Designation: D 5293 – 04

An American National Standard

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

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.

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 Section 8.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 2602 Test Method for Apparent Viscosity of Engine Oils at Low Temperature Using the Cold-Cranking Simulator[3]

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products

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:

$$\eta = \tau / \dot{\gamma} \tag{1}$$

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

[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] 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.

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

FIG. 1 Cold Cranking Simulator

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.

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[4] 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 2602[5] and CRC Report 409.[4] 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.[6]

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).[7]

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*[8], 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 coolant circulator compatible with the temperature control system. See Fig. 1.

6.3 *Automated CCS*[8], 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*[8]—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.

NOTE 1—In some CCS instruments, the refrigeration may be achieved using solid state thermoelectric modules.

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

[4] 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.

[5] Supporting data (Appendixes X1 and X2) have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1402.

[6] 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.).

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

[8] 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 16804. 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[1], which you may attend.

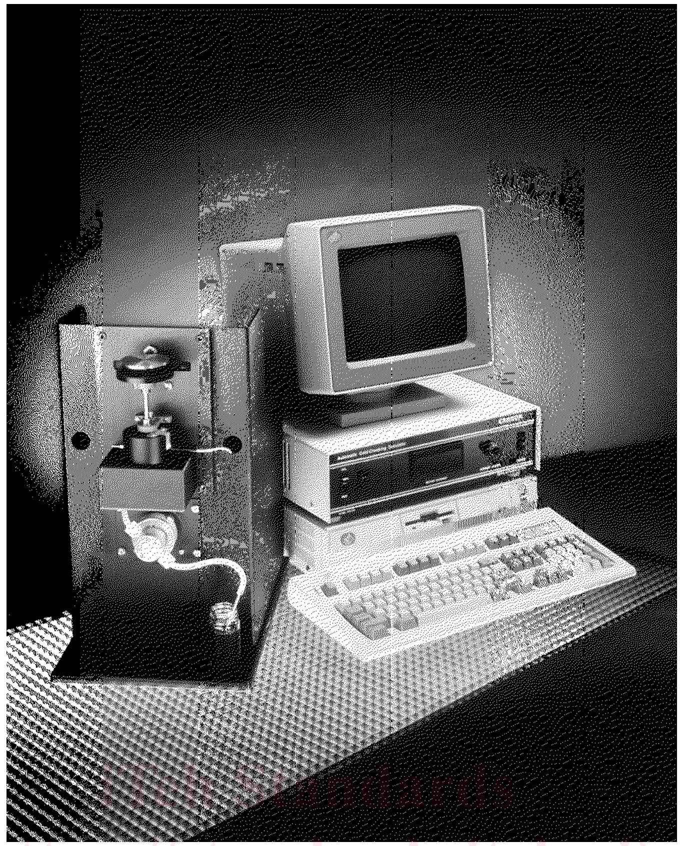

FIG. 2 Automated Cold-Cranking Simulator

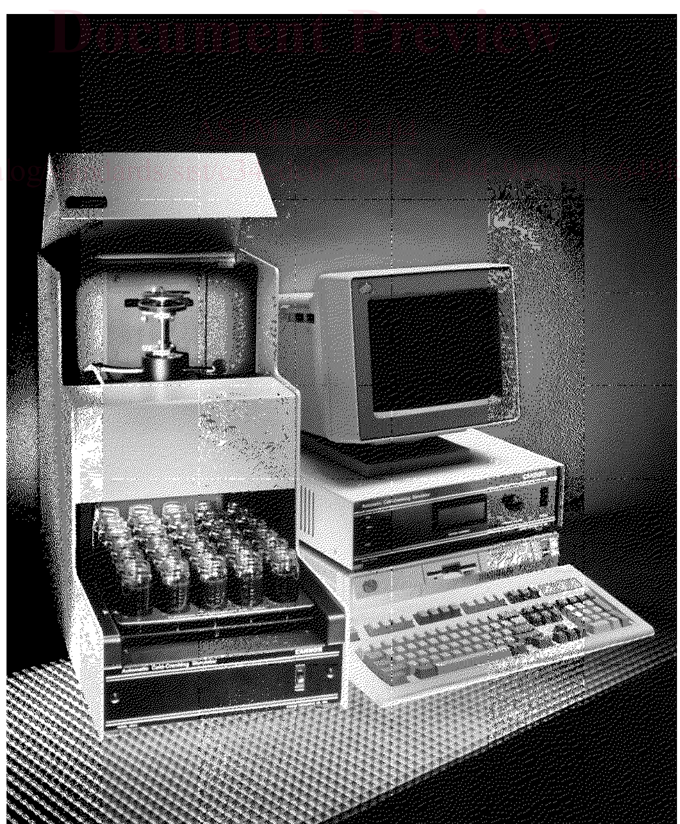

FIG. 3 Automatic Automated Cold-Cranking Simulator

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.

NOTE 2—Thermoelectric cooling may be used instead of mechanical refrigeration or use of dry ice, and so forth.

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 high-silver-containing heat transfer medium. Adjust the temperature of the coolant to the viscometric cell to be at least 10°C below the test temperature.

NOTE 3—If a thermoelectric cooling system is used in the instrument, the liquid cooling temperature of the water or other appropriate liquid used in the refrigeration system (chiller) should be set to approximately 5°C in order to maintain the sample 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*[8]—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 4—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.

8. Hazards

8.1 Observe both toxicity and flammability warnings that apply to the use of 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:*

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

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	...	...	...	...	...

^{A} Consult supplier for specific values.
^{B} Oil to be used for calibration checks with CCS-2B or CCS-4 or 5 with software version 3.x or 5.x.
^{C} Oil to used for calibration checks with CCS-4 or 5 software versions 4.x or 6.x.