Designation: E2847 − 21

Standard Test Method for Calibration and Accuracy Verification of Wideband Infrared Thermometers[1]

This standard is issued under the fixed designation E2847; 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 This test method covers electronic instruments intended for measurement of temperature by detecting the intensity of thermal radiation exchanged between the subject of measurement and the sensor.

1.2 The devices covered by this test method are referred to as infrared thermometers in this document.

1.3 The infrared thermometers covered in this test method are instruments that are intended to measure temperatures below 1000°C, measure thermal radiation over a wide bandwidth in the infrared region, and are direct-reading in temperature.

1.4 This test method covers best practice in calibrating infrared thermometers. It addresses concerns that will help the user perform more accurate calibrations. It also provides a structure for calculation of uncertainties and reporting of calibration results to include uncertainty.

1.5 Details on the design and construction of infrared thermometers are not covered in this test method.

1.6 This test method does not cover infrared thermometry above 1000°C. It does not address the use of narrowband infrared thermometers or infrared thermometers that do not indicate temperature directly.

1.7 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.8 *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.*

1.9 *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]

E344 Terminology Relating to Thermometry and Hydrometry

E1256 Test Methods for Radiation Thermometers (Single Waveband Type)

E2758 Guide for Selection and Use of Wideband, Low Temperature Infrared Thermometers

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *cavity bottom, n*—the portion of the cavity radiation source forming the end of the cavity.

3.1.1.1 *Discussion*—The cavity bottom is the primary area where an infrared thermometer being calibrated measures radiation.

3.1.2 *cavity radiation source, n*—a concave shaped geometry approximating a perfect blackbody of controlled temperature and defined emissivity used for calibration of radiation thermometers.

3.1.2.1 *Discussion*—A cavity radiation source is a subset of thermal radiation sources.

3.1.2.2 *Discussion*—To be a cavity radiation source of practical value for calibration, at least 90 % of the field-of-view of a radiation thermometer is expected to be incident on the cavity bottom. In addition, the ratio of the length of the cavity versus the cavity diameter is expected to be greater than or equal to 5:1.

3.1.3 *cavity walls, n*—the inside surfaces of the concave shape forming a cavity radiation source.

3.1.4 *customer, n*—the individual or institution to whom the calibration or accuracy verification is being provided.

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[1] This test method is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.02 on Radiation Thermometry.

Current edition approved Nov. 1, 2021. Published December 2021. Originally approved in 2011. Last previous edition approved in 2014 as E2847 – 14. DOI: 10.1520/E2847-21.

[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.

3.1.5 *distance-to-size ratio (D:S), n*—see *field-of-view*.

3.1.6 *effective emissivity, n*—the ratio of the amount of energy over a given spectral band exiting a thermal radiation source to that predicted by Planck's Law at a given temperature.

3.1.7 *field-of-view, n*—a usually circular, flat surface of a measured object from which the radiation thermometer receives radiation. (**1**)[3]

3.1.7.1 *Discussion*—Many handheld infrared thermometers manufacturers include distance-to-size ratio (D:S) in their specifications. Distance-to-size ratio relates to the following physical situation: at a given distance (D), the infrared thermometer measures a size (S) or diameter, and a certain percentage of the thermal radiation received by the infrared thermometer is within this size. Field-of-view is a measure of the property described by distance-to-size ratio. (**1**)

3.1.8 *flatplate radiation source, n*—a planar surface of controlled temperature and defined emissivity used for calibrations of radiation thermometers.

3.1.8.1 *Discussion*—A flatplate radiation source is a subset of thermal radiation sources.

3.1.9 *measuring temperature range, n*—temperature range for which the radiation thermometer is designed. (**1**)

3.1.10 *purge, n*—a process that uses a dry gas to remove the possibility of vapor on a measuring surface.

3.1.11 *radiance temperature, n*—temperature of an ideal (or perfect) blackbody radiator having the same radiance over a given spectral band as that of the surface being measured. (**2**)

3.1.12 *thermal radiation source, n*—a geometrically shaped object of controlled temperature and defined emissivity used for calibration of radiation thermometers.

3.1.13 *usage temperature range, n*—temperature range for which a radiation thermometer is designed to be utilized by the end user.

4. Summary of Practice

4.1 The practice consists of comparing the readout temperature of an infrared thermometer to the radiance temperature of a radiation source. The radiance temperature shall correspond to the spectral range of the infrared thermometer under test.

4.2 The radiation source may be of two types. Ideally, the source will be a cavity source having an emissivity close to unity (1.00). However, because the field-of-view of some infrared thermometers is larger than typical blackbody cavity apertures, a large-area flatplate source may be used for these calibrations. In either case, the traceable measurement of the radiance temperature of the source shall be known, along with calculated uncertainties.

4.3 The radiance temperature of the source shall be traceable to a national metrology institute such as the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland or the National Research Council (NRC) in Ottawa, Ontario, Canada.

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.

5. Significance and Use

5.1 This test method provides guidelines and basic test methods for the accuracy verification of infrared thermometers. It includes test set-up and calculation of uncertainties. It is intended to provide the user with a consistent method, while remaining flexible in the choice of calibration equipment. It is understood that the uncertainty obtained depends in large part upon the apparatus and instrumentation used. Therefore, since this guide is not prescriptive in approach, it provides detailed instruction in uncertainty evaluation to accommodate the variety of apparatus and instrumentation that may be employed.

5.2 This test method is intended primarily for calibrating handheld infrared thermometers. However, the techniques described in this guide may also be appropriate for calibrating other classes of radiation thermometers. It may also be of help to those calibrating thermal imagers.

5.3 This test method specifies the necessary elements of the report of calibration for an infrared thermometer. The required elements are intended as a communication tool to help the end user of these instruments make accurate measurements. The elements also provide enough information, so that the results of the calibration can be reproduced in a separate laboratory.

6. Sources of Uncertainty

6.1 Uncertainties are present in all calibrations. Uncertainties are underestimated when their effects are underestimated or omitted. The predominant sources of uncertainty are described in Section 10 and are listed in Table 1 and Table X1.1 of Appendix X1.

6.2 Typically, the most prevalent sources of uncertainties in this method of calibration are: (*1*) emissivity estimation of the calibration source, (*2*) size-of-source of the infrared thermometer, (*3*) temperature gradients on the radiation source, (*4*) improper alignment of the infrared thermometer with respect to the radiation source, (*5*) calibration temperature of the radiation source, (*6*) ambient temperature and (*7*) reflected temperature. The order of prevalence of these uncertainties may vary, depending on use of proper procedure and the type of thermal radiation source used. Depending on the temperature of the radiation source, the calibration method of the radiation source, the optical characteristics of the infrared thermometer and the detector and filter characteristics of the

TABLE 1 Components of Uncertainty

	Uncertainty Component	Discussion	Evaluation Method
Source Uncertainties			
U_1	Calibration Temperature	10.4	10.4.1
U_2	Source Emissivity	10.5	10.2.3, X2.4 (example)
U_3	Reflected Ambient Radiation	10.6	10.2.2, X2.5 (example)
U_4	Source Heat Exchange	10.7	10.7.1
U_5	Ambient Conditions	10.8	10.8.1
U_6	Source Uniformity	10.9	10.9.1
Infrared Thermometer Uncertainties			
U_7	Size-of-Source Effect	10.11	Test Methods E1256
U_8	Ambient Temperature	10.12	Appendix X3
U_9	Atmospheric Absorption	10.13	X2.3
U_{10}	Noise	10.14	10.14.1
U_{11}	Display Resolution	10.15	10.15.2

infrared thermometer, the contribution of these uncertainties may change significantly in the overall uncertainty budget.

7. Apparatus

7.1 *Thermal Radiation Source:*

7.1.1 There are two different classes of thermal radiation sources which can be used for infrared thermometer calibrations: a cavity source and a flatplate source. Some sources may be considered a hybrid of both categories. Each of these sources has advantages and disadvantages. The cavity source provides a source of radiation that has a more predictable emissivity. However, the flatplate source can usually be made less expensively, and can be made with a diameter large enough to calibrate infrared thermometers with low distance to size ratios (D:S).

7.1.2 Ideally, the size of the thermal radiation source should be specified by the infrared thermometer manufacturer. In many cases, this information may not be available. In these cases a field-of-view test should be completed as discussed in E1256. The portion of signal incident on the infrared thermometer that does not come from the source should be accounted for in the uncertainty budget.

7.1.3 *Cavity Source:*

7.1.3.1 A cavity source can be constructed in several shapes as shown in Fig. 1. In general, a high length-to-diameter ratio (L:D) or radius-to-diameter ratio (R:D) in the spherical case will result in a smaller uncertainty. A smaller conical angle Φ will also result in a smaller uncertainty.

7.1.3.2 The location of a reference or a control probe, or both, and the thermal conductivity of the cavity walls are important considerations in cavity source construction. In general, a reference or control probe should be as close as practical to the center of the area where the infrared thermometer will typically measure, typically the cavity bottom. If there is a separation between the location of the reference probe and the cavity surface, cavity walls with a higher thermal conductivity will result in a smaller uncertainty due to temperature gradients in this region.

7.1.3.3 The walls of the cavity source can be treated in several different ways. A painted or ceramic surface will generally result in higher emissivity than an oxidized metal surface. By the same measure an oxidized metal surface will generally result in higher emissivity than a non-oxidized metal surface. In some cases, it may be impossible to paint the cavity source surface. This is especially true at high temperatures.

7.1.3.4 The effective emissivity of the cavity source shall be calculated to determine the radiance temperature of the cavity. Calculation of effective emissivity is beyond the scope of this standard. Determination of effective emissivity can be mathematically calculated or modeled.

7.1.4 *Flatplate Source:*

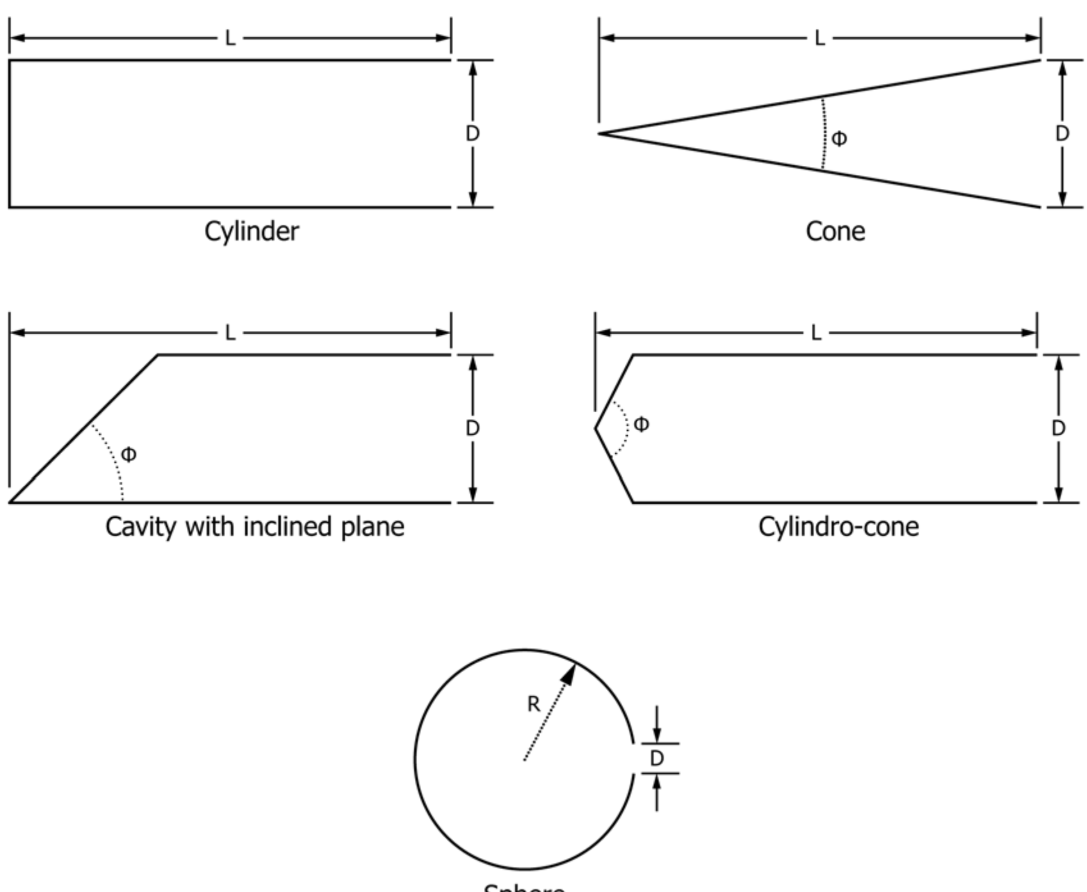

FIG. 1 Cavity Shapes