Designation: D8055 – 17

Standard Guide for Selecting an Appropriate Electronic Thermometer for Replacing Mercury Thermometers in D04 Road and Paving Standards[1]

This standard is issued under the fixed designation D8055; 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 Interstate Mercury Education and Reduction Clearinghouse (IMERC) and the U.S. Environmental Protection Agency (EPA) are phasing out the use of mercury thermometers because of safety and environmental concerns. This guide was developed to support replacing mercury thermometers in D04 standards with appropriate electronic thermometers.

1.2 This guide provides assistance for the D04 subcommittees when selecting electronic thermometers for general use in water or oil baths and ovens and as possible replacements for Specification E1 mercury thermometers currently used in D04 road and paving standards. Guidance for using non-mercury liquid thermometers in place of mercury thermometers can be found in Specification E2251.

1.3 Some guidance is also provided for selecting a hand-held infrared thermometer for use in field applications.

1.4 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this guide.

1.5 *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.*

1.6 *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]

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
E1 Specification for ASTM Liquid-in-Glass Thermometers
E644 Test Methods for Testing Industrial Resistance Thermometers
E1137/E1137M Specification for Industrial Platinum Resistance Thermometers
E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

3. Summary of Practice

3.1 Guidance is provided for selecting a sensor based on a desired upper and lower range of temperatures, and accuracy. Guidance is also provided for selecting an appropriate sensor for replacing specific Specification E1 mercury thermometers currently used in D04 standards.

4. Significance and Use

4.1 General guidance is provided for electronic thermometers for general temperature measurements typically needed for D04 practices and test methods which need to monitor oven, water and oil bath, and material temperatures during drying, heating, aging, and mixing.

4.2 All ASTM standards under the management of the D04 Main Committee were individually reviewed, and a list of all Specification E1 mercury thermometers was prepared along with the required temperature range and information about the thermometer placement in each method.

4.2.1 This specific information was used to identify the most appropriate type(s) of electronic thermometers which can

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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.

be used to replace mercury thermometers in the current D04 road and paving standards.

5. Electronic Thermometers

5.1 *Basic Background Information for Understanding Key Elements of Different Types of Electronic Temperature Sensors:*

5.1.1 Most sensors require multiple algorithms to convert electrical signals to temperature measurements. These algorithms are only useful over a portion of a temperature range, and different algorithms are needed above and below 0 °C.

5.1.2 Sensor accuracy is improved by increasing the number of algorithms which are applicable over narrower temperature ranges. The digital meter programming is critical to the accuracy of the temperature measurements, and the meter capabilities for accuracy need to be matched to the requirements for each type of sensor.

5.1.3 More than one sensor can be paired with a single digital meter, but temperature measurements with each sensor-digital meter pair need to be independently verified and documented.

5.1.4 Each sensor and digital meter needs to be labeled so that the sensor can be matched with the appropriate digital meter for laboratory accreditation documentation required in Specification D3666.

5.2 *Platinum Resistance Thermometers (PRTs):*

5.2.1 A platinum resistance thermometer is a specific type of resistance temperature device (RTD). A wide range of names are used by various sensor manufacturers and suppliers of these devices. Some suppliers market these sensors as simply RTDs and the information about the metal used in each sensor is only found in the more detailed sensor description. Other suppliers market electronic platinum RTD sensors as PT, for platinum, or PRT for platinum resistance thermometer. Specification E1137/E1137M uses the PRT abbreviation and provides the basic requirements for PRT sensors.

5.2.2 PRT sensors use one of two reference resistance levels: 100 ohms and 1000 ohms. PRT sensors with a resistance of 100 ohms have an upper temperature limit of 204 °C while a PRT sensor with a resistance of 1000 ohms has an upper temperature limit of 482 °C. PRT sensors with a resistance of 100 ohms are most useful for D04 application temperatures.

5.2.3 A reference temperature of 0 °C is the temperature at which the sensor accuracy is the best (that is, smallest ± range). PRT sensor accuracy decreases linearly with increasing or decreasing temperatures on either side of 0 °C.

5.2.3.1 The purity of the platinum greatly influences the accuracy of the sensor.

5.2.4 The wiring configuration of the PRT sensor also greatly influences the accuracy of the temperature readings. PRT sensors should be ordered with three- or four-wire configurations. Two-wire configurations should be avoided.

5.2.5 PRTs can be easily damaged if dropped or mishandled and should not be subjected to shock or vibration. This type of temperature sensor is best used when it can be permanently or at least semi-permanently mounted in or on the test equipment.

5.2.5.1 The sensor needs to be protected by a metal sheath and the wiring needs to be insulated to minimize heat transfer from surrounding environmental conditions and external electronic noise. The overall sheath length shall be least 50 mm greater than the immersion depth (see Section 7).

5.3 *Thermistors:*

5.3.1 Thermistors with negative temperature coefficients (NTC) have nonlinear decreasing resistance with increasing temperatures and are very sensitive to temperature changes. The beta value (B-value) is a function of the nonlinearity of the resistance-temperature relationship. Higher B-values indicate increased sensor sensitivity to small changes in temperature. Thermistors are characterized by manufacturers by their resistance, in ohms, at 25 °C, and their B-value.

5.3.2 Drift (stability) in the electronic thermometer readings over time occurs because of changes in the sensor resistance and B-value. Drift increases with increases in the temperatures which are measured with the sensor. More expensive thermistors can be preconditioned to provide very stable temperature measurements over years of service.

5.3.3 Thermistors are the most accurate with the least drift over time when used to measure temperatures from 0 °C to 70 °C. If thermistors are used for extended periods of time at temperatures over 100 °C, the electronic thermometer may need to be verified or recalibrated more frequently than required in Specification D3666.

5.3.4 Thermistor response time depends on the test medium. Response times are from 1 to 2 s in liquids and up to 25 s in air.

5.3.5 The sensor needs to be protected by a metal sheath and the wiring needs to be insulated to minimize heat transfer from surrounding environmental conditions and external electrical noise. The overall sheath length shall be least 50 mm greater than the immersion depth (see Section 7).

5.4 *Thermocouples:*

5.4.1 Thermocouples consist of a pair of dissimilar metals, twisted together at one end (that is, junction), which generate a small voltage when the temperature at the twisted end is different than the temperature at the other end (that is, reference temperature).

5.4.1.1 Type T has a lower temperature range from –250 °C to 0 °C and an upper temperature range from 0 °C to 350 °C. The thermocouple sensor accuracy decreases linearly, increasing or decreasing temperatures on either side of 0 °C. Type T thermocouple (ANSI Type T has a blue connector; IEC Type T has a brown connector). The National Institute of Standards (NIST) lists the expanded uncertainty as 0.4 °C for Type T thermocouple wire sensor, and Type T is the most useful type for the majority of ASTM D04 standards.

5.4.1.2 Type K has a lower temperature range from –200 °C to 0 °C and an upper temperature range from 0 °C to 1250 °C. The thermocouple sensor accuracy decreases linearly, with increasing or decreasing temperatures on either side of 0 °C. Type K thermocouple (ANSI Type K has a yellow connector; IEC Type K has a green connector) wire. NIST lists the expanded uncertainty as 1 °C, and Type K is useful for ASTM D04 applications which only require a low level of accuracy for temperature measurements.

5.4.2 Thermocouple wire can be protected by mounting in a metal sheath. The sheath gives the thermocouple wire a similar physical diameter and length to that of conventional mercury