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Standard Specification for Digital Contact Thermometers for Test Methods Measuring Flow Properties of Fuels and Lubricants[1]

This standard is issued under the fixed designation D8278; 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~~ Scope*

1.1 This specification establishes criteria for digital contact thermometers (DCT) for use in test methods that measure flow properties of materials within the scope of Committee D02. The DCT criteria are based on the design and sensing characteristics of the liquid-in-glass thermometers that are used successfully in Committee D02 test methods.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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.*

1.4 *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]

D97 Test Method for Pour Point of Petroleum Products
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D2162 Practice for Basic Calibration of Master Viscometers and Viscosity Oil Standards
D2500 Test Method for Cloud Point of Petroleum Products and Liquid Fuels
D2983 Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer
D3829 Test Method for Predicting the Borderline Pumping Temperature of Engine Oil
D4539 Test Method for Filterability of Diesel Fuels by Low-Temperature Flow Test (LTFT)
D4684 Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature
D5481 Test Method for Measuring Apparent Viscosity at High-Temperature and High-Shear Rate by Multicell Capillary Viscometer
D5853 Test Method for Pour Point of Crude Oils
D6371 Test Method for Cold Filter Plugging Point of Diesel and Heating Fuels
D6821 Test Method for Low Temperature Viscosity of Drive Line Lubricants in a Constant Shear Stress Viscometer
D6896 Test Method for Determination of Yield Stress and Apparent Viscosity of Used Engine Oils at Low Temperature

[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.

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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.

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

D7279 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids by Automated Houillon Viscometer
D7962 Practice for Determination of Minimum Immersion Depth and Assessment of Temperature Sensor Measurement Drift
D8210 Test Method for Automatic Determination of Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants Using a Rotational Viscometer
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E563 Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature
E644 Test Methods for Testing Industrial Resistance Thermometers
E1750 Guide for Use of Water Triple Point Cells
E2877 Guide for Digital Contact Thermometers

2.2 *ISO Standard:*[3]
ISO 17025 General requirements for the competence of testing and calibration laboratories

3. Terminology

3.1 *Definitions:*

3.1.1 *accuracy, n*—the closeness of agreement between a test result and an accepted reference value. **E177**

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

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 thermometers, a subset of digital contact thermometers (DCT).

3.1.3 *DCT immersion depth, n*—depth that a DCT sensor ~~should be~~ is immersed in a uniform temperature environment, such that further immersion does not produce a change in indicated temperature greater than the specified tolerance.

3.1.3.1 *Discussion*—
This is a DCT probe characteristic and establishes a baseline immersion for the probe. This is separate and distinct from how the probe is located in a test method. The use and positioning of a DCT probe in a test method is to be described in the test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *range-of-use, n*—a subset of the nominal DCT temperature range.

3.2.1.1 *Discussion*—
This is the temperature range over which a particular DCT is to be used. For example, if a DCT is to be used for viscosity measurements as 40 °C and 100 °C, then its "range-of-use" is 60 °C.

4. Summary

4.1 This specification sets the criteria for digital contact thermometers (DCT) used in measuring flow properties of fuels and lubricants. The DCT criteria were selected so that DCT temperature measurements would be essentially the same as those measured using a liquid-in-glass (LiG) thermometer. For some of the noted test methods, the temperature of a small static sample volume is measured, thus, the difference in thermal conductivity between the different types of devices will have an impact on measurement equivalence.

4.2 The DCT temperature sensing elements noted in this specification are platinum resistance temperature (PRT) detectors or thermistors whose sheath or enclosure is in direct contact with the substance being measured and are referred to as a digital contact thermometers. Both PRTs and thermistors are members of a group referred to as resistance temperature detectors (RTD) as their resistance is a function of temperature.

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

5. Significance and Use

5.1 The DCTs meeting the indicated requirements have been found to be suitable for replacing the liquid-in-glass thermometers in the noted test methods. The criteria are based on key elements of liquid-in-glass (LiG) thermometers, such as bulb length, immersion depth, measurement precision, and thermometer positioning. The prescribed dimensions for sensor length, immersion depth, and sheath diameter are critical variables when measuring the temperature of small static samples due to differences in temperature probe thermal conductivity. Therefore, a DCT that is suitable for use in a stirred constant temperature bath will likely result in temperature measurement errors when used to measure the temperature of small static sample volumes.

6. DCT Criteria

6.1 The DCT requirements shown in Table 1 are for various temperature measurement applications used in Subcommittee D02.07 test ~~methods.~~methods and reference in the test method. The DCT response time requirements are shown in Table 2 with the procedure for determining a probe's response time in 6.4.

NOTE 1—DCT with a PRT element that is a suspended wire, such as those used in a SPRT, are extremely sensitive to mechanical shock which usually will alter its calibration. Other PRT sensing element designs such as thin film and mandrel wrapped wire can be sensitive to vibrations which alter their calibration or result in failure.

6.1.1 When considering the use of a DCT criteria in Table 1 for test methods other than those noted, careful consideration must be given to the DCT probe's placement in the new application versus its placement in the media, bath, or sample of the noted method. The metal construction of DCT probes can have a significant impact on measured value when compared to a liquid-in-glass thermometer in a similar environment due to its greater thermal conductivity. Each of the DCT criteria in the table were developed for the indicated method's unique test environment. Other factors can impact the ability of a DCT to mimic the temperature measurement of a LiG thermometer. When a DCT probe is immersed in the sample, its immersion depth and ratio of probe volume to sample volume will have an impact on the measured value. Thus the smaller the probe diameter the smaller the impact on sample temperature.

NOTE 2—The DCT's electronics are typically limited to an environment of 0 °C to 35 °C. A DCT's temperature limits can be found in its manual or in the manufacturer's specifications.

6.2 *DCT Probe Immersion Depth*—This criteria quantifies the length of the DCT probe above the tip that needs to be covered by the material being measured in order to obtain an accurate temperature measurement. Immersing the probe in a material by less than its minimum immersion depth can result in temperature measurements that significantly differ from actual temperature. The error is dependent on the temperature difference between the material being measured and surrounding (ambient) temperature. A test method will set the immersion requirements for the DCT probe.

6.3 *Measurement Drift*—The drift in calibration should be checked periodically and at least yearly. This can be accomplished using Practice D7962, Practice E563, Test Methods E644, or similar procedure. When the DCT calibration drift just exceeds the noted limit for calibration drift, then it is to be rechecked within a short period of time but no longer than month. If the subsequent measurement of DCT calibration drift exceeds the specified limit, it is to be fully recalibrated consistent with its range-of-use. If the DCT calibration drift significantly exceeds the noted limit, then it must be recalibrated consistent with its range-of-use. See Practice E563, Test Methods E644, or Guide E1750 for more information regarding checking calibrations.

NOTE 3—For reference temperatures, additional information on preparing and using an ice bath can be found in Practice E563. Guide E1750 provides guidance for preparing and using a water triple point cell.

6.4 *Response Time*—~~Applies to a digital contact thermometer's (DCT)~~ A DCT's response time for the combined display and sensor ~~system. Conformance with this requirement is to be provided in the manufacturer's or supplier's product documentation. Response time is~~ is defined as the time for a DCT to respond to a 63.2 % of a step change in ~~temperature.~~ temperature as determined by either 6.4.1 or 6.4.2~~The step change begins with the DCT probe at an initial temperature of~~. The response time limits for the DCTs in this specification are shown in Table 2~~20 °C ± 5 °C air and the timing begins when it is transferred to water at 77 °C ± 5 °C, which is flowing at 0.9 m/s ± 0.09 m/s past the sensor, as described in Test Methods~~. The response time is affected by the DCT probe construction as well as the signal ~~E644, or an equivalent method.~~ processing parameters to display the measurement. The DCT display refresh rate is to be at intervals of every ~~3 s~~2 s or less.

6.4.1 When determining response time without a data logger use a 40 °C constant temperature bath with temperature control and temperature uniformity appropriate for kinematic viscosity measurements such as those in Test Method D445. For a determination

TABLE 1 DCT Criteria for D02 Test Methods

NOTE 1—When making measurements below –40 °C with a PRT, it may be necessary to use a 1000 Ω PRT sensor in order to obtain accurate measurements.

NOTE 2—Additional information on PRT sensors and their testing can be found in Test Methods E644.

D02–DCT ID	D02-DCT01	D02-DCT02	D02-DCT03	D02-DCT04
Test Method	D97, D2500, D5853	D97, D5853	D97, D2500, D5853	D445
Parameter	**DCT Criteria**			
Nominal temperature range,[A] °C	–38 to 50	32 to 127	–80 to 20	–80 to 0
Display resolution, °C minimum	0.1	0.1	0.1	0.01
Accuracy,[B] °C minimum	0.5	0.5	0.5	0.05
~~Sensor type (Note 1 and Note 2)~~	~~PRT, Thermistor~~	~~PRT, Thermistor~~	~~PRT~~	~~PRT~~
Sensor type (Note 1 and Note 2)	PRT, Thermistor, Thermocouple Type T	PRT, Thermistor, Thermocouple Type T	PRT, Thermistor, Thermocouple Type T	PRT, Thermistor
Sensor sheath,[C] max diameter, mm	4.2[D]	4.2	4.2[D]	7
~~Sensor length,[E] max mm~~	~~10~~	~~10~~	~~10~~	~~25~~
~~DCT immersion depth by D7962,[E] mm (see 6.2)~~	~~<40~~	~~<40~~	~~<40~~	~~<40~~
DCT immersion depth by D7962,[E] mm (see 6.2)	<40	<40	<40	<40
~~Measurement drift,[G] less than °C (see 6.3)~~	~~0.5~~	~~0.5~~	~~0.5~~	~~0.05~~
Measurement drift,[F] less than °C (see 6.3)	0.5	0.5	0.5	0.02
~~Response time, less than or equal to, seconds (see 6.4)~~	~~10~~	~~10~~	~~10~~	~~10~~
~~Calibration data,[H] (see 6.5)~~	~~2 to 4~~	~~2 to 4~~	~~2 to 4~~	~~2 to 4~~
Calibration data,[G] minimum (see 6.5)	2 to 4	2 to 4	2 to 4	2 to 4

D02–DCT ID	D02-DCT05	D02-DCT06	D02-DCT07	D02-DCT08	D02-DCT11
Test Method	D445	D445, D5481	D7279	D2162	D2983 Procedures A, B, C
Parameter	**DCT Criteria**				
~~Nominal temperature range,[A] °C~~	~~0 to 100~~	~~100 to 175~~	~~0 to 150~~	~~10 to 175~~	~~–60 to 60 (Note 1)~~
Nominal temperature range,[A] °C	0 to 100	>100	20 to 150	10 to 175	–60 to 60 (Note 1)
Display resolution, °C minimum	0.01	0.01	0.01	0.001	0.1
Accuracy,[B] °C minimum	0.02	0.05	0.02	0.007	0.1
~~Sensor type (Note 1 and Note 2)~~	~~PRT, Thermistor~~	~~PRT~~	~~PRT, Thermistor~~	~~PRT~~	~~PRT~~
Sensor type (Note 1 and Note 2)	PRT, Thermistor	PRT, Thermistor	PRT, Thermistor	PRT, SPRT preferred	PRT
Sensor sheath,[C] max diameter, mm	7	7	7	7	4.2
~~Sensor length,[E] max mm~~	~~25~~	~~25~~	~~18~~	~~40~~	~~20~~
~~DCT immersion depth by D7962,[F] mm (see 6.2)~~	~~<40~~	~~<40~~	~~<40~~	~~<105~~	~~<40~~
DCT immersion depth by D7962,[E] mm (see 6.2)	<40	<40	<40	<105	<40
~~Measurement drift,[G] less than °C (see 6.3)~~	~~0.02~~	~~0.02~~	~~0.02~~	~~0.01~~	~~0.1~~
Measurement drift,[F] less than °C (see 6.3)	0.02	0.02	0.01	0.01	0.1
~~Response time, less than or equal to, seconds (see 6.4)~~	~~10~~	~~10~~	~~10~~	~~10~~	~~10~~
~~Calibration data,[H] (see 6.5)~~	~~2 to 4~~	~~2 to 4~~	~~2 to 4~~	~~2 to 4~~	~~2 to 4~~
Calibration data,[G] minimum (see 6.5)	2 to 4	2 to 4	2 to 4	3 to 4[H]	2 to 4

D02–DCT ID	D02-DCT12	D02-DCT13	D02-DCT14	D02-DCT15
Test Method	D4539, D6371	D4539, D6371	D3829, D4684, D6821, D6896	D8210, D2983 Procedure D
Parameter	**DCT Criteria**			
Nominal temperature range,[A] °C	–38 to 50	–80 to 50	–45 to 100	–45 to 60
Display resolution, °C minimum	0.1	0.1	0.1	0.1
Accuracy,[B] °C minimum	0.5	0.5	0.05	0.1
Sensor type (Note 1 and Note 2)	PRT	PRT	PRT, Thermistor	PRT
Sensor sheath,[C] max diameter, mm	4.2	4.2	3[I]	1.7
~~Sensor length,[E] max mm~~	~~10~~	~~10~~	~~20~~	~~20~~
~~DCT immersion depth by D7962,[F] mm (see 6.2)~~	~~<40~~	~~<40~~	~~<40~~	~~<40~~
DCT immersion depth by D7962,[E] mm (see 6.2)	<40	<40	<40	<40
~~Measurement drift,[G] less than °C (see 6.3)~~	~~0.5~~	~~0.5~~	~~0.05~~	~~0.1~~
Measurement drift,[F] less than °C (see 6.3)	0.5	0.5	0.05	0.1
~~Response time, less than or equal to, seconds (see 6.4)~~	~~10~~	~~10~~	~~10~~	~~10~~
~~Calibration data,[H] (see 6.5)~~	~~2 to 4~~	~~2 to 4~~	~~2 to 4~~	~~2 to 4~~
Calibration data,[G] minimum (see 6.5)	2 to 4	2 to 4	4[J]	2 to 4

[A] A device's minimum and maximum temperature may be different than the values shown provided the calibration requirements are met.

[B] Accuracy is the combined accuracy of the DCT unit that is the display and sensor without correction factors. See Guide E2877 for more information regarding selecting a DCT.

[C] Sensor sheath is the tube that holds the sensing element. The value is the nominal outside diameter of the sheath segment containing the sensing element. Also see 6.7.

[D] Supporting data have been filed at ASTM international headquarters and may be obtained by requesting Research Report RR:D02-1849. Contact ASTM Customer Service at service@astm.org.

~~[E] The physical length of the temperature sensing element. Contact the DCT supplier to determine whether this parameter is met, as it will not be accessible to the user.~~