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Standard Guide for Selecting an Appropriate Electronic Thermometer for Replacing Mercury Thermometers in D04 Road and Paving Standards¹

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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 handheld 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, health, and environmental 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.*

¹ This guide is under the jurisdiction of ASTM Committee **D04** on Road and Paving Materials and is the direct responsibility of Subcommittee **D04.99** on Sustainable Asphalt Pavement Materials and Construction.

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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

E230/E230M Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

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

2.2 *IEC Standards*:³

IEC 60584-1 Thermocouples—Part 1: EMF Specifications and Tolerances

IEC 60751 Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors

3. Summary of Guide

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

NOTE 1—Accuracy is expressed as a tolerance range in the tables in this standard because the relevant sensor standards use the term “tolerance” in their tables to specify sensor characteristics.

4. Significance and Use

4.1 General guidance is provided for electronic thermometers for general temperature measurements typically needed

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 International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, <https://www.iec.ch>.

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 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 $\pm$ 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 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 and Technology (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.