



Designation: **D4741–06 D4741 – 12**

Standard Test Method for Measuring Viscosity at High Temperature and High Shear Rate by Tapered-Plug Viscometer¹

This standard is issued under the fixed designation D4741; 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 method² covers the laboratory determination of the viscosity of oils at 150°C and $1 \times 10^6 \text{s}^{-1}$ and at 100°C and $1 \times 10^6 \text{s}^{-1}$, using high shear rate tapered-plug viscometer models BE/C or BS/C.

1.2 Newtonian calibration oils are used to adjust the working gap and for calibration of the apparatus. These calibration oils cover a range from approximately 1.8 to 5.9 mPa-s (cP) at 150°C and 4.2 to 18.9 mPa-s (cP) at 100°C. This test method should not be used for extrapolation to higher viscosities than those of the Newtonian calibration oils used for calibration of the apparatus. If it is so used, the precision statement will no longer apply.

1.3 A non-Newtonian reference oil is used to check that the working conditions are correct. The exact viscosity appropriate to each batch of this oil is established by testing on a number of instruments in different laboratories. The agreed value for this reference oil may be obtained from the chairman of the Coordinating European Council (CEC) Surveillance Group for CEC L-36-A90, or from the distributor.

1.4 Applicability to products other than engine oils has not been determined in preparing this test method.

1.5 This test method uses the millipascal seconds, mPa-s, as the unit of viscosity. For information, the equivalent cgs unit, centipoise, cP, is shown in parentheses.

1.6 *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:*³
- [D91 Test Method for Precipitation Number of Lubricating Oils](#)
 - [D4683 Test Method for Measuring Viscosity of New and Used Engine Oils at High Shear Rate and High Temperature by Tapered Bearing Simulator Viscometer at 150 °C](#)
 - [D5481 Test Method for Measuring Apparent Viscosity at High-Temperature and High-Shear Rate by Multicell Capillary Viscometer](#)
- 2.2 *Coordinating European Council (CEC) Standard:*⁴
- [L36-A90 The Measurement of Lubricant Dynamic Viscosity under Conditions of High Shear \(Ravenfield\)](#)
- 2.3 *Energy Institute:*⁵
- [IP 370 Test Method for the Measurement of Lubricant Dynamic Viscosity Under Conditions of High Shear Using the Ravenfield Viscometer](#)

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

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² This test method is technically identical to that described in CEC L36–A90 (under the jurisdiction of the CEC Engine Lubricants Technical Committee) and in IP 370.

³ 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 Available from Coordinating European Council, Madou Plaza, 25th floor, Place Madou 1, B-1030, Brussels, Belgium; CEC Secretariat, Interlynk Administrative Services, Ltd., Lynk House, 17 Peckleton Lane, Desford, Leicestershire, LE9 9JU, United Kingdom.

⁵ Available from Energy Institute, 61 New Cavendish St., London, W1G 7AR, U.K.

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

3. Terminology

3.1 Definitions:

3.1.1 *apparent viscosity, n*—the determined viscosity obtained by this test method.

3.1.2 *density, n*—the mass per unit volume. In the SI, the unit of density is the kg/m³, but for practical use, a submultiple is more convenient. The g/cm³ is 10⁻³ kg/m³ and is customarily used.

3.1.3 *kinematic viscosity, n*—the ratio of the viscosity to the density of a liquid. It is a measure of the resistance of flow of a liquid under gravity. In the SI, the unit of kinematic viscosity is the metre squared per second; for practical use, a submultiple (millimetre squared per second) is more convenient. The centistoke (cSt) is 1 mm²/s and is often used.

3.1.4 *Newtonian oil or fluid, n*—an oil or fluid, which at a given temperature, exhibits a constant viscosity at all shear rates or shear stresses.

3.1.5 *non-Newtonian oil or fluid, n*—an oil or fluid that exhibits a viscosity that varies with changing shear stress or shear rate.

3.1.6 *shear rate, n*—the velocity gradient in fluid flow. The SI unit for shear rate is the reciprocal second (s⁻¹).

3.1.7 *shear stress, n*—the motivating force per area for fluid flow. The area is the area of shear. In the SI, the unit for shear stress is the Pascal (Pa).

3.1.8 *viscosity, n*—the ratio between the applied shear stress and rate of shear. It is sometimes called the coefficient of dynamic viscosity. This coefficient is a measure of the resistance to flow of the liquid. In the SI, the unit of viscosity is the pascal second (Pa-s); for practical use, a submultiple, millipascal second (mPa-s), is more convenient. The centipoise (cP) is 1 mPa-s and is commonly used.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *calibration oils, n*—Newtonian oils used to establish the reference framework of viscosity versus torque in this instrument from which the test oil viscosity is determined.

3.2.2 *non-Newtonian check oil, n*—non-Newtonian oil used to check that the gap or distance between the rotor and stator will produce the desired operating shear rate of 1 × 10⁶ s⁻¹.

3.2.2.1 Discussion—

Check oil is an acceptable name for non-Newtonian reference oil.

3.2.3 *test oil, n*—any oil for which apparent viscosity is to be determined.

4. Summary of Test Method

4.1 The lubricant under test fills the annulus between a close-fitting rotor and stator. The rotor and stator have a slight, matching taper to allow adjustment of the gap and hence the shear rate. The rotor is spun at a known speed, and the lubricant viscosity is determined from measurements of the reaction torque by reference to a curve prepared using Newtonian calibration oils.

5. Significance and Use

5.1 Viscosity measured under the conditions of this test method is considered to be representative of that at the temperatures and shear rates but not the pressures in the journal bearings of internal combustion engines under operating conditions.

5.2 The relevance of these conditions to the measurement of engine-oil viscosity has been discussed in many publications.⁶

6. Apparatus

6.1 *Tapered-Plug High Shear Rate Viscometer*, Model BE/C (single speed) or BS/C (multi-speed). The viscometer uses a rotating tapered plug in a matched stator.

NOTE 1—Model BE/C has a restricted torque range and may not be capable of measuring higher viscosities at 100°C.

6.2 *Vacuum Extract Pipe*, to ensure constant oil level. The extract pipe is supplied with all current models.

6.3 *Calibration Weight* (supplied with instrument).

6.4 *Thermostatically Controlled Heating Bath*, with fluid circulator. For acceptable temperature control and recovery time, the temperature difference between the bath and measurement head should be targeted at 4°C and shall not exceed 8°C. This temperature difference is influenced by the nature and rate of flow of the circulating fluid; the length and bore of the heating pipes; and the viscosity of the bath fluid.

NOTE 2—Bath oil with kinematic viscosity not greater than 10 mm²/s at 150°C is recommended.

⁶ For a comprehensive review, see “The Relationship Between High-Temperature Oil Rheology and Engine Operation,” ASTM Data Series Publication 62 (out of print).

6.5 A means of measuring temperature is not necessary for current instruments since a precision temperature sensor is now built-in. For older instruments still in the field, a device with a precision not worse than $\pm 0.20^{\circ}\text{C}$ is necessary.

6.6 The use of an ultrasonic cleaner is recommended.

6.7 The manufacturer offers a package incorporating all the above and including the necessary calibration oils, reference oils, and bath oil.

6.8 *Vacuum Pump*, with suitable liquid trap.

7. Materials

7.1 *Newtonian Calibration Oils*⁷—CEC Reference Oils RL 102, RL 103, RL 104, RL 105, RL 106, and RL 107.

7.2 *Non-Newtonian Reference Oil*⁷—CEC Reference Oil RL ~~174~~.232.

7.3 *Washing Solvent*—ASTM precipitation naphtha as specified in Test Method **D91** or a suitable replacement solvent. (**WARNING** —Extremely flammable. Vapors may cause flash fire. See **Annex A1**.)

7.4 *Flushing Solvent*—_While spirit or Stoddard solvent.

8. Sampling

8.1 Test oils that are visually free from haze and particulates need not be filtered before evaluation. A sample shall be free of particles larger than $3\mu\text{m}$. If heavy concentration of smaller particles is still visible after filtration through a filter of pore size $3\mu\text{m}$, it is recommended to reduce their concentration by further filtration. This will reduce the possibility of the particles wedging in the measurement gap and so causing erosion of the rotor/stator or erroneous readings. Do not filter formulated oils through pore sizes below $1\mu\text{m}$ because certain lubricant additives may be removed.

8.2 Used oils may also be tested in these instruments, though no precision statement is available for these materials.

8.2.1 Filter used oils through a suitable filter such as Whatman GF/C fibreglass filter. The process of filtration is greatly accelerated by either warming or applying pressure. Procedures shall be such that all risk of particulate contamination is avoided.

NOTE 3—Suggestions have been made that the process of filtration may itself cause a change of viscosity by the removal of particles. No doubt if there is a very heavy concentration of particles greater than $3\mu\text{m}$, this will be so. It is not expected or intended that this test method will be used for such oils. Evidence to date is that filtration of used oils from normal engines in normal periods of use is acceptable. It is, however, advisable to use pressure filtration rather than vacuum filtration so that volatile components will not be removed. No precision statement is available for used oils.

9. Initial Preparation of Apparatus

9.1 These instructions relate to instruments incorporating a computer, in other words, Models BE/C and BS/C. Changes from earlier editions of this test method are those given in **10.1.5**, **10.5.1**, **10.5.2**, **11.1.2**, and **11.1.3** and the use of a vacuum extract pipe to ensure constant oil level (see **6.2**).

9.2 Set up the apparatus in accordance with the manufacturer's manual. Attach the funnel to the side arm, using the rubber sleeve provided.

NOTE 4—The funnel has a larger bore than stock funnels in order to increase the rate of flow of oil samples.

9.3 It is recommended that the instrument is NOT mounted in a fume cupboard since this draws in dirt particles. Local extraction over the heating bath is all that is necessary since the manufacturer's bath is practically sealed.

9.4 When setting up the apparatus, a torque calibration shall be performed following the instructions in the manufacturer's manual.

9.5 The instrument is supplied by the manufacturer with all other functions already calibrated and set up. It is recommended that these other initial settings be accepted until sufficient familiarity is obtained with the use of the apparatus. When it is desired to modify the initial settings, full instructions will be found in the manufacturer's manual.

9.6 It is advisable to gain access to the list of calibration oils held in the memory of the instrument in order to be familiar with its contents and to check that it is in accordance with the standards actually supplied.

9.7 *Preparation of Apparatus on All Other Occasions:*

9.7.1 Turn on the heating bath.

9.7.2 Flush out the measurement chamber using washing solvent.

9.7.3 Refill the measurement chamber with Reference Oil RL ~~174~~.232.

9.7.4 Leave for not less than half an hour for temperature to stabilise.

9.7.4.1 If the bath does not reach correct temperature in this time, then either extend this period or, preferably, address the problem of why heating is slow.

⁷ Under the jurisdiction of CEC Engine Lubricants Technical Committee. Ravenfield Designs Limited are distributors.