus a measure of the resistance to flow of the liquid. The SI unit of viscosity is the pascal second (Pa·s). The centipoise (cP) is one millipascal second (mPa·s) and is often used.~~ apparent viscosity—the determined viscosity obtained by use of this test method.

2.1.2 *Newtonian oil or fluid*—an oil or fluid that at a given temperature exhibits a constant viscosity at all shear rates or shear stresses.

2.1.3 *non-Newtonian oil or fluid*—an oil or fluid that at a given temperature exhibits a viscosity that varies with changing shear stress or shear rate.

2.1.4 ~~*apparent viscosity*—the determined viscosity obtained by use of this test method.~~

~~2.1.5~~*shear rate*—the velocity gradient in fluid flow. For a Newtonian fluid in a concentric cylinder rotary viscometer in which the shear stress is measured at the inner cylinder surface (such as the apparatus being described), and ignoring any end effects, the shear rate is given as follows:

$$G_r = \frac{2\Omega R_s^2}{(R_{s2} - R_r^2)} \quad (1)$$

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$$G_r = \frac{4\pi R_s^2}{t(R_s^2 - R_r^2)} \quad (2)$$

where:

G_r = shear rate at the surface of the rotor in reciprocal seconds, s^{-1},
Ω = angular velocity, rad/s,
R_s = stator radius, mm,
R_r = rotor radius, mm, and
t = time in seconds for one revolution of the rotor.

For the specific apparatus being described in 5.1.1,

[1] This test method is under the jurisdiction of ASTM Committee ~~D-2~~D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

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$$G_r = \frac{63}{t} \tag{3}$$

~~2.1.6~~2.1.5 *shear stress*—the motivating force per unit area for fluid flow. Area is the area under shear. For the rotary viscometer being described, the rotor surface is the area under shear.

$$T_r = 9.81M(R_o + R_t) \times 10^{-6} \tag{4}$$

$$S_r = \frac{T_r}{2\pi R_r^2 h} \times 10^9 \tag{5}$$

where:

T_r = torque applied to rotor, N·m,
M = applied mass, g,
R_o = radius of the shaft, mm,
R_t = radius of the thread, mm,
S_r = shear stress at the rotor surface, Pa, and
h = height of the rotor, mm.

For the dimensions given in 5.1.1,

$$T_r = 31.7M \times 10^{-6} \tag{6}$$

$$S_r = 3.5M \tag{7}$$

2.1.6 *viscosity*—the ratio between the applied shear stress and rate of shear. It is sometimes called the coefficient of dynamic viscosity. This value is thus a measure of the resistance to flow of the liquid. The SI unit of viscosity is the pascal second (Pa·s). The centipoise (cP) is one millipascal second (mPa·s) and is often used.

2.2 *Definitions of Terms Specific to This Standard:*

2.2.1 *borderline pumping temperature*—the maximum temperature at which the critical yield stress or critical viscosity occurs, whichever is the higher temperature.

2.2.2 *calibration oils*—those oils for establishing the instrument's reference framework of apparent viscosity versus speed from which the apparent viscosities of test oils are determined. Calibration oils, which are essentially Newtonian fluids, are available commercially, and have an approximate viscosity of 30 000 mPa·s (30 000 cP) at −20°C.[2]

~~2.2.2*test oil*—any oil for which the apparent viscosity and yield stress are to be determined by use of the test method under description.~~

2.2.3 ~~*yield stress*—the shear stress required to initiate flow. For all Newtonian fluids and some non-Newtonian fluids, yield stress is zero. Some engine oils have a yield stress that is a function of their low-temperature cooling rate, soak time, and temperature.~~ critical viscosity—the maximum viscosity at a defined shear rate to allow adequate flow of oil to the oil pump in an automotive engine. A higher viscosity can cause failure to maintain adequate oil pressure through the limiting of flow through the oil screen or oil inlet tubes.

2.2.4 *critical yield stress*—the maximum yield stress that allows oil to flow to the inlet oil screen in an automotive engine. With a higher yield stress, air may be drawn into the pump and cause failure to maintain adequate oil pressure through air-binding of the pump.

2.2.5 ~~*critical viscosity*—the maximum viscosity at a defined shear rate to allow adequate flow of oil to the oil pump in an automotive engine. A higher viscosity can cause failure to maintain adequate oil pressure through the limiting of flow through the oil screen or oil inlet tubes.~~ test oil—any oil for which the apparent viscosity and yield stress are to be determined by use of the test method under description.

2.2.6 ~~*borderline pumping temperature*—the maximum temperature at which the critical yield stress or critical viscosity occurs, whichever is the higher temperature.~~ yield stress—the shear stress required to initiate flow. For all Newtonian fluids and some non-Newtonian fluids, yield stress is zero. Some engine oils have a yield stress that is a function of their low-temperature cooling rate, soak time, and temperature.

3. Summary of Test Method

3.1 An engine oil sample is cooled from 80°C to the desired test temperature at a nonlinear programmed cooling rate over a 10-h period and held at the test temperature for the remainder of a 16-h period. After completion of the soak period, two standard torques of increasing severity are applied to the rotor shaft and the speed of rotation in each case is measured. From the results at three or more temperatures, the borderline pumping temperature is determined.

~~3.2Alternatively,~~3.2 Alternatively, for some specification or classification purposes it may be sufficient to determine that the BPT is less than a certain specified temperature.

4. Significance and Use

4.1 Borderline pumping temperature is a measure of the lowest temperature at which an engine oil can be continuously and adequately supplied to the oil pump inlet of an automotive engine.

5. Apparatus

5.1 *Mini-Rotary Viscometer,*[2] consisting of one or more viscometric cells including a calibrated rotor-stator assembly, which are contained in a temperature-controlled aluminum block.

5.1.1 The viscometric cell has the following nominal dimensions:

Diameter of rotor	17.0 mm
Length of rotor	20.0 mm
Inside of diameter of cup	19.0 mm
Radius of shaft	3.18 mm
~~Radius of string~~	~~0.05 mm~~
Radius of string	0.1 mm

5.2 *Thermometers,*[2] for measuring temperature of the block. Two are required, one graduated from at least +70 to 90°C in 1°C subdivisions, the other with a scale from at least −36 to +5°C in 0.2°C subdivisions.

5.3 A means of lowering the temperature to the predetermined test temperature at a controlled, nonlinear rate.

5.4 *Circulating System,*[2] for supplying suitable liquid coolant to the block as needed. Methanol is a suitable coolant. One should observe toxicity and flammability precautions that apply to the use of methanol. The circulating system must be capable of maintaining test temperature over a 16-h test period. If methanol is leaking from the system, discontinue the test and repair the leak before continuing.

5.5 *Chart Recorder*, to verify that the correct cooling curve is being followed, it is recommended that a chart recorder be used to monitor the block temperature.

6. Reagents and Materials

6.1 *Low Cloud-Point, Newtonian Oil,*[2] of approximately 30 Pa·s (30 000 cP) viscosity at −20°C for calibration of the viscometric cells.

6.2 *Methanol*, commercial or technical grade of dry methanol is suitable for the cooling bath.

6.3 *Oil Solvent*, commercial ~~Heptanes~~heptanes or similar solvent is suitable.

6.4 *Acetone*, technical grade of acetone is suitable provided it does not leave a residue upon evaporation.

7. Sampling

7.1 A representative sample of test oil free from suspended solid material and water is necessary to obtain valid results. If the sample in its container is received below the dew-point temperature of the room, allow to warm to room temperature before opening.

8. Calibration and Standardization

8.1 Calibration is required for the temperature dial on the panel.

8.1.1 Place calibrated thermometer in position (see assembly instructions) and turn the RESET dial fully counterclockwise.

8.1.2 Set the dial at 100 and allow to cool to control temperature. Allow approximately 30 min for temperature equilibrium to be established.

8.1.3 Record the temperature.

8.1.4 Repeat 8.1.3 and 8.1.4 for dial settings of 200, 300, 500, 700, and 900 or until −37°C has been reached.

8.1.5 On one- or two-cycle semilog graph paper, plot log (reading) versus temperature (°C) to establish calibration curve. See Fig. 1.

8.2 The calibration of each viscometric cell (viscometer constants) can be determined with the viscosity standard and the following procedure at −20 ± 0.2°C.

8.2.1 Use steps 9.1.1-9.1.5.

8.2.2 Set the temperature-control, ten-turn dial to correspond to −20°C and turn switch to cool.

8.2.3 Allow to soak at −20 ± 0.2°C for at least 1 h, making small temperature adjustments, if necessary, to maintain the test temperature.

8.2.4 At the end of the soak period record the temperature reading (test temperature), and remove the cover of the viscometer cell.

8.2.5 Proceed to steps 9.2.1-9.2.3.

8.2.6 Place a 150-g mass on the string in accordance with instructions in 9.3.1.

8.2.7 Repeat 8.2.5 and 8.2.6 for each of the remaining cells, taking the cells in order from left to right.

8.2.8 Calculate the viscometer constant for each cell (rotor/stator combination) with the following equation:

$$C = \frac{\eta_o}{Mt} \qquad (8)$$

~~[2] Available from Cannon Instrument Co., P.O. Box 16, State College, PA 16801.~~

[2] The sole source of supply of the apparatus known to the committee at this time is Cannon Instrument Co., P.O. Box 16, State College, PA 16801. 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.