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Standard Test Method for Apparent Viscosity of Engine Oils and Base Stocks Between –5 and –35°C Using Cold-Cranking Simulator[1]

This standard is issued under the fixed designation D5293; 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.

~~ε[1] NOTE—Moved headings in 13.1 and updated Summary of Changes editorially in February 2009.~~

1. Scope*

1.1 This test method covers the laboratory determination of apparent viscosity of engine oils and base stocks by cold cranking simulator (CCS) at temperatures between –5 and –35°C at shear stresses of approximately 50 000 to 100 000 Pa and shear rates of approximately 10^5 to 10^4 s^{-1} for viscosities of approximately 900 to 25 000 mPa·s. The range of an instrument is dependent on the instrument model and software version installed. Apparent Cranking Viscosity results by this method are related to engine-cranking characteristics of engine oils.

1.2 A special procedure is provided for measurement of highly viscoelastic oils in manual instruments. See Appendix X2.

1.3 Procedures are provided for both manual and automated determination of the apparent viscosity of engine oils using the cold-cranking simulator.

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.* Specific warning statements are given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

D2602 Test Method for Apparent Viscosity of Engine Oils at Low Temperature Using the Cold-Cranking Simulator[3]

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

2.2 *ISO Standard:*

ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *Newtonian oil or fluid*, *n*—one that exhibits a constant viscosity at all shear rates.

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

3.1.3 *viscosity,* η, *n*—the property of a fluid that determines its internal resistance to flow under stress, expressed by:

(1) $\eta = \tau\gamma$

where:

τ = the stress per unit area, and

γ = the rate of shear.

3.1.3.1 *Discussion*—It is sometimes called the coefficient of dynamic viscosity. This coefficient is thus a measure of the resistance to flow of the liquid. In the SI, the unit of viscosity is the pascal-second; for practical use, a submultiple

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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] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

(millipascal-second) is more convenient and is customarily used. The millipascal second is 1 cP (centipoise).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent viscosity*, *n*—the viscosity obtained by use of this test method.

3.2.1.1 *Discussion*—Since many engine oils are non-Newtonian at low temperature, apparent viscosity can vary with shear rate.

3.2.2 *calibration oils*, *n*—oils with known viscosity and viscosity/temperature functionality that are used to define the calibration relationship between viscosity and cold-cranking simulator rotor speed.

3.2.3 *check oil*, *n*—a batch of test oil used to monitor measurement performance.

3.2.4 *test oil*, *n*—any oil for which the apparent viscosity is to be determined by use of this test method.

3.2.5 *viscoelastic oil*, *n*—a non-Newtonian oil or fluid that climbs up the rotor shaft during rotation.

4. Summary of Test Method

4.1 An electric motor drives a rotor that is closely fitted inside a stator. The space between the rotor and stator is filled with oil. Test temperature is measured near the stator inner wall and maintained by removing heat with a controlled process to maintain a constant stator temperature during test. The speed of the rotor is calibrated as a function of viscosity. Test oil viscosity is determined from this calibration and the measured rotor speed.

5. Significance and Use

5.1 The CCS apparent viscosity of automotive engine oils correlates with low temperature engine cranking. CCS apparent viscosity is not suitable for predicting low temperature flow to the engine oil pump and oil distribution system. Engine cranking data were measured by the Coordinating Research Council (CRC) L-49[5] test with reference oils that had viscosities between 600 and 8400 mPa·s (cP) at –17.8°C and between 2000 and 20 000 mPa·s (cP) at –28.9°C. The detailed relationship between this engine cranking data and CCS apparent viscosities is in Appendixes X1 and X2 of the 1967 T edition of Test Method D2602[6] and CRC Report 409.[5] Because the CRC L-49 test is much less precise and standardized than the CCS procedures, CCS apparent viscosity need not accurately predict the engine cranking behavior of an oil in a specific engine. However, the correlation of CCS apparent viscosity with average CRC L-49 engine cranking results is satisfactory.

5.2 The correlation between CCS and apparent viscosity and engine cranking was confirmed at temperatures between –1 and –40°C by work on 17 commercial engine oils (SAE grades 5W, 10W, 15W, and 20W). Both synthetic and mineral oil based products were evaluated. See ASTM STP 621.[7]

5.3 A correlation was established in a low temperature engine performance study between light duty engine startability and CCS measured apparent viscosity. This study used ten 1990s engines at temperatures ranging from –5 down to –40°C with six commercial engine oils (SAE 0W, 5W, 10W, 15W, 20W, and 25W).[8]

5.4 The measurement of the cranking viscosity of base stocks is typically done to determine their suitability for use in engine oil formulations. A significant number of the calibration oils for this method are base stocks that could be used in engine oil formulations.

6. Apparatus

6.1 Two types of apparatus are described for use in this test method: the manual cold-cranking simulator (see Appendix X1) and the automated CCS (see 6.2 and 6.3).

6.2 *Automated CCS,*[9] consisting of a direct current (dc) electric motor that drives a rotor inside a stator; a rotor speed sensor or tachometer that measures rotor speed; a dc ammeter and fine current-control adjust dial; a stator temperature control system that maintains temperature within 0.05°C of set point; and a heat removal system with a temperature control system, a computer, computer interface, and test sample injection pump.

6.3 *Automatic Automated CCS,*[9] as described in 6.2 with the addition of an automated sample table allowing multiple test samples to be run sequentially under computer control without operator attention.

6.4 *Calibrated Thermistor,*[9] sensor for insertion in a well near the inside surface of the stator to indicate the test temperature.

6.4.1 There must be good thermal contact between the temperature sensor and the thermal well in the stator; clean this thermal well periodically and replace the small drop of high-silver-containing heat transfer medium.

6.5 *Heat Removal System*:

6.5.1 For stators with coolant contact, a refrigerator for the liquid coolant is needed to maintain coolant temperature at least 10°C below the test temperature. When the coolant temperature is below –30°C a two-stage refrigeration system is likely needed.

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[5] CRC Report No. 409 "Evaluation of Laboratory Viscometers for Predicting Cranking Characteristics of Engine Oils at -0°F and -20°F," April 1968 available from the Coordinating Research Council, Inc., 219 Perimeter Center Parkway, Atlanta, GA 30346.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report D02-1402.

[7] Stewart, R. M., "Engine Pumpability and Crankability Tests on Commercial "W" Grade Engine Oils Compared to Bench Test Results," *ASTM STP 621*ASTM 1967, 1968. *1969 Annual Book of ASTM Standards* , Part 17 (Also published as SAE Paper 780369 in SAE Publication SP-429.).

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report D02-1442.

[9] The sole source of supply of the apparatus known to the committee at this time is Cannon Instrument Co., State College, PA 16804. Website: www.cannoninstrument.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.