Designation: ~~E2847 – 14~~ 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 ~~guide~~ 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 ~~*The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.*~~*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.*

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[1] This ~~practice~~ 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.

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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.

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**)

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

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.

5. Significance and Use

5.1 This ~~guide~~ 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 ~~guide~~ 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 ~~guide~~ 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

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

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 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)

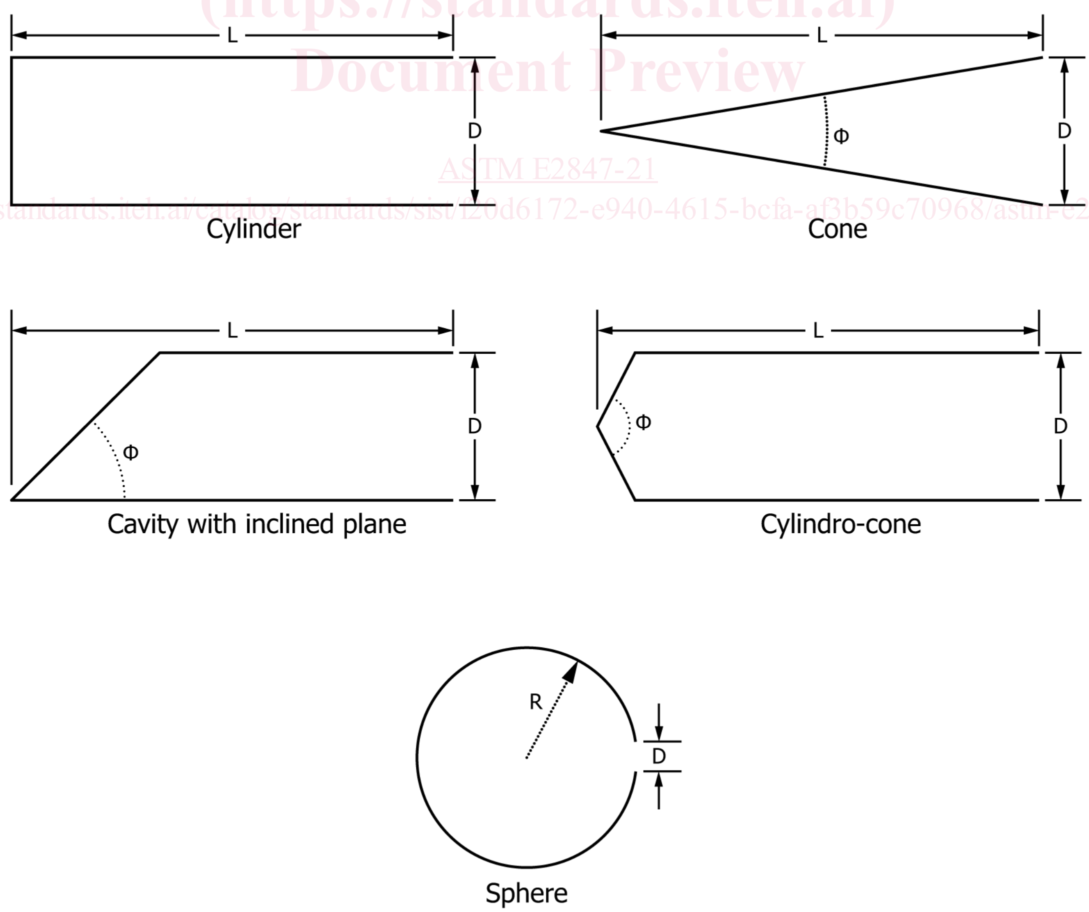

FIG. 1 Cavity Shapes

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:*

7.1.4.1 A flatplate source is a device that consists of a painted circular or rectangular plate. The emissivity is likely to be less well defined than with a cavity source. This can be partially overcome by performing a radiometric transfer (see Scheme II in 7.3.7) to the flatplate source. However, the radiometric transfer should be carried out with an instrument operating over a similar spectral band as the infrared thermometer under test.

7.1.4.2 A cavity source is the preferred radiometric source for infrared thermometer calibrations. The cavity source has two main advantages over a flatplate source. First, the cavity source has better defined emissivity and an emissivity much closer to unity due to its geometric shape. Second, along with the emissvity being closer to unity, the effects of reflected temperature are lessened. Temperature uniformity on the flatplate source may be more of a concern as well. However, a flatplate source has a main advantage over a cavity source. The temperature controlled flatplate surface can be much larger than a typical cavity source opening, allowing for much smaller D:S ratios (greater field-of-view).

7.2 *Aperture:*

7.2.1 An additional aperture may not be needed for all calibrations. An aperture is typically used to control scatter. If used, the aperture should be temperature-controlled or reflective. An aperture should be used if recommended by the infrared thermometer manufacturer. If an aperture is used for calibration, this information should be stated in the report of calibration. The information that shall be included is the aperture distance, the aperture size, and the measuring distance. A possible configuration for aperture use is shown in Fig. 2.

7.2.2 In Fig. 2, d_{apr} is the aperture distance. The measuring distance is shown by d_{meas}.

7.3 *Transfer Standard:*

7.3.1 The thermal radiation source shall be calibrated with a transfer standard traceable to a national metrological institute such as the National Institute of Standards and Technology (NIST) or National Research Council (NRC). If a reference thermometer (radiometric or contact) is used during the calibration of the unit-under-test, this serves as the calibration of the radiation source. In this case, the reference thermometer shall have a calibration traceable to a national metrological institute.

7.3.2 This calibration of the thermal radiation source may take place in the calibration laboratory, or it may be done by a third party calibration laboratory. The interval of these checks is determined by the calibration laboratory. The drift related to the calibration interval is part of the calibration uncertainties for the infrared thermometer calibration.

7.3.3 Regardless of whether a cavity source or a flatplate source is used, there are two approaches to calibrating the source: contact calibration (Fig. 3, Scheme I) and radiometric calibration (Fig. 3, Scheme II). **(3)**

7.3.4 In Fig. 3 the arrows show the path of traceability to the International System of Units (SI) through a national metrological institute (NMI). The reference radiation source is the cavity source or blackbody source used to calibrate the infrared thermometer.

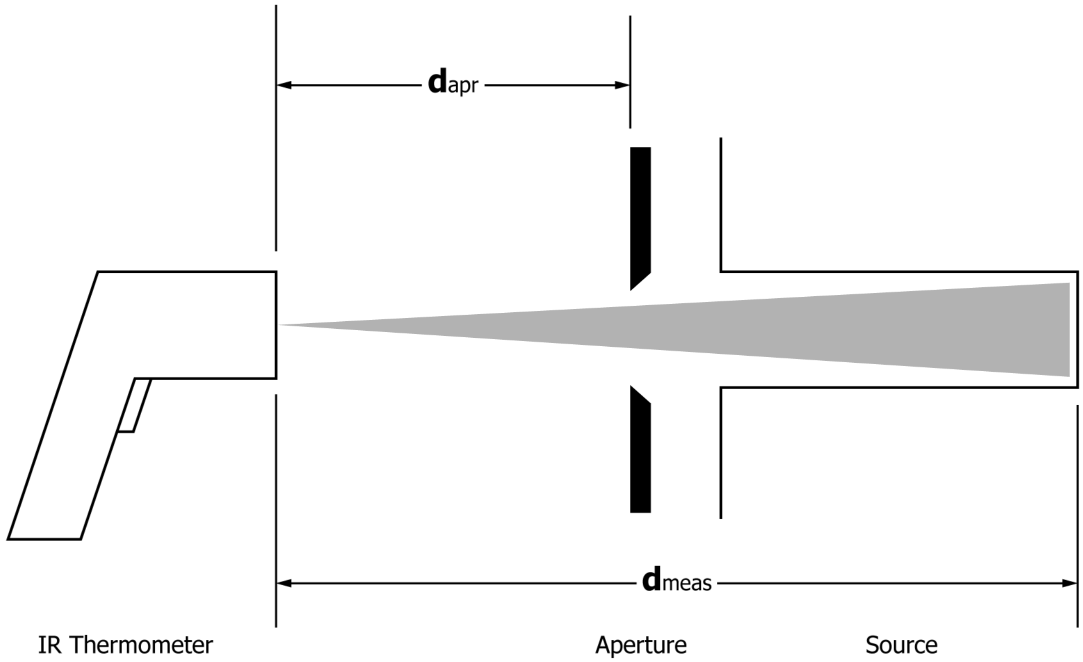

FIG. 2 Use of an Aperture for a Calibration

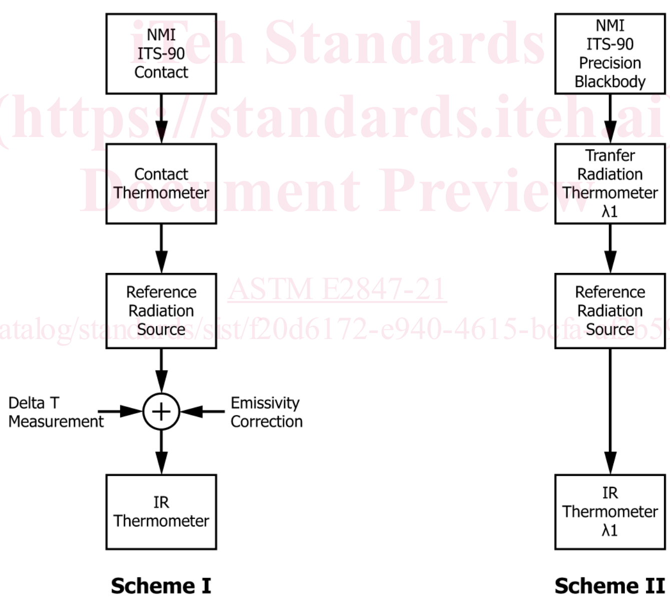

FIG. 3 Calibration Schemes I and II

In Scheme I, it is shown that the ΔT measurement and the emissivity correction shall be added into the temperature calculation. The ΔT measurement is based on the difference in temperature between the reference thermometer and the cavity walls. The emissivity correction is based on the radiation source not having the same emissivity as the infrared thermometer's emissivity setting. The symbol λ1 refers to the wavelength and bandwidth of the transfer radiation thermometer and the infrared thermometer.

7.3.5 In either scheme, the transfer standard shall be traceable to a national metrological institute.

7.3.6 In Scheme I, a contact thermometer is used as the transfer standard. The emissivity uncertainties become of greater concern. This is especially the case when using a flatplate source.

7.3.7 In Scheme II, a radiation thermometer is used as the transfer standard. In this scheme, the emissivity and heat exchange uncertainties are greatly reduced. This is especially significant in the case of using a flatplate source. the radiation thermometer should operate over a similar spectral range as the infrared thermometer to be calibrated. Any differences in spectral range will result in additional uncertaintes. For instance, if the radiation source is calibrated with an 8 to 14 µm radiation thermometer, and an infrared thermometer with a 7 to 14 µm spectral response is being calibrated, even this difference in bandwidth shall be accounted for in the uncertainty budget, since the radiance temperature (due mostly to the effective emissivity) will be different.

7.4 *Ambient Temperature Thermometer:*

7.4.1 The ambient temperature should be monitored during the calibration to ensure that it is within the laboratory's limits. This should be done using a calibrated thermometer. At a minimum, the laboratory's ambient temperature limits should be recorded on the report of calibration.

7.5 *Mounting Device:*

7.5.1 The infrared thermometer may be mounted on a tripod or similar mounting fixture. Mounting may not be required in the case of a manually held calibration. In this case the hand is the mounting device.

7.6 *Distance Measuring Device:*

7.6.1 The distance between the radiation source and the infrared thermometer is a critical factor in calibration. This distance should be either measured during the infrared thermometer calibration or set by fixturing. This measuring distance along with the target size shall be recorded on the report of calibration.

7.7 *Calibrations Below the Dew-Point or Frost-Point:*

7.7.1 For calibrations where the set-point of the radiation source is below the dew or frost point, it may be necessary to purge the area around the source with a dry gas such as dried nitrogen or dried air to prevent ice buildup. It may be desirable to use a vacuum for this purpose. It is beyond the scope of this standard to recommend a specific design or method for such a purge.

8. Preparation of Apparatus

8.1 *Infrared Thermometer:*

8.1.1 The infrared thermometer should be allowed to reach ambient temperature before any measurements are made. The amount of time may be specified by the manufacturer. If this is not the case, experimentation may need to be done to determine the proper time for the device to thermally stabilize. This uncertainty should be accounted for in the ambient temperature section of the uncertainty budget.

8.1.2 If a lens cleaning is required, it shall be performed following the manufacturer's guidelines.

8.2 *Radiation Source:*

8.2.1 The radiation source should be set to the desired calibration temperature and allowed to stabilize at the set calibration temperature. Any effects due to settling time should be accounted for in the uncertainty budget.

8.2.2 If a purge device is used with the radiation source for the calibration, it should be in place before the radiation source is stabilized.

9. Procedure

9.1 *Calibration Points:*

9.1.1 The number of calibration points used during a calibration should be determined by the customer. If the customer does not know what points to use for a calibration, a recommendation may be made. For an infrared thermometer used over a narrow range of temperature, one point may be enough. For an infrared thermometer used over a wide range of temperature, a minimum of three calibration points should be chosen. These points should represent at least the minimum, maximum and midpoint temperature of the infrared thermometer usage temperature range. The usage range may not be the same as the measuring temperature range of the infrared thermometer.

9.1.2 The order of calibration points may be arbitrary. However, it is important to note that heating of the infrared thermometer by the calibration source may cause a condition similar to thermal shock. This is especially true when going from a calibration source at a higher temperature to a calibration source at a lower temperature. Thus, it is best practice to calibrate at lower temperature points before higher temperature points.

9.2 Steps 9.3 to 9.6 should be repeated for each calibration point.

9.3 *Reflected Temperature:*

9.3.1 If required, set the infrared thermometer's reflected temperature setting to the radiation source's reflected temperature. This setting should represent the temperature of the ambient surroundings facing the thermal radiation source. The reflected temperature setting may be called background temperature or ambient temperature on some devices. Many infrared thermometers do not have a manual reflected temperature setting. On these devices, reflected temperature is compensated for internally.

9.4 *Emissivity Setting:*

9.4.1 The emissivity setting of the infrared thermometer should match the emissivity or emissivity setting of the radiation source.

9.4.2 Some infrared thermometers have a fixed emissivity setting and some radiation sources have a fixed emissivity. In a case where both settings are fixed and are not equal, a mathematical adjustment shall be made. An example of such an adjustment can be found in X2.3.

9.4.3 The preferred method is to adjust the infrared thermometer emissivity setting to the radiation source's emissivity. If the radiation source receives a contact calibration (Fig. 3, Scheme I), this emissivity would be the emissivity of the surface. If the radiation source receives a radiometric calibration (Fig. 3, Scheme II), the emissivity would be the emissivity setting of the transfer standard. If the emissivity setting of the infrared thermometer cannot be set exactly to the effective emissivity of the thermal radiation source, then a correction may be made as is shown in X2.3.

9.5 *Alignment:*

9.5.1 *Preparation:*

9.5.1.1 If an additional aperture is used for the calibration, ensure that the aperture is properly emplaced at the specified distance as shown in Fig. 2. If the aperture is temperature-controlled, ensure that the aperture is within its specified temperature limits.

9.5.1.2 In Fig. 4, the measuring distance is designated by 'd'. The 'X' axis refers to the horizontal direction; the 'Y' axis refers to the vertical direction; and the 'Z' axis refers to the direction coming out of the cavity or flat plate. In the case of the flatplate, the 'Z' axis is always normal to the flatplate surface.

9.5.1.3 If a fixture is being used to hold the infrared thermometer for calibration, mount the infrared thermometer.

9.5.1.4 If the infrared thermometer calibration mounting is manual, hold the infrared thermometer in front of the radiation source at the specified distance.

9.5.1.5 Ensure that the infrared thermometer is roughly level and normal to the target surface. Ideally, the angle between the normal to a flatplate source and the line of sight of the infrared thermometer should be less than 5°. When using a cavity source, the angle of incidence should be small enough to allow for the infrared thermometer's field-of-view to see the uniform part of the cavity bottom.

9.5.1.6 If the infrared thermometer is equipped with a lens cap, remove the lens cap before measuring.

9.5.2 *'Z'-Axis Alignment:*

9.5.2.1 Set the distance from the source using the measuring device. The distance may be measured from the aperture, from the cavity source opening, or from the radiation source surface.

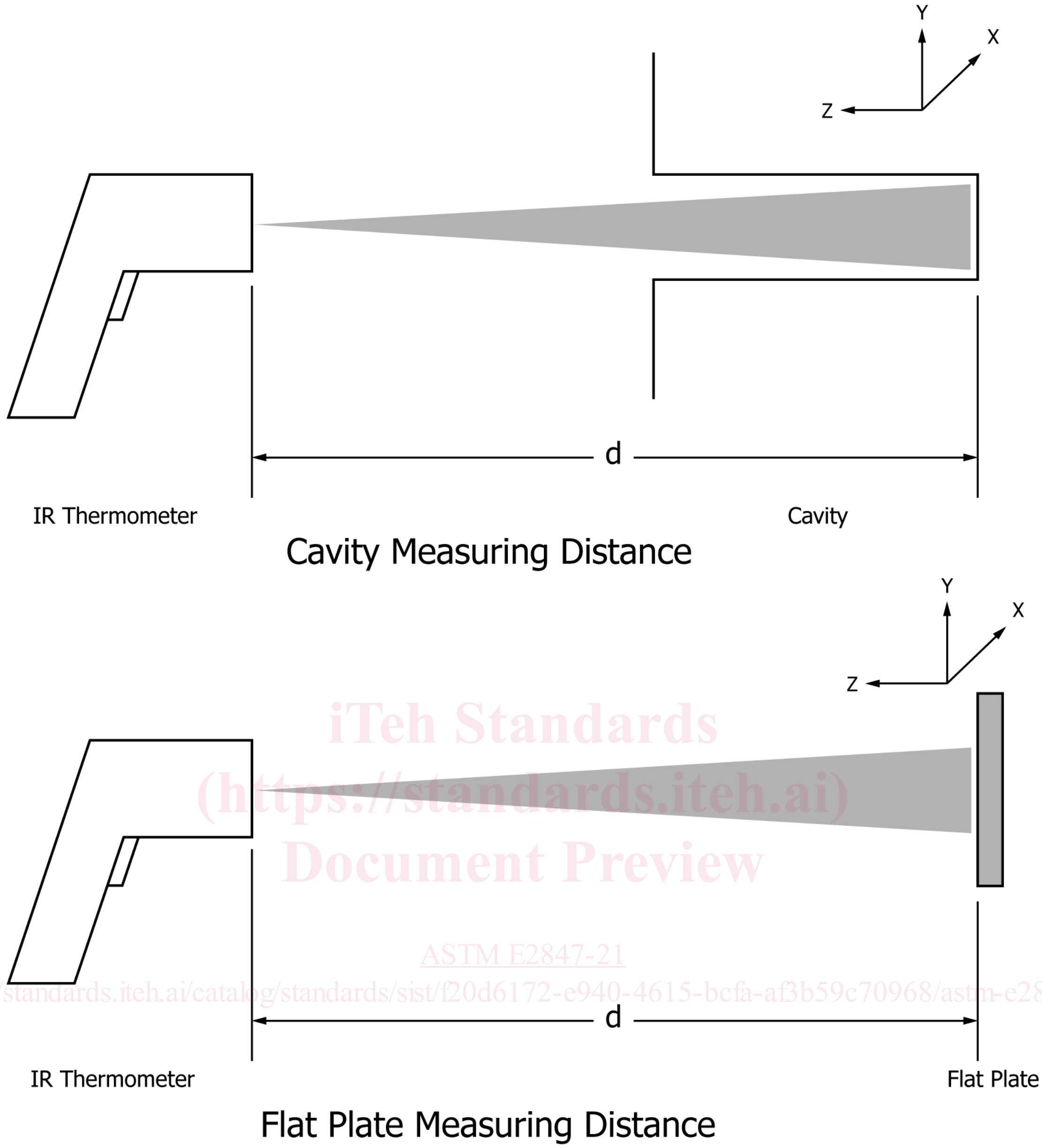

FIG. 4 Calibration Setup Showing Measuring Devices

NOTE 1—In most cases, it may not be good practice to touch the radiation source surface. In such cases, an alternate point of known distance from the surface may be used for the distance measurement.

9.5.3 *'X'- and 'Y'-Axes Alignment:*

9.5.3.1 Alignment in the 'X' and 'Y' directions may be done using lasers provided with the infrared thermometer or it may be done by maximizing the signal. Use of laser pointers is a quicker method, but the laser pointer may not represent the optical center of the infrared thermometer. A given infrared thermometer may have some other optical alignment device such as light-emitting diodes that may be used as well. Maximizing the signal is the preferred method.

9.5.3.2 If using laser alignment, center the laser on the center of the radiation source.

9.5.3.3 If maximizing the signal, for calibration points above ambient, the position of the infrared thermometer shall be adjusted vertically and horizontally to produce maximum temperature while also maintaining the line of sight perpendicular to the source. This is illustrated in Fig. 5. In the example in Fig. 5, the maximum temperature observed on the infrared thermometer's readout is 300.3°C. For calibration points below ambient, the temperature shall be minimized.

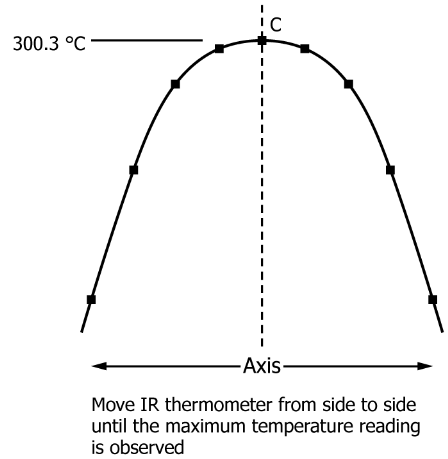

FIG. 5 X-Y Alignment in the Maximizing Case

9.5.3.4 In cases where the size of the radiation source is much larger than the field-of-view of the radiation thermometer, the temperature may plateau instead of reaching a simple maximum or minimum. In such cases, a defined change in temperature should be observed while moving the infrared thermometer along an axis. Then the infrared thermometer should be centered midway between these two points. This shall be done for both axes. This is illustrated in Fig. 6. In this case, the infrared thermometer is moved from side to side. A plateau in the temperature readout of 300.3°C is observed. In this case the user shall observe a drop-off in the temperature readout of 3.0°C. This means the user should be looking for a reading of 297.3°C. Points ‘A’ and ‘B’ indicate where this drop-off occurs. Point ‘C’ represents the mid-point of ‘A’ and ‘B’.

9.5.3.5 The defined change should be at least 1 % of the infrared thermometer plateau reading in °C or 1°C, whichever is greater. For example, if the infrared thermometer readout is 120.0°C, the defined change should be at least 1.2°C. If the infrared thermometer readout is 50.0°C, the defined change should be at least 1.0°C.

9.6 *Measurement:*

9.6.1 Perform measurements according to the manufacturer’s procedures. The measurement time should be a period significantly longer than the infrared thermometer’s response time. It may be necessary to take more than one measurement to determine repeatability and reduce uncertainty due to noise. Record the measured temperature.

9.7 *Adjustment:*

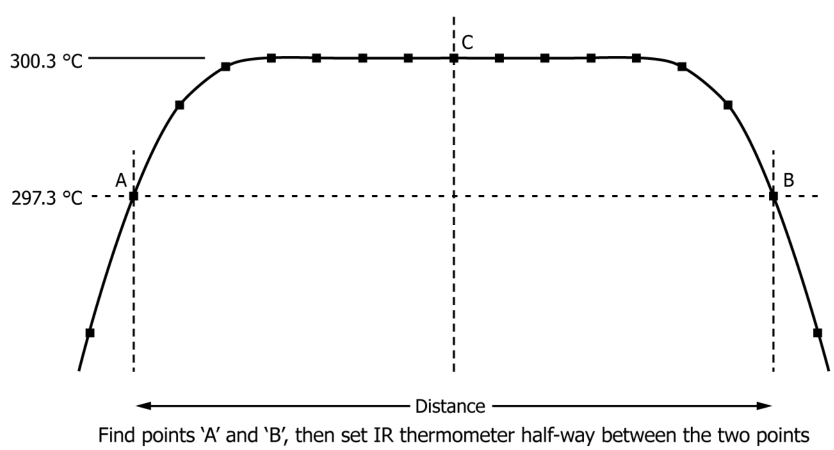

FIG. 6 X-Y Alignment in the Plateau Case

9.7.1 In some cases the adjustment may be done by laboratory personnel. This shall only be done with the permission of the customer. Any measurement before the calibration should be included in the report of calibration. Consult the infrared thermometer manufacturer for the adjustment procedure.

9.7.2 After any adjustment, the infrared thermometer adjustment should be verified at all calibration points.

9.7.3 In cases where an adjustment cannot be done, a table of corrections at each calibration point should be provided to the customer.

10. Measurement Uncertainty

10.1 *Overview:*

10.1.1 While it is beyond the scope of this document to provide tests and methods to determine each element of the uncertainty budget, the format shown here should provide a basic framework for uncertainty budget calculations. Any calculations of measurement uncertainty should follow local uncertainty budget calculation guidelines such as the "U.S. Guide to the Expression of Uncertainty in Measurement" or the "Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement."

10.1.2 The uncertainties as presented in this guide are listed in Table 1.

10.2 *Measurement Equation:*

10.2.1 The measurement equation is shown in Eq 1. Uncertainty in the calibration temperature is accounted for by evaluating T_S. The uncertainty in reflected ambient radiation is accounted for by evaluating by $S(T_W)$. The effects of uncertainty in source emissivity are accounted for by evaluating ε_S.

$$S(T_{meas}) = S(T_S) + \frac{(1-\epsilon_{instr})}{\epsilon_{instr}}[S(T_W) - S(T_d)] + \frac{(\epsilon_S - \epsilon_{instr})}{\epsilon_{instr}}[S(T_S) - S(T_W)] \quad (1)$$

where:

$S(T)$ = implementation of the Sakuma-Hattori Equation
ε_S = emissivity of the measured surface
ε_{INST} = instrument emissivity setting
T_{MEAS} = infrared thermometer readout temperature
T_S = expected radiation temperature of the thermal radiation source
T_W = reflected radiation temperature (walls)
T_d = detector temperature

10.2.2 Uncertainty due to Reflected Temperature.

10.2.2.1 To evaluate for reflected temperature uncertainty, Eq 1 is differentiated to get Eq 2. This number is then used in Eq 3 to get the temperature measurement uncertainty due to reflected temperature. An example of this calculation is shown in X2.5.

$$\frac{\partial S(T_{meas})}{\partial S(T_W)} = \frac{1-\epsilon_S}{\epsilon_{instr}} \quad (2)$$

$$U_{REFL}(T_{meas}) = \frac{\partial T_{meas}}{\partial T}(T_W) = \frac{\partial S(T_{meas})}{\partial S(T_W)} \frac{\frac{\partial S(T_W)}{\partial T}}{\frac{\partial S(T_{meas})}{\partial T}} U(T_W) \quad (3)$$

10.2.3 Uncertainty due to Emissivity.

10.2.3.1 To evaluate for source emissivity uncertainty, Eq 1 is differentiated to get Eq 4. This number is then used in Eq 5 to get the uncertainty due to reflected temperature. An example of this calculation is shown in X2.4.

$$\frac{\partial S(T_{meas})}{\partial \epsilon_S} = \frac{1}{\epsilon_{instr}}[S(T_S) - S(T_W)] \quad (4)$$