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.

Designation: D8164 – 21

Standard Guide for Digital Contact Thermometers for Petroleum Products, Liquid Fuels, and Lubricant Testing[1]

This standard is issued under the fixed designation D8164; 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 The intent of this guide is to suggest an initial configuration and provide guidance when establishing the appropriate criteria needed for a DCT to correctly measure the temperature in a laboratory test method for products within the scope of this committee. This guide includes examples of the approximate digital contact thermometer (DCT) criteria that was found suitable for measuring temperature in the test methods utilized by Committee D02.

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
D2386 Test Method for Freezing Point of Aviation Fuels
D2500 Test Method for Cloud Point of Petroleum Products and Liquid Fuels
D2532 Test Method for Viscosity and Viscosity Change After Standing at Low Temperature of Aircraft Turbine Lubricants
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
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
D8278 Specification for Digital Contact Thermometers for Test Methods Measuring Flow Properties of Fuels and Lubricants
E1 Specification for ASTM Liquid-in-Glass Thermometers
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

---

[1] This guide 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 April 1, 2021. Published April 2021. Last previous edition approved in 2019 as D8164 – 19. DOI: 10.1520/D8164-21.

[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**

E644 Test Methods for Testing Industrial Resistance Thermometers

E1750 Guide for Use of Water Triple Point Cells

E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

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

3.1.2.1 *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.

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

3.1.3.1 *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.

3.1.3.2 *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.

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

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 and calibrated. 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.

3.3 *Acronyms:*

3.3.1 *PRT, n*—Platinum Resistance Thermometer

3.3.1.1 *Discussion*—The sensor used in a PRT is made from platinum, whose resistance varies with temperature.

3.3.2 *SPRT, n*—Standard Platinum Resistance Thermometer

3.3.2.1 *Discussion*—An SPRT is a high precision PRT with an accuracy on the order of a milliKelvin (0.0010 °C).

4. Summary of Guide

4.1 The purpose of this guide is to assist users in determining the criteria needed to define the performance of a digital contact thermometer (DCT) that is suitable for use in test methods within the scope of Committee D02. This guide includes examples of criteria that are approximately those used successfully to measure the temperature in different measurement test configurations. The parameters in these examples are based on the design and sensing characteristics of the liquid-in-glass thermometers. These examples should be considered as a starting point for establishing the DCT criteria for other applications. Other temperature measurement configurations may require additional criteria in order to appropriately assess the temperature in a test method. *It is the responsibility of the standard developer and user to ensure that the chosen DCT criteria will adequately indicate the test temperature especially when replacing a cited liquid-in-glass thermometer.*

4.2 The DCT temperature sensing elements used in this guide are platinum resistance temperature (PRT) detector, thermistor or thermocouple which are in contact with the substance thus referred to as a digital contact thermometer. Both PRTs and thermistors are members of a group referred to as resistance temperature detectors (RTD) as their resistance is a function of temperature. Thermocouples are created by linking two dissimilar metals which results in a temperature dependent potential.

5. Significance and Use

5.1 The information in the examples of this guide are intended to be a starting point for determining the appropriate DCT criteria for a test method that measures a temperature-dependent property of a product within the scope of Committee D02. The criteria examples noted in this guide are based on the liquid-in-glass (LiG) thermometer design components, which are the bulb length, immersion depth, precision of measurement, thermometer position, and so forth. The parameters such as sensor length, immersion depth, and sheath diameter are especially critical when measuring the temperature of small static samples. This is due in part to the difference in thermal conductivity of a LiG vs. a DCT, however other aspects of the devices can contribute to unequal results. For example a DCT that is suitable for use in a stirred constant temperature bath will likely result in measurement errors when used to measure the temperature of a small static sample. This difference can be a degree or more when the sample temperature differs from room temperature by 40 °C or more using a 7 mm probe. This error is due to the difference in thermal conductivity and specific heat value of a DCT and LiG thermometer, however other aspects of the two different devices can contribute unequal results. One way to counter this is by reducing DCT sheath diameter, insulating the sheath above the immersion level, and using a probe that has a small immersion depth as determined by Practice D7962. For more guidance on selecting an appropriate DCT, see Guide E2877.

5.2 When replacing a LiG thermometer with a DCT noted in this guide and the test method does not list any DCT criteria, *it is incumbent on the user to verify the suitability of the DCT*

---

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

they have selected. This can be done by comparing measurements made with the selected DCT to those of a LiG thermometer and following the test procedure. Comparative measurements are especially important when measuring the temperature of a small static sample where there is a large difference between sample and room temperature. Covering the DCT probe sheath except for the sensing portion with a glass, plastic, or tubing with a lower thermal conductivity can improve the agreement between LiG and DCT measurements.

6. DCT Criteria

6.1 As a first step in choosing the initial DCT criteria for an application, a careful review of the test method's temperature measurement environment should be made. Table 1 provides examples of DCT criteria that are similar to those in current test methods. These example criteria should be considered as an initial starting point for establishing DCT criteria for a new measurement application. The example criteria shown may not reflect the indicated test method's current DCT criteria. The temperature measurement environment associated with the various examples differ in measurement accuracy, measurement precision, and temperature range as well as whether the measurement is of a static or stirred sample. When a DCT probe displaces a significant volume of the sample, it can have a significant impact on measured temperature due in large part to measurement devices thermal conductivity. This is especially noticeable when comparing LiG temperature measurements to those made by DCT devices in small static samples. This difference can be reduced by reducing the DCT probe diameter. A smaller diameter DCT probe decreases the time to sense a change in temperature. Examples of response time criteria are shown in Table 2.

6.1.1 The DCT criteria associated with the test methods noted in Table 1 are likely different than the criteria in the current test method. A test method's current DCT criteria will be found in a current edition of the test method or in Specification D8278.

6.1.2 If the DCT with the chosen criteria is replacing a current temperature measuring device, then a study comparing the measurement devices is of critical importance in assuring that the change in temperature measuring devices yields equivalent results within the precision of the method.

NOTE 1—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 *Sensor Type*—A platinum resistance temperature (PRT) sensor is noted in all of the Table 1 example configurations, while a few configurations indicate a thermistor or thermocouple as a suitable alternative. Before choosing a sensor type for an application, the differences in temperature measurement characteristics of the sensors should be considered before making the selection. See Guide E2877 for more information on sensor characteristics.

6.2.1 *PRT Sensors*—The PRT sensors used in the examples are typically 100 Ω elements, except for Configuration H, which is appropriate for the noted temperature ranges. The sensing elements for these PRTs are typically a film mounted platinum element or coiled platinum wire. PRTs are sensitive to mechanical shock or vibrations that can induce strain in the sensor element, resulting in a shift in its calibration. To reduce a sensing element's sensitivity to shock and vibration, the sensor may be surrounded by a ceramic powder material which improves heat transfer between the sheath and sensing element. However, by supporting the sensing element, there may be a reduction in temperature accuracy. See Guide E2877 for more information regarding PRTs.

6.2.1.1 For high precision temperature measurements an SPRT, as in Configuration H, is typically the choice. An SPRT typically has a measurement resolution of 0.1 mK or less with an accuracy of less than 7 mK. It is often used as the temperature reference for calibrations where precise temperature measurement is required. SPRTs are considerably more susceptible to mechanical shock than typical PRTs. To assure accurate measurements, the calibration is frequently checked using the triple point of water as a reference point.

6.2.1.2 For applications where the temperatures are significantly below -40 °C, measurement errors may occur due to the increased current needed to obtain a temperature measurement due to self heating. To avoid self heating errors at temperatures below -40 °C, consideration should be given to using a PRT with a higher resistance, such as 1000 Ω.

6.2.2 *Thermistor* has the advantage of having a smaller sensing volume than a PRT sensor, thus they are a suitable alternative to the use of a PRT when the sensor placement has size restrictions or when thermal mass must be minimized, or both. While their temperature sensitivity is similar to PRTs, they are less sensitive to mechanical shock. Their relationship between temperature and resistance is non-linear which can limit its useful temperature range.

6.2.3 *Thermocouples*—There are only three example configurations offering thermocouples as an appropriate sensor. This is due to required measurement accuracy noted in the example configurations. Thermocouples are more prone to calibration drift than either the thermistor or PRT. Mechanical shock or vibration will not appreciably impact their calibration.

6.3 *DCT Probe Immersion Depth*—The method for determining the minimum DCT probe immersion depth, which is a characteristic of the DCT probe, is Practice D7962. This criteria quantifies the distance from the DCT probe tip that it should 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 differ from actual temperature. The error is dependent on the temperature difference between the material being measured and surrounding (ambient) temperature. Immersions greater than this immersion depth are acceptable. The DCT immersion depth is a probe characteristic and not necessarily a suitable immersion depth in a test method especially when replacing a LiG thermometer.

6.4 *Measurement Drift*—The drift in calibration should be checked periodically and at least once per year. This can be accomplished using Practice D7962 or Test Methods E644. When a DCT's calibration drifts in one direction over several calibration checks against a reference temperature, such as the ice point, it may be an indication of deterioration of the DCT. The probe is to be recalibrated, when the check value differs by more than the calibration drift listed in Table 1 from the last probe calibration. See Practice E563, Test Methods E644, or Guide E1750 for more information regarding checking calibrations.

NOTE 2—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.

6.5 *Response Time*—A digital contact thermometer's response time is for the combined display and sensor system. It is determined by measuring the change in measurement when the DCT probe environment is changed from room temperature to an elevated temperature. Response time is defined as the time for the device to respond to a 63.2 % step change in temperature as determined per 6.5.1 or 6.5.2. The recommended response time limits are listed in Table 2. The DCT display refresh rate is to be at intervals of every 2 s or less.

6.5.1 When determining response time without a data logger for the elevated temperature, 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 the DCT probe will initially be at 20 °C ± 5 °C in either an air or liquid bath and showing a stable measurement value. To measure response time, the probe will be inserted into a constant temperature bath's media to the probe's minimum immersion depth (see Practice D7962). Timing begins the moment the probe enters the 40 °C bath media and ends when the displayed temperature is 63.2 % of the difference between its initial temperature and the 40 °C bath temperature. When manually measuring the response time, the response time is to be an average of at least four determinations.

6.5.1.1 *Example*—When the initial probe temperature is 22 °C and the bath temperature is 40 °C, the response time is the time it takes the DCT display to show a change in temperature of 11.4 °C [(40 – 22) * 0.632)] which is when the displayed temperature is 33.4 °C.

6.5.2 When determining the response time per the procedure in Test Methods E644, the step change begins with the DCT probe at an initial temperature of 20 °C ± 5 °C. The timing begins when it is transferred to water bath at 77 °C ± 5 °C, which is flowing at 0.9 m/s ± 0.09 m/s past the sensor. Due to the very short time span, this procedure requires a DCT system capable of automatically recording time and temperature. Response times obtained from a supplier or manufacturer of the DCT using Test Methods E644 are acceptable.

6.5.2.1 *Example*—When the initial probe temperature is 22 °C and the bath temperature is 78 °C, the response time is the time it takes the DCT display to show a change in temperature of 35.4 °C [(78 – 22) * 0.632)] which is when the displayed temperature reaches 57.4 °C.

6.6 *Calibration*—When a device is calibrated for the full nominal temperature range, or the "range-of-use" span is 90 °C or more, the calibration data should consist of a minimum of four data points. When the "range-of-use" span is 30 °C or greater to less than 90 °C, then a minimum of three data points are sufficient. When the "range-of-use" span is less than 30 °C, then a minimum of two data points are sufficient. The calibration data should be distributed over the calibration range and included in the calibration report. The calibration report should be obtained from a calibration laboratory with demonstrated competency in temperature calibration which is traceable to a national calibration laboratory or metrology standards body. An example is a calibration laboratory with a ISO 17025 accreditation that includes temperature calibration.

6.7 *DCT Sheath Diameter*—The sheath diameters noted in Table 1 are based on metal-sheathed probes. Glass-sheathed probes 7 mm OD have been found to be suitable alternatives to both 3 mm and 7 mm OD metal-sheathed DCT probes.

6.8 *Thermowells*—When a test method places the temperature sensor in a thermowell, good thermal contact between the sensing probe and the thermowell wall is essential for accurate measurements. This is especially true for metal sheathed DCTs. To fill the space between the probe and the thermowell wall, use a metal sleeve or a gel with a high thermal conductivity to ensure good thermal transfer from the wall to the DCT sheath. A metal sleeve is to be made from a thermally conductive substance such as copper, brass, bronze, aluminum, steel, or other similar material.

6.9 *Other DCT Criteria*—There are additional criteria that may be needed for a particular measurement application such as linearity of the calibration data or DCT system response time.

6.10 A DCT Certification/Calibration report may differ from a liquid-in-glass thermometer since a system adjustment can allow readings to be matched to the reference at the test point values. If system adjustments can not be made then the report needs to include the correction factors needed to bring the display temperature to the correct value along with guidance on applying them. A report may show AS FOUND values that were documented before adjustments, and AS LEFT which are the values documented after adjustments may have been made.

7. DCT Citation

7.1 The DCT citation in a standard should list the Table 1 criteria elements, including the information in subsections 6.2 through 6.6, as well as any additional DCT criteria.

8. Keywords

8.1 DCT; digital contact thermometers; LiG; liquid-in-glass thermometers