



Standard Test Method for Apparent Viscosity of Engine Oils Between –5 and –35°C Using the Cold-Cranking Simulator¹

This standard is issued under the fixed designation D 5293; 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.

^{ε1} NOTE—Table 1 was corrected editorially in November 2000.

1. Scope

1.1 This test method covers the laboratory determination of apparent viscosity of engine oils 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 and viscosities of approximately 500 to 25 000 mPa·s. The range of an instrument is dependent on the instrument model and software version installed. These results are related to engine-cranking characteristics of engine oils.

1.2 A special procedure is provided in Annex A1 for highly viscoelastic oils.

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 A special manual procedure is provided in Annex A1 for highly viscoelastic oils.

1.5 The values stated in SI units are to be regarded as the standard.

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.* Specific warning statements are given in 7.1, 7.2, 7.3, and 7.5 and Section 8.

2. Referenced Documents

2.1 ASTM Standards:

D 2602 Test Method for Apparent Viscosity of Engine Oils at Low Temperature Using the Cold-Cranking Simulator²

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products³

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁴

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:

$$\eta = \tau/\dot{\gamma} \quad (1)$$

where:

τ = the stress per unit area, and

$\dot{\gamma}$ = 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 (millipascal-second) is more convenient and is customarily used. The millipascal second is 1 cP.

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

3.2.4 *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 regulated flow of refrigerated coolant through the stator. 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.

¹ This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.07.0C on Low Temperature Rheology of Non-Newtonian Fluids.

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² Discontinued; see 1993 Annual Book of ASTM Standards, Vol 05.02.

³ Annual Book of ASTM Standards, Vol 05.02.

⁴ Annual Book of ASTM Standards, Vol 14.02.

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-49⁵ 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 relation between this engine cranking data and CCS apparent viscosities is in Appendixes X1 and X2 of the 1967 T edition of Test Method D 2602⁶ 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 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 1990's engines at temperatures ranging from -5 down to

-40°C with six commercial engine oils (SAE 0W, 5W, 10W, 15W, 20W, and 25W).⁸

6. Apparatus

6.1 Two types of apparatus are available for use in this test method: the manual cold-cranking simulator (see 6.2) and the automated CCS (see 6.3 and 6.4).

6.2 *Manual 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 $\pm 0.05^{\circ}\text{C}$ of set point; and a coolant circulator compatible with the temperature control system. See Fig. 1.

6.3 *Automated CCS*⁹, consisting of the CCS described in 6.2, with computer, computer interface, and test sample injection pump. The methanol circulator (see 6.6.1) is not used because the test sample injection displaces the previous test sample. See Fig. 2.

6.4 *Automatic Automated CCS*⁹—The CCS described in 6.3 with the addition of an automated sample table allowing up to 30 test samples to be run sequentially under computer control without operator attention. See Fig. 3.

6.5 *Calibrated Thermistor*—Sensor for insertion in a well near the inside surface of the stator to indicate the test temperature.

6.6 *Refrigeration System*—A refrigerator for the liquid coolant is needed to maintain coolant temperature at least 10°C below the test temperature. Mechanical refrigeration is preferred, but dry ice systems have been used satisfactorily. The length of the tubing connections between the CCS and the refrigerator should be as short as possible and well insulated.

6.6.1 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

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 Appendixes X1 and X2 have been filed at ASTM Headquarters. Request RR: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 Headquarters. Request RR:D02-1442.

⁹ Available from Cannon Instrument Co., P.O. Box 16, State College, PA 16804.



FIG. 1 Cold Cranking Simulator

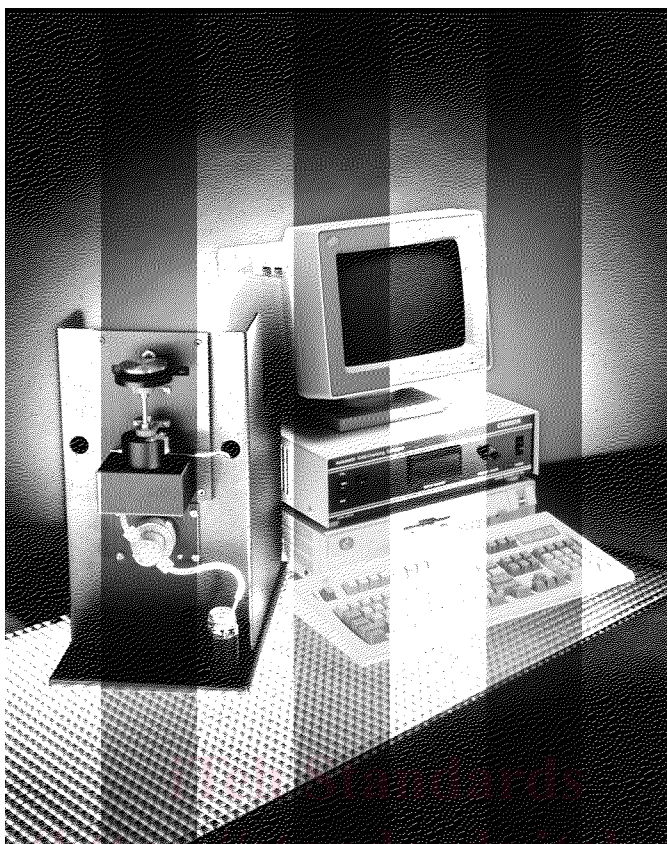


FIG. 2 Automated Cold-Cracking Simulator

high-silver-containing heat transfer medium or mercury. The use of mercury is unacceptable in some laboratories for toxicity reasons; the use of high-silver-containing heat transfer medium is then required. Adjust the temperature of the coolant to the viscometric cell to be at least 10°C below the test temperature.

6.6.1.1 To ensure optimum control of temperature using the dry-ice system, the valve settings on the coolant circulator are set for control of coolant with a low-viscosity test sample in the viscometric cell and the simulator motor turned on.

6.7 *Coolant, dry methanol*—If contaminated with water from operating under high humidity conditions, replace it with dry methanol to ensure consistent temperature control, especially when cooled by dry-ice.

6.8 *Optional Methanol Circulator*⁹—This option (for the Manual CCS only) circulates warm methanol through the stator to facilitate sample changes and aid the evaporation of cleaning solvents.

7. Reagents and Materials

7.1 *Acetone* (**Warning**—Danger—Extremely flammable. Vapors can cause fire.).

7.2 *Methanol* (**Warning**—Danger—Flammable. Vapor harmful.).

7.3 *Petroleum Naphtha* (**Warning**—Combustible vapor harmful.).

7.4 *Calibration Oils*—Low-cloud point Newtonian oils of known viscosity and viscosity/temperature functionality. Approximate viscosities at certain temperatures are listed in Table 1, whereas exact viscosities are supplied with each standard.

NOTE 1—Blind reference samples are available from the supplier of the calibration oils for checking on the shear rate of the viscometric cell and the overall procedure.

7.5 *Mercury* (**Warning**—Paragraph 6.6.1 mentions the optional use of an OSHA-designated hazardous chemical (mercury). For specific hazard information and guidance relative to use, consult the health and safety documents provided by the supplier, for example, the material safety data sheet.).

8. Hazards

8.1 Observe both toxicity and flammability warnings that apply to the use of mercury, methanol, acetone, and petroleum naphtha.

8.2 If methanol is leaking from the apparatus, repair the leak before continuing the test.

9. Sampling

9.1 To obtain valid results, use an appropriate means of bulk sampling (see Practice D 4057) to obtain a representative sample of test oil free from suspended solid material and water. When the sample in its container is received below the dew point temperature of the room, allow the sample to warm to room temperature before opening its container. When the sample contains suspended solid material, use a filter or centrifuge to remove particles greater than 5 µm in size. Do not shake the sample of test oil. This leads to entrainment of air, and a false viscosity reading.

10. Calibration

10.1 *Calibration of Manual CCS:*

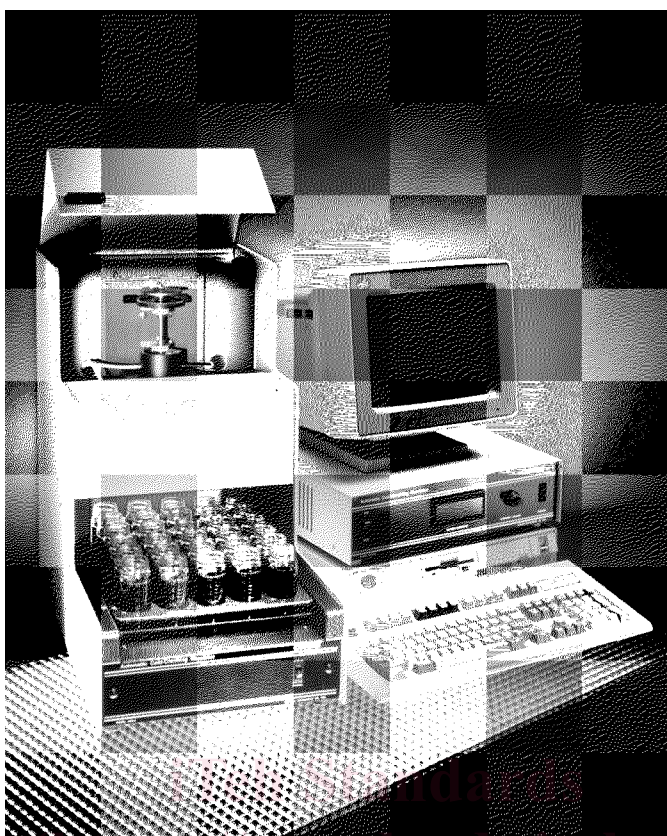


FIG. 3 Automatic Automated Cold-Cranking Simulator

TABLE 1 Calibration Oils

	Calibration Oil						
	Approximate ^A Viscosity in mPa·s at:						
	-5°C	-10°C	-15°C	-20°C	-25°C	-30°C	-35°C
CL-10	...	...	...	...	...	...	1 700
CL-12	...	...	...	...	800	1 600	3 200
CL-14	...	...	...	...	1 600	3 250 ^B	7 000 ^C
CL-16	...	...	...	...	2 500	5 500	11 000
CL-19	...	...	...	1 800	3 500 ^B	7 400 ^C	17 000
CL-22	...	...	1 300	2 500	5 100	11 000	...
CL-25	...	...	1 800	3 500 ^B	7 400 ^C	17 200	...
CL-28	...	1 200	2 500	5 000	9 300	...	...
CL-32	...	1 800	3 500 ^B	7 300 ^C	15 900	...	...
CL-38	...	2 900	5 800 ^C	13 000	...	...	...
CL-48	2300	4 500 ^B	9 500	21 000	...	...	...
CL-60	3700	7 400 ^C	15 600	...	...	...	...
CL-74	6000 ^B	12 000	...	...	...	...	...

^AConsult supplier for specific values.

^BOil to be used for calibration checks with CCS-2B or CCS-4 or 5 with software version 3.x or 5.x.

^COil to be used for calibration checks with CCS-4 or 5 software versions 4.x or 6.x.

10.1.1 On start-up of a new instrument or when any part of the viscometric cell or drive component (motor, belt, tachometer-generator, and so forth) is replaced, determine the required motor drive current. Initially, recheck the drive current (as described in 10.1.2) monthly until the change in drive current in consecutive months is less than 0.020 A and every three months thereafter.

10.1.2 *Drive Current Determination*—Plug the tachometer into the CAL jack, where fitted with a CAL jack. Run the 3500 mPa·s, -20°C viscosity standard at -20°C as described in Section 11. When the drive motor is turned on, establish a speed meter reading of 0.240 ± 0.010 by adjustment of the

current adjust dial. Keep this current setting constant for all subsequent calibration and test sample runs at all temperatures. When the current setting must be changed to maintain a dial reading of 0.240 ± 0.010 units with the 3500 mPa·s reference oil at -20°C, recalibrate the instrument by either procedure described in 10.1.3.

10.1.3 *Calibration Procedure*—At each test temperature, calibrate with the oils listed for that temperature in Table 1 by using the procedure described in Section 11.

10.1.3.1 When only a narrow viscosity range of test liquids is to be measured, use a minimum of three calibration oils spanning the narrow viscosity range of the oils to be tested.