Designation: D8210 – 22

Standard Test Method for Automatic Determination of Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants Using a Rotational Viscometer[1]

1. Scope*

1.1 This test method automates the determination of low temperature, low-shear-rate viscosity of driveline and hydraulic fluids, such as automatic transmission fluids, gear oils, hydraulic fluids, and other lubricants. It utilizes a thermoelectrically temperature-controlled sample chamber along with a programmable rotational viscometer. This test method covers a viscosity range of 300 mPa·s to 900 000 mPa·s measured at temperatures from –40 °C to –10 °C.

1.2 The precision data were determined at –40 °C and –26 °C for a viscosity range of 6380 mPa·s to 255 840 mPa·s.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard except those noted below.

1.3.1 *Exception*—The test method uses the SI unit, milliPascal-second (mPa·s), as the unit of viscosity. (1 cP = 1 mPa·s).

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D341 Practice for Viscosity-Temperature Equations and Charts for Liquid Petroleum or Hydrocarbon Products

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

D2983 Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D5133 Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique

D5293 Test Method for Apparent Viscosity of Engine Oils and Base Stocks Between –10 °C and –35 °C Using Cold-Cranking Simulator

D6708 Practice for Statistical Assessment and Improvement of Expected Agreement Between Two Test Methods that Purport to Measure the Same Property of a Material

D6821 Test Method for Low Temperature Viscosity of Drive Line Lubricants in a Constant Shear Stress Viscometer

D8278 Specification for Digital Contact Thermometers for Test Methods Measuring Flow Properties of Fuels and Lubricants

2.2 *ISO Standard:*[3]

ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories

ISO 17034 General requirement for the competence of reference material producers

3. Terminology

3.1 *Definitions:*

3.1.1 *apparent viscosity, n*—the determined viscosity obtained by use of this test method. **D4175**

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

Current edition approved July 1, 2022. Published August 2022. Originally approved in 2018. Last previous edition approved in 2020 as D8210 – 20. DOI: 10.1520/D8210-22.

[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] 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**

3.1.1.1 *Discussion*—In all cases the term "viscosity" implies that the value is the "apparent viscosity."

3.1.1.2 *Discussion*—Apparent viscosity may vary with the spindle speed (shear rate) of a rotational viscometer when the fluid is non-Newtonian.

3.1.2 *digital contact thermometer (DCT), n*—an electronic device consisting of a digital display and associated temperature sensing probe. **D4175**

3.1.2.1 *Discussion*—This device consists of a temperature sensor connected to a measuring instrument; this instrument measures the temperature-dependent quantity of the sensor, computes the temperature from the measured quantity, and provides a digital output. This digital output goes to a digital display and/or recording device that may be internal or external to the device.

3.1.2.2 *Discussion*—The devices are often referred to as a "digital thermometers," however the term includes devices that sense temperature by means other than being in physical contact with the media.

3.1.2.3 *Discussion*—PET is an acronym for portable electronic thermometer, a subset of digital contact thermometers (DCT).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *initial viscosity, n*—average apparent viscosity measured shortly after initiating spindle rotation.

3.2.1.1 *Discussion*—This is apparent viscosity is the average for the 7 s to 9 s time span after initiating the spindle rotation at a spindle speed.

3.2.2 *reference viscosity, n*—the viscosity of Newtonian reference fluid whose values were determined by the use of a master viscometer at one or more temperatures.

3.2.3 *stabilized viscosity, n*—average apparent viscosity measured during the last 10 s at a spindle speed.

3.2.4 *test chamber retaining ring, n*—cone-shaped collar that secures the sample tube in the test chamber.

3.2.5 *viscometer retaining ring, n*—the collar that holds the viscometer in position on the viscometer tray.

3.2.6 *viscometer tray, n*—the support platform on which the viscometer is mounted.

4. Summary of Test Method

4.1 A 20 mL sample of the test fluid is heated to 50 °C and held there for 30 min before cooling it to room temperature. This is followed by cooling in a prescribed manner that mimics a sample cooling in an air bath to the test temperature, which follows Newton's Cooling Law. This thermal conditioning is consistent with that described in the Annex of Test Method D2983. The equation with the constants used are noted in Annex A1. The sample is cooled to test temperature in 1.7 h, then held there for 14 h before the viscosity is measured with a specific insulated spindle at specific series of shear rates (rotational speeds). When the viscosity measurements are complete, the sample chamber is returned to room temperature.

4.2 This test method includes an abbreviated thermal conditioning program, Option B, which is based on the reference in the 1987 and earlier versions of Test Method D2983. This abbreviated program reduces to 4 h the time the sample is held at test temperature before beginning viscosity measurement. Since the time at test temperature is less for this option, the measured viscosity may be lower than the normal length test, Option A, noted in 4.1.

4.3 From the beginning of a test until viscosity measurements are complete, the digital viscometer records elapsed time, and sample temperature. Near the end of the thermal conditioning the viscosity is measured at spindle speeds of 0.6 rpm, 1.5 rpm, 3.0 rpm, 6.0 rpm, 12 rpm, 30 rpm, 60 rpm, and 120 rpm for 180 s for each speed step. Two average apparent viscosities are calculated for each spindle speed. The initial viscosity is the average from 7 s to 9 s at a spindle speed. The stabilized viscosity is the average from 160 s to 179 s at a spindle speed. The results are shown in table format in order of increasing spindle speeds listing the spindle speed, viscosity, torque, and temperature. The test data can be printed or saved to a CSV (comma-separated values) file, which provides a record to both the thermal conditioning and viscosity measurements. Confirmation of the thermal conditioning can be verified by plotting elapsed time versus temperature recorded in the data file.

4.4 In recognition of the fact that some samples come directly from the process line at temperatures near the preheat temperature of 50 °C, Appendix X1 lists the program criteria needed for either the full-length test (Option A) without preheat or the abbreviated test (Option B) without preheat.

5. Significance and Use

5.1 The low-temperature, low-shear-rate viscosity of automatic transmission fluids, gear oils, torque and tractor fluids, power steering fluids, and hydraulic oils are of considerable importance to the proper operation of many mechanical devices. Low-temperature viscosity limits of these fluids are often specified to ensure their suitability for use and are cited in many specifications.

5.2 The manual test method, Test Method D2983, was developed to determine whether a gear oil or an automatic transmission fluid (ATF) would meet low-temperature performance criterion originally defined using a particular model viscometer.[4] The viscosity range covered in the original ATF performance correlation studies was from less than 1000 mPa·s to more than 60 000 mPa·s. The success of these correlations and the development of this test method with gear oil and ATF performance has over time been applied to other fluids and lubricants such as hydraulic fluids, and etc.

5.3 Some formulated fluid types may form a structure, presumably due to the presence of wax, when soaked at or below a certain low temperature. The viscometer's spindle rotation can degrade this structure during the viscosity measurement, which may result in a decrease in the apparent viscosity as the step time increases. This decrease in a fluid's apparent viscosity is often referred to as shear thinning. A

[4] Selby, T. W., "Automatic Transmission Fluid Viscosity at Low-Temperatures and Its Effect on Transmission Performance," SAE Technical Paper 600049, 1960, https://doi.org/10.4271/600049.

sample that exhibits a high initial apparent viscosity may impede the lubrication of certain machinery, such as automatic transmissions.[4] However, it is not unusual to see a sample exhibit shear thinning behaviour when measuring high viscosity products such as gear oils, especially those formulated using solvent refined base stocks. It is recommended, that if this phenomenon is observed in ATF or similar low viscosity products, the suitability of the fluid for the application should be carefully considered. If desired, Test Method D5133 or D6821, may be used to study the behavior of these fluids.

5.4 The viscosity determined by this test method using option A was found to be statistically indistinguishable from Test Method D2983 – 16 measurements based on the ILS data to establish this test method's precision. The ILS results were consistent with the data obtained on numerous ATF and gear oils evaluated in developing this test method.[5]

5.5 Due to the shorter time at test temperature, results from the abbreviated thermal conditioning (Option B) may differ from results obtained with the 14 h soak at test temperature (Option A). For the samples used in developing this test method, results obtained with the abbreviated procedure (Option B) tended to be less than 14 h soak (Option A). This difference seemed to be larger for products that contained high wax base stock.

6. Apparatus

6.1 *Thermal Conditioning Unit (TCU) and Viscometer Support*[6]—The TCU provides an upper mechanism to hold and position the viscometer described in 6.2 over the sample chamber with its spindle centered on the sample chamber. The lower element of the unit contains a thermo-electric temperature controlled chamber that holds the sample tube. Temperature control is by means of a PID (proportional-integral-derivative) programmable controller capable of at least 0.1 °C control over a range from –45 °C to +90 °C. The time and temperature requirements for each test temperature are in Annex A1.

6.2 *Rotational Viscometer*[7]—A digital rotational viscometer with selectable spindle speeds and a maximum torque between 0.0670 mN·m and 0.1800 mN·m and capable of sensing a change in torque of less than 0.3 % of maximum torque. The viscometer shall have an accuracy that is no more than ±1 % of maximum torque. The selection of spindle speeds is at least 0.6 r/min, 1.5 r/min, 3.0 r/min, 6.0 r/min, 12.0 r/min, 30.0 r/min, 60.0 r/min, and 120 r/min. It shall have an integrated RTD sensor with a calibrated range from –45 °C to +90 °C with a resolution of 0.1 °C or less. It shall be capable of automatically initiating the viscosity measurement after a specified elapsed test time, at multiple spindle speeds with each for a specific duration. It shall record elapsed time, temperature, spindle speed, torque, and viscosity throughout a test consistent with data collection parameters in Annex A2. A summary of the measured viscosity, torque, and spindle speed will be displayed at test completion with an option to print or save.

NOTE 1—When measuring viscosities below 7000 mPa(s), a viscometer with a maximum torque near the lower limit shown in 6.2 should be selected.

6.3 *Viscometer Spindle*—Insulated viscometer spindle conforming to the following dimensions (Fig. 1): A ~ 115 mm, B and C = ~3.17 mm, D = 31.1 mm ± 0.1 mm and made from stainless steel. As shown in Fig. 1, the insulated spindle shall have a gap of ~ 4 mm in the upper segment which is covered by a material with poor thermal conduction and pinned to both the upper and lower portions of the upper segment. The gap is

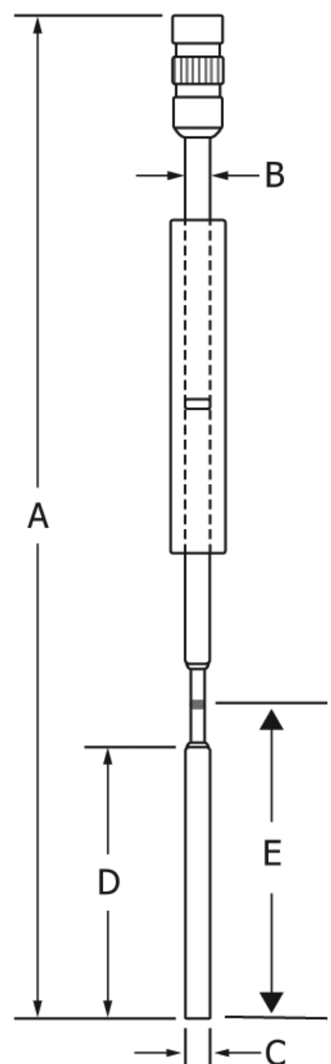

FIG. 1 Insulated Spindle

[5] Henderson, K. O., J. T. Masteropierro, R. A. Patterson, "Automating ASTM D2983 Low-Temperature Viscosity Measurements," JTE20160292, https://doi.org10.1520/JTE20160292

[6] The sole source of supply known to the committee at this time is Cannon Instrument Company, 2143 High Tech Road, State College, PA 16803, www.cannoninstrument.com. TESC is a registered trademark of Cannon Instrument Company. 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.

[7] The sole source of supply known to the committee at this time is AMETEK Brookfield, 11 Commerce Blvd., Middleboro, MA 02346, www.brookfieldengineering.com. Brookfield is a registered trademark of AMETEK Brookfield. 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.