Designation: E2847 – 14

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 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.*

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*.

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[1] This practice 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] 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.

3.1.6 *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.

5. Significance and Use

5.1 This guide 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 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 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

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

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:*

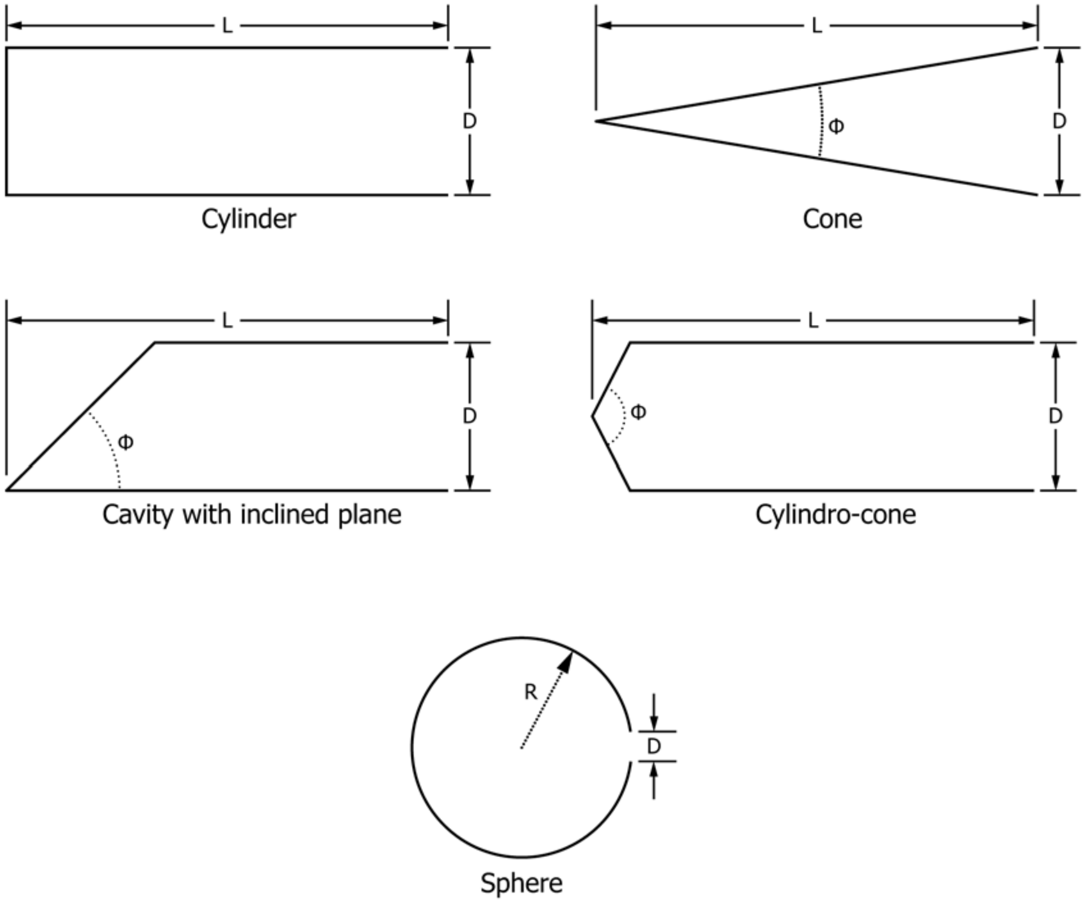


FIG. 1 Cavity Shapes

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. 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.

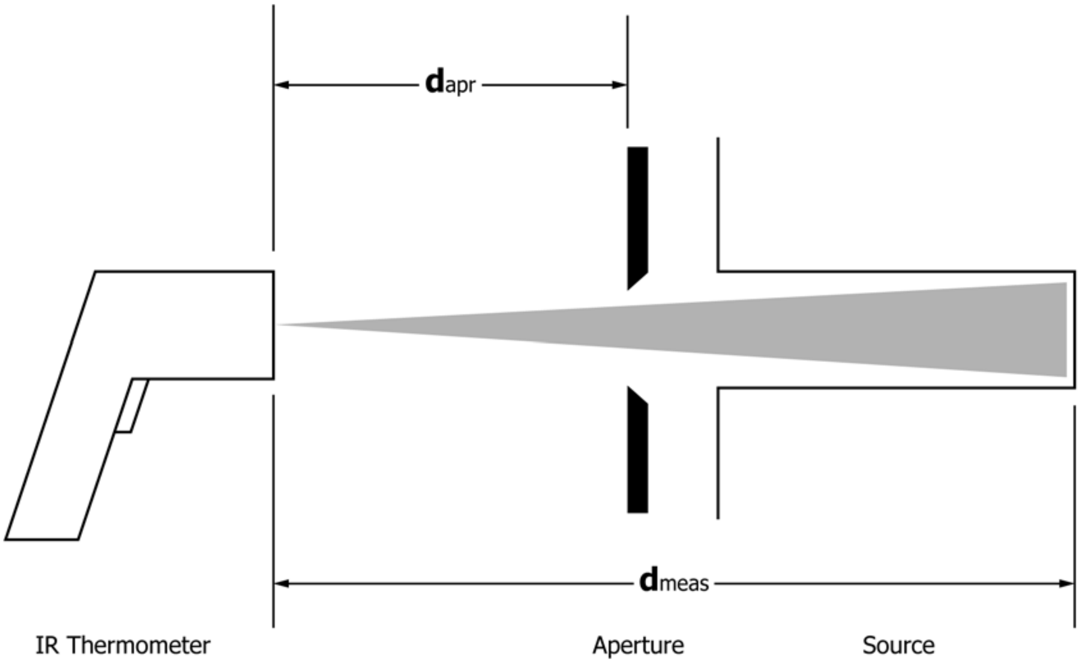


FIG. 2 Use of an Aperture for a Calibration

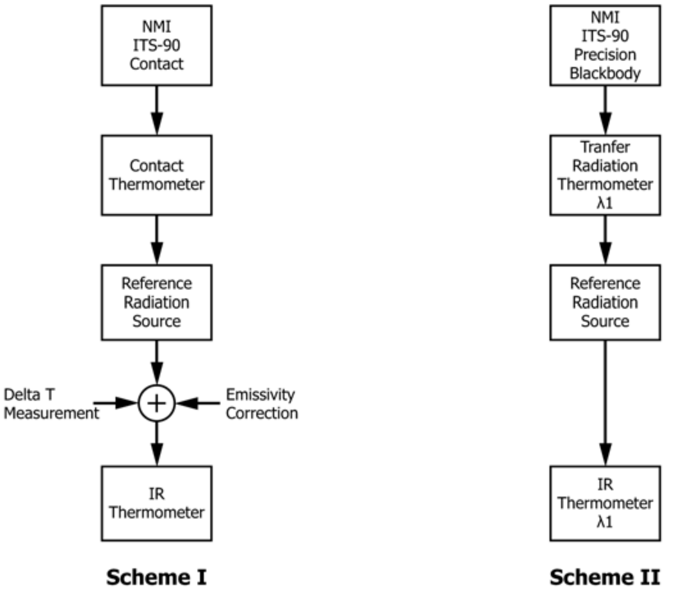


FIG. 3 Calibration Schemes I and II

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.

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.

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:*

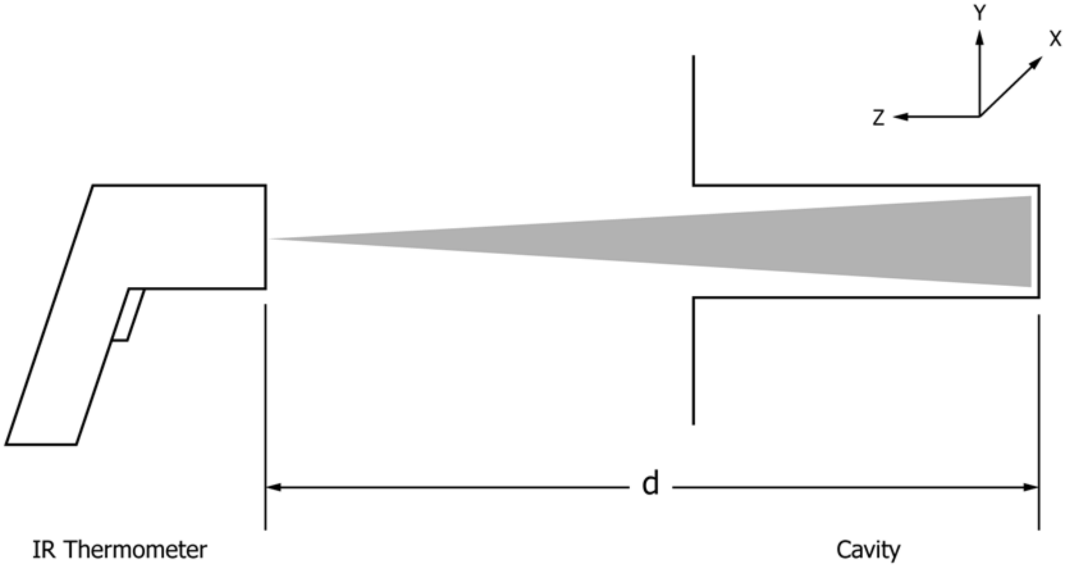
9.6.1 Perform measurements according to the manufacturer's procedures. The measurement time should be a period significantly longer than the infrared thermometer's response time. It may be necessary to take more than one measurement to determine repeatability and reduce uncertainty due to noise. Record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

9.7 *Adjustment:*

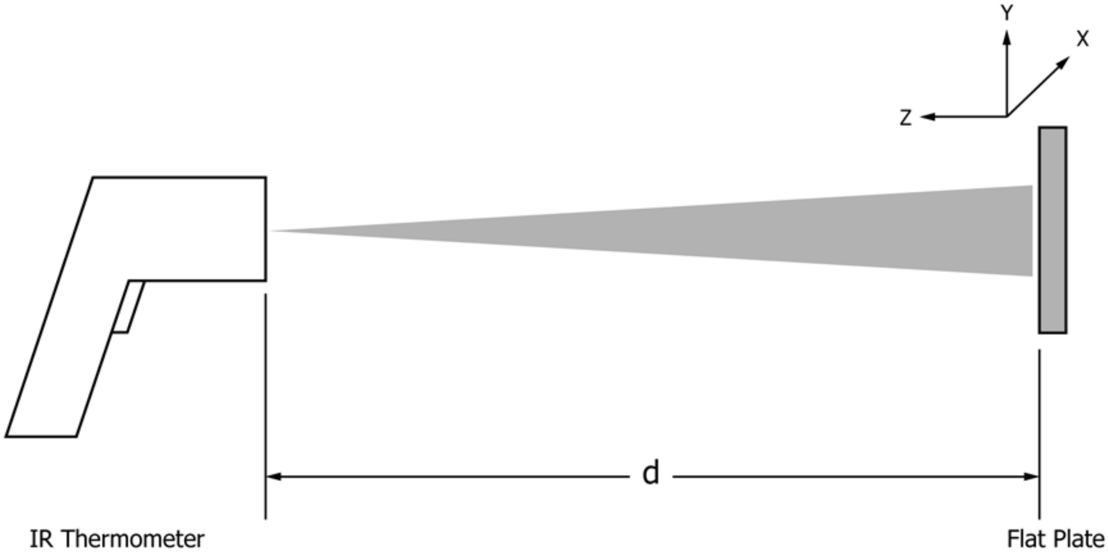
9.7.1 In some cases the adjustment may be done by laboratory personnel. This shall only be done with the permission of the customer. Any measurement before the calibration should be included in the report of calibration. Consult the infrared thermometer manufacturer for the adjustment procedure.

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.

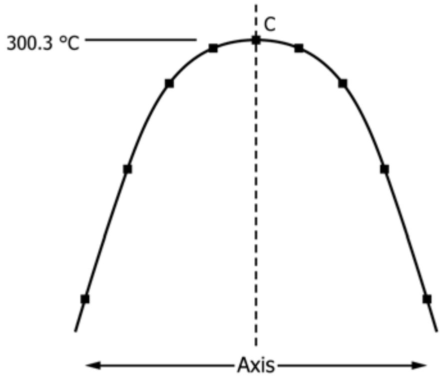


Cavity Measuring Distance



Flat Plate Measuring Distance

FIG. 4 Calibration Setup Showing Measuring Devices



Move IR thermometer from side to side until the maximum temperature reading is observed

FIG. 5 X-Y Alignment in the Maximizing Case

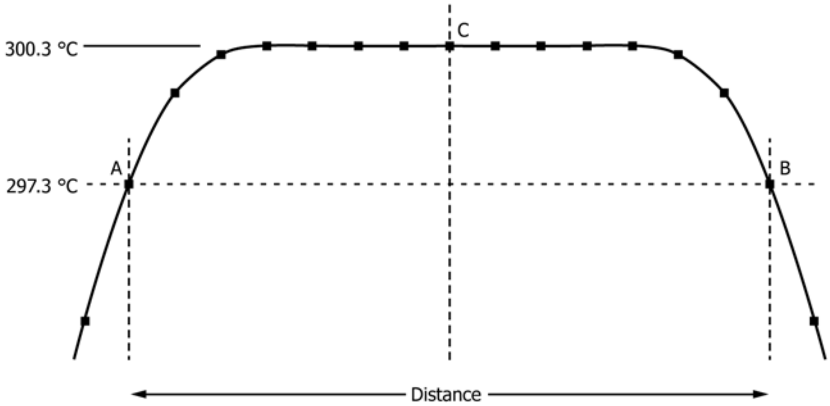
10. Measurement Uncertainty

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:*



Find points 'A' and 'B', then set IR thermometer half-way between the two points

FIG. 6 X-Y Alignment in the Plateau Case

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.

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

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.

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

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

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.

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

$$U_{\epsilon}(T_{meas}) = \frac{\partial T_{meas}}{\partial \epsilon_S}U(\epsilon_S) = \frac{\frac{\partial S(T_{meas})}{\partial \epsilon_S}}{\frac{\partial S(T_{meas})}{\partial T}}U(\epsilon_S) \tag{5}$$

10.3 *Source Related Uncertainties:*

10.3.1 The uncertainties listed in 10.4 – 10.9 relate to the thermal radiation source.

10.4 *Calibration Temperature:*

10.4.1 The calibration temperature of the source is the temperature of the source as indicated by the source's readout. In Scheme I, this is the uncertainty of the temperature readout as determined by contact traceability. In Scheme II, this is the uncertainty of the radiance temperature readout as determined by radiometric traceability.

10.5 *Source Emissivity:*

10.5.1 *Calibration Scheme I – Flatplate Source*—In this case, the emissivity of the surface is determined by some other method such as Fourier-transform infrared or radiometric comparison. Test methods to determine emissivity are outlined in Guide E2758. Since the emissivity for a specific surface coating may vary widely, this can cause a large amount of variance in the emissivity value and the resulting uncertainty.

10.5.2 *Calibration Scheme I – Cavity Source*—In a Calibration Scheme I with a cavity source, the emissivity should be determined by either modeling, or by the emissivity uncertainty provided by the source's manufacturer.

10.5.3 *Calibration Scheme II*—For Calibration Scheme II, the emissivity may still vary over time or be dependent on spectral bandwidth. However, these uncertainties are reduced significantly compared to those in Scheme I.

10.6 *Reflected Ambient Radiation:*

10.6.1 Reflected radiation is sometimes referred to as background radiation. The cause of its effect is sometimes referred to as background temperature. This uncertainty is much more of a concern when calibrating instruments with a flatplate source than it is with a cavity source. It is especially a concern when measuring objects at temperatures below ambient. To calculate this uncertainty, utilize Eq 2 and 3.

10.7 *Source Heat Exchange:*

10.7.1 Source heat exchange is the uncertainty of the difference between the source's control sensor or readout temperature and the source's actual surface temperature. This uncertainty is due to heat flow between the sensor location and the source's surface. If the flatplate source is calibrated with a radiometrically, this uncertainty is minimized. However, there still is some uncertainty since the heat flow may be different from time to time.

10.8 *Ambient Conditions:*

10.8.1 This uncertainty largely accounts for variances due to convection, although other factors may play a role. For a flatplate source, the effects of convection are minimal. For a cavity source, the effects of convection should be even less. However, if a source of forced air is close to the source, this uncertainty may be more of an issue. Essentially, when a forced air source is placed close to the surface, the uniformity pattern of the surface may be changed. This may be a very difficult uncertainty to determine. The conditions of air flow may have to be exaggerated to get a true idea of this effect.

10.9 *Source Uniformity:*

10.9.1 Source uniformity is uncertainty due to temperature non-homogeneity on the calibrator surface. Since an infrared thermometer averages the temperatures within its field-of-view, this uncertainty is calculated by considering how much the uniformity will cause a difference in measurement between a measurement of a small spot at the center of the source and a larger spot corresponding to the infrared thermometer under test.

10.10 *Infrared Thermometer Related Uncertainties:*

10.10.1 The uncertainties listed in 10.11 – 10.15 relate to the infrared thermometer under test.

10.11 *Size-of-Source Effect:*

10.11.1 Size-of-source effect uncertainty is caused by any radiation measured from the source or its surroundings not accounted for by the source uniformity uncertainty in 10.9. Most of the effects of the size-of-source effect uncertainty are caused by optical scatter. This uncertainty will be large if the source diameter is smaller than the field-of-view of the infrared thermometer.

10.12 *Ambient Temperature:*

10.12.1 Ambient temperature is an uncertainty related to how well the detector temperature accounts for changes in reflected ambient temperature. Detector temperature can be calculated by a method shown in Appendix X3. The infrared thermometer under test should be allowed enough time to reach a steady-state housing temperature. This is especially critical after the infrared thermometer is introduced into a new environment. The effects of ambient temperature and changes in detector temperature on radiometric measurements should be determined for each specific model of infrared thermometer under test.

10.13 *Atmospheric Absorption:*

10.13.1 The uncertainties related to atmospheric absorption are typically very low. Nevertheless, they should be accounted for. The calculations outlined in this standard are based on a *Bureau international des poids et mesures* (BIPM) document. **(4)**

10.13.2 For measuring distances greater than 1 m, a model of standard atmosphere shall be consulted. For measuring distances of 1 m or less, the expanded uncertainty (k = 2) is normally 0.0006.

10.13.3 Table X2.1 in X2.6 gives calculated values for the atmospheric absorption uncertainties at various temperatures. This table is specific to the 8 to 14 µm spectral band. For calculations for other spectral bands, consult X2.6.

10.14 *Noise:*

10.14.1 Noise is unwanted signal experienced by the infrared thermometer's measurement system. The origin of the noise can be from both electrical and physical sources. This uncertainty can be taken from the infrared thermometer's specifications or determined by experimentation.

10.15 *Display Resolution:*

10.15.1 This is the contribution due to quantization error of the infrared thermometer readout.

10.15.2 To calculate display resolution uncertainty, take the display resolution and divide by two. This result has a rectangular distribution. Use standard practice to determine the expanded uncertainty of a rectangular distribution. For example, if an infrared thermometer has a display resolution of 0.1°C, then the rectangular distribution is ±0.05°C and the expanded uncertainty is 0.058°C.

10.16 *Sample Uncertainty Budget:*

10.16.1 A sample uncertainty budget for an infrared thermometer calibration is shown in Table X1.1. This structure in no manner represents an uncertainty budget for a specific model of infrared thermometer or a specific calibration source. Note that all uncertainties listed in this table are expanded uncertainties (k = 2).

11. Report

11.1 Report the calibration results in any convenient form. This may be a table of values of nominal temperature with the temperature readout of the infrared thermometer at each of the calibration points.

11.2 The report should include at a minimum a title, a unique identification of the item calibrated, a record of the person who performed the calibration, the date of calibration, the source temperature (or the corrected source temperature) versus infrared thermometer readout temperature, the measuring distance, the emissivity setting of the infrared thermometer, the diameter of the source, the ambient temperature, a description of the aperture including aperture distance (if used), and the measurement uncertainties. The infrared thermometer reading versus corrected source temperature is best represented in a table. Supplementary information, including a concise description of the calibration method, a list of the reference instruments used, a statement regarding the traceability of the calibration, a reference to or a description of the uncertainty budget, and a citation of this guide, may be requested by customers.

11.3 A sample report is included in Appendix X4.

12. Recordkeeping Requirements

12.1 A record system of all calibrations shall be kept. This system shall contain sufficient information to permit regeneration of the certificate, however named, and shall include the identity of personnel involved in preparation and calibration.

12.2 Calibration records shall be retained for the period of time defined by the laboratory's quality system.

13. Precision and Bias

13.1 Due to the varying nature of the equipment used in this test method, no statement can be made about the precision and bias of this test method. Instead, an estimate of uncertainty, otherwise known as an uncertainty budget, is used. This uncertainty evaluation shall follow the method shown in the Measurement Uncertainty section.

14. Keywords

14.1 accuracy verifications; background radiations; blackbodies; calibrations; cavity radiation sources; distance to size ratios; emissivities; fields-of-view; flatplate radiation sources; handheld thermometers; infrared; infrared thermometers; radiation thermometers; reflected radiations; size-of-source effects; spot sizes; temperature measurements; thermal imagers; thermal radiation sources; thermometries; transfer standards; uncertainties

APPENDIXES

(Nonmandatory Information)

X1. SAMPLE UNCERTAINTY BUDGET

X1.1

TABLE X1.1 Sample Uncertainty Budget

Uncertainty	Desig.	Type	U(0°C) (°C)	U(100°C) (°C)	U(420°C) (°C)	U(800°C) (°C)
Source						
Calibration Temperature	U_1	B	0.300	0.380	1.050	1.940
Source Emissivity	U_2	B	0.090	0.198	0.918	0.587
Reflected Ambient Radiation	U_3	A	0.186	0.090	0.048	0.005
Source Heat Exchange	U_4	B	0.016	0.049	0.223	0.325
Ambient Conditions	U_5	B	0.019	0.054	0.245	0.125
Source Uniformity	U_6	A	0.100	0.180	0.380	0.750
Infrared Thermometer						
Size-of-Source Effect	U_7	B	0.002	0.006	0.027	0.520
Ambient Temperature	U_8	A	0.100	0.100	0.400	0.800
Atmospheric Absorption	U_9	B	0.033	0.059	0.177	0.356
Noise	U_{10}	A	0.125	0.125	0.520	1.000
Display Resolution	U_{11}	A	0.058	0.058	0.058	0.058
Combined Expanded Uncertainty (k=2)			0.416	0.512	1.633	2.614

X2. UNCERTAINTY CALCULATION

X2.1 General

X2.1.1 Wideband infrared thermometers measure radiation in a specific electromagnetic spectral band. Using Planck's Law to model the effects of wideband radiation is complicated. A method to perform this calculation is presented here. **(5)**

X2.2 Sakuma-Hattori Equation (Planckian Form)

X2.2.1 The Sakuma-Hattori Equation is shown in Eq X2.1. The inverse Sakuma-Hattori is shown in Eq X2.2. The first derivative of the Sakuma-Hattori is shown in Eq X2.3. When doing the mathematics using these equations, Kelvins shall be used for temperature rather than °C.

$$S(T) = \frac{C}{exp\left(\frac{c_2}{AT+B}\right) - 1} \tag{X2.1}$$

$$T = \frac{c_2}{A\ln\left(\frac{C}{S}+1\right)} - \frac{B}{A} \tag{X2.2}$$

$$\frac{\partial S}{\partial T} = [S(T)]^2 \frac{Ac_2}{C(AT+B)^2} exp\left(\frac{c_2}{AT+B}\right) \tag{X2.3}$$

X2.2.2 In Eq X2.1, Eq X2.2, and Eq X2.3, c_2 is a physical constant. A, B, and C are constants derived from the infrared thermometer's relationship between signal received and temperature. A and B are derived from the infrared thermometer's spectral response. C is a scalar based on infrared thermometer gain and can be considered as unity for this analysis. Calculation for these constants is shown in Eq X2.4, Eq X2.6, Eq X2.6, and Eq X2.7. The value for Δλ is the infrared thermometer's bandwidth. The value for λ_0 is the infrared thermometer's center wavelength based on a simple average of the infrared thermometer's high and low bandwidth limits.

$$A = \lambda_0\left(1 - \frac{\Delta\lambda^2}{2\lambda_0^2}\right) \quad \text{(X2.4)}$$

$$B = \frac{c_2\Delta\lambda^2}{24\lambda_0^2} \quad \text{(X2.5)}$$

$$C = 1.0 \quad \text{(X2.6)}$$

$$c_2 = 14387.752\,\mu mK \quad \text{(X2.7)}$$

X2.2.3 For example, the 8 to 14 µm spectral band is considered. For the 8 to 14 µm spectral band, λ_0=11 µm and $\Delta\lambda$=6 µm. Using X2.4 and X2.5, A=9.364 µm and B=178.4 µmK.

X2.2.4 Table X2.1 shows computed values for the 8 to 14 µm spectral band for S(T) and ∂S/∂T. The computed values are based on the parameters discussed in X2.2.3.

TABLE X2.1 Sakuma-Hattori Calculations for the 8 to 14 µm Spectral Band

T (°C)	S(T)	∂S/∂T (K^{-1})
-50	0.0017606	0.000046195
-25	0.0031919	0.000068911
0	0.0052311	0.000094630
23	0.0076966	0.000119945
50	0.0113476	0.000150582
100	0.0202920	0.000206805
200	0.0461160	0.000305968
300	0.0807067	0.000382129
400	0.1218801	0.000438476
500	0.1679132	0.000480126
750	0.2969221	0.000544734
1000	0.4378341	0.000579281

X2.3 Infrared Thermometer with a Fixed Emissivity Setting

X2.3.1 If an 8 to 14 µm infrared thermometer with a fixed emissivity setting is used with a source at a different emissivity, Eq 1 can be rewritten as Eq X2.8. This assumes $T_D = T_W$ as the ambient temperature uncertainty accounts for this.

$$S(T_{meas}) = S(T_S) + \frac{(\epsilon_S - \epsilon_{instr})}{\epsilon_{instr}}[S(T_S) - S(T_W)] \quad \text{(X2.8)}$$

X2.3.2 As an example, an infrared thermometer with a fixed emissivity setting (ε_{instr}) of 0.95 is calibrated. The radiation source's emissivity (ε_S) is 0.97. The source's true temperature (T_S) is 100.00°C. The reflected temperature (T_W) is 23.0°C.

X2.3.3 Using Table X2.1 $S(T_S)$ = 0.0202920 and $S(T_W)$ = 0.0076966. These values are used in Eq X2.8 resulting in Eq X2.9.

$$S(T_{MEAS}) = 0.0202920 + \frac{[0.97 - 0.95]}{0.95}[0.0202920 - 0.0076966]$$
$$= 0.0205572 \quad \text{(X2.9)}$$

X2.3.4 To determine what the measured temperature should be, use Eq X2.2. This results in a temperature of 374.43 K or 101.28°C.

X2.4 Emissivity Uncertainty

X2.4.1 For this calculation, Eq 4 and Eq 5 are used.

X2.4.2 For this example, an 8 to 14 µm infrared thermometer is being calibrated. The true temperature of the source (T_S) is 200.00°C. The emissivity setting of the infrared thermometer (ε_{IRT}) is 0.95. The nominal emissivity of the surface (ε_{SURF}) is 0.95 with an expanded uncertainty of $U(\varepsilon_S)$ = 0.02. The reflected temperature (T_{REFL}) is 23°C.

X2.4.3 Using Table X2.1, $S(T_S)$ = 0.0461160 and $S(T_W)$ = 0.0076966. These values are used in Eq 4 to give the value in Eq X2.10.

$$\frac{\partial S(T_{meas})}{\partial \epsilon_S} = \frac{1}{\epsilon_{instr}}[S(T_S) - S(T_W)] = \frac{1}{0.95}[0.0461160 - 0.0076933]$$
$$= 0.0404415 \quad \text{(X2.10)}$$

X2.4.4 This value is used in Eq 5 with the value for $\partial S(T_{meas})/\partial T$ = 0.000305968 K^{-1} obtained from Table X2.1. This calculates the expanded uncertainty in terms of temperature as shown in Eq X2.11.

$$U_\epsilon(T_{meas}) = \frac{\dfrac{\partial S(T_{meas})}{\partial \epsilon_S}}{\dfrac{\partial S(T_{meas})}{\partial T}}U(\epsilon_S) = \frac{0.0404415}{0.000305968\,K^{-1}}0.02 = 2.64\,K \quad \text{(X2.11)}$$

X2.4.5 A graphical representation of a similar example is shown in Fig. X2.1 in with TS ranging from -50°C to 1000°C. In this example, $U(\varepsilon_S)$ = 0.01.

X2.5 Reflected Temperature Uncertainty

X2.5.1 To calculate the uncertainty due to reflected temperature use Eq 2 and Eq 3.

X2.5.2 In this example, the emissivity setting (ε_{INSTR}) of the 8 to 14 µm infrared thermometer is correctly set to 0.95. The true temperature of the source (T_S) is 0°C. The infrared thermometer calculates the reflected temperature (T_D) at 23°C. The reflected temperature uncertainty is $U(T_W)$ = 3 K.

X2.5.3 Use Eq 2 to calculate $\partial S(T_{meas}) / \partial S(T_W)$ as is shown in Eq X2.12.

$$\frac{\partial S(T_{meas})}{\partial S(T_W)} = \frac{1 - \epsilon_S}{\epsilon_{instr}} = \frac{1 - 0.95}{0.95} = 0.052632 \quad \text{(X2.12)}$$

X2.5.4 Use the result obtained in Eq X2.12 with Eq 3. From Table X2.1, $\partial S(T_W)/\partial T$ = 0.000119945 K^{-1} and $\partial S(T_{meas})/\partial T$ = 0.000094630 K^{-1}. These values are used in Eq 3 to calculate the uncertainty as is shown Eq X2.13.

$$U_{REFL}(T_{meas}) = \frac{\partial S(T_{meas})}{\partial S(T_W)}\frac{\dfrac{\partial S(T_W)}{\partial T}}{\dfrac{\partial S(T_{meas})}{\partial T}}U(T_W)$$
$$= 0.052632\frac{0.00019945\,K^{-1}}{0.000094630\,K^{-1}}3.0\,K = 0.20\,k \quad \text{(X2.13)}$$

X2.5.5 A graphical representation of a similar example is shown in Fig. X2.2 with TS ranging from -50°C to 1000°C. In this example, $U(T_W)$ = 1.0 K.

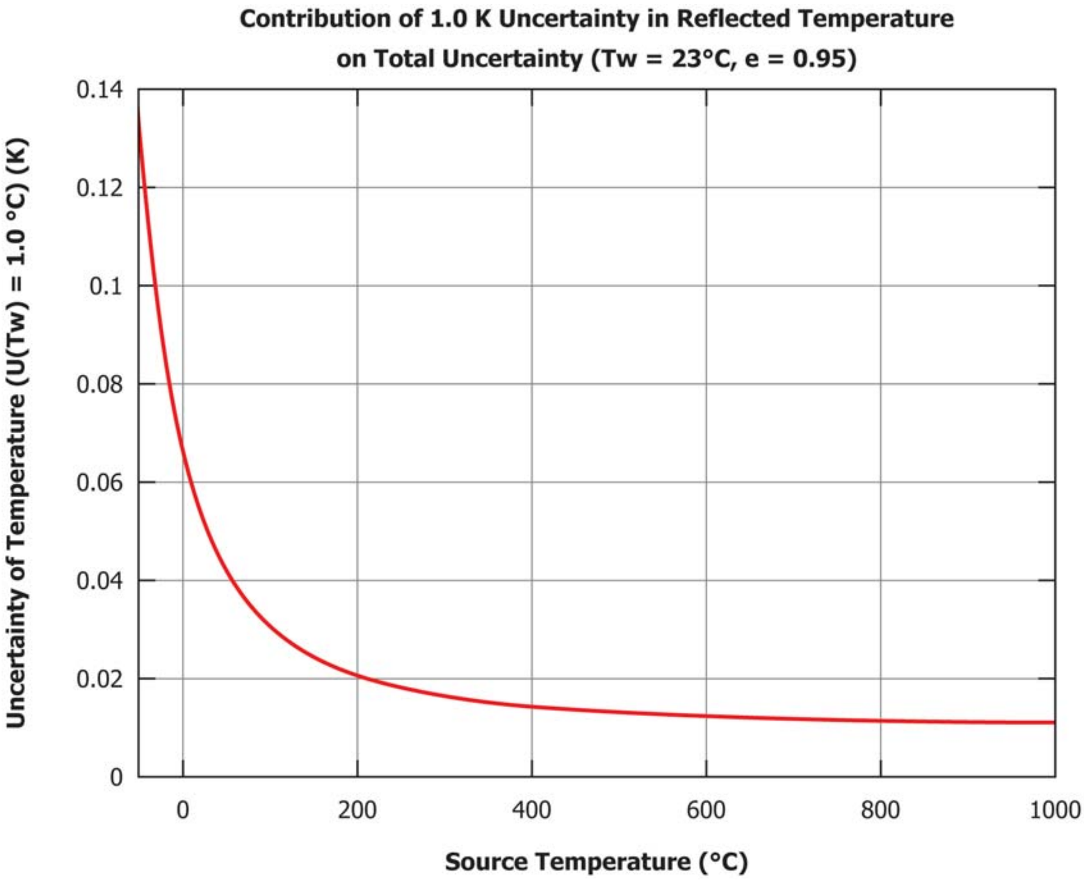


FIG. X2.1 Emissivity Uncertainty Contribution to Total Uncertainty

X2.6 Atmospheric Absorption Uncertainty

X2.6.1 To determine the uncertainty due to atmospheric absorption, *Bureau international des poids et mesures* (International Bureau of Weights and Measures or BIPM) provides values in uncertainty in terms of signal strength. The normal value for this uncertainty in terms of expanded uncertainty (k = 2) is 0.0006.

X2.6.2 For example, consider calculating the uncertainty due to atmospheric absorption. An 8 to 14 µm infrared thermometer is calibrated using a 200°C (473.15 K) source. Using Eq X2.1, S = 0.0461160, and Eq 3.1.13∂S/∂T = 0.000305968 K^{-1}.

X2.6.3 Apply these data to Eq X2.14. The solution is shown in Eq X2.15.

$$U(T) = \frac{1}{\left(\frac{\partial S}{\partial T}\right)} \frac{U(S)}{S} S \quad (X2.14)$$

$$U(T) = \frac{0.0006}{0.000305968\ K^{-1}} 0.0461160 = 0.09\ K \quad (X2.15)$$

X2.6.4 Table X2.2 shows calculated uncertainty due to atmospheric absorption for the 8 to 14 µm spectral band.

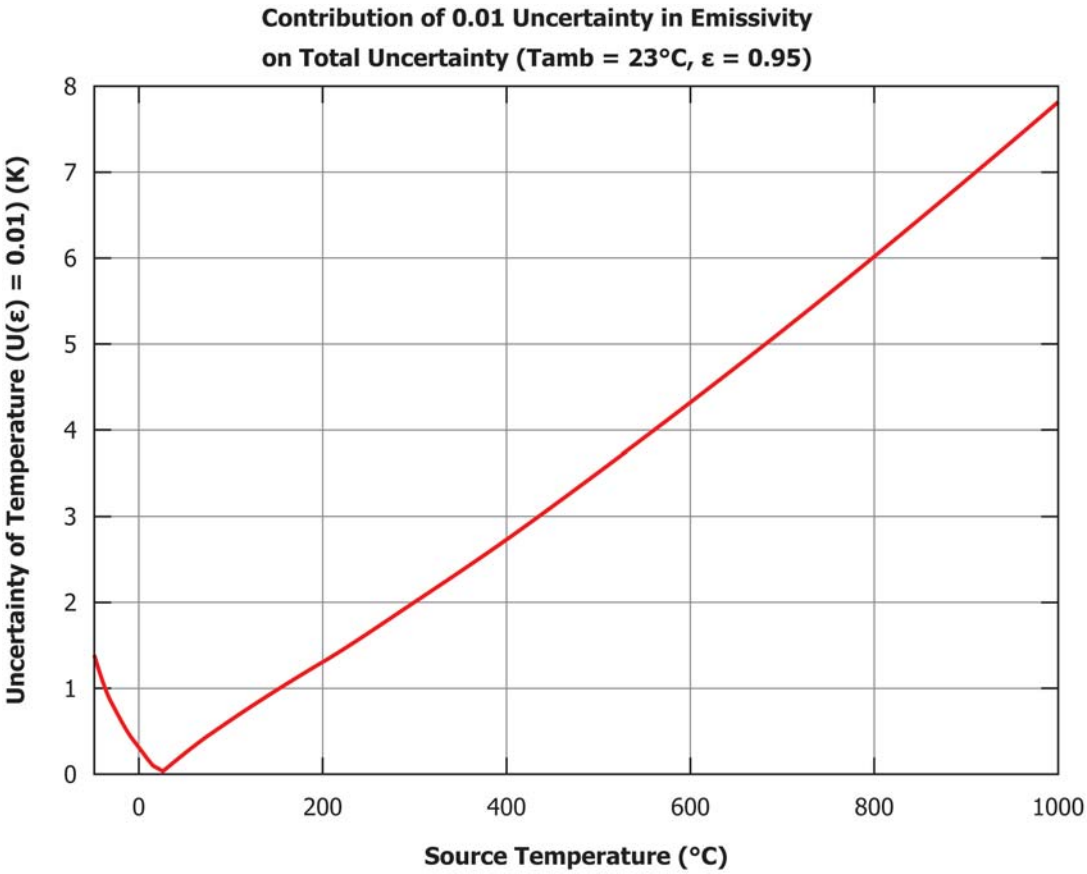


FIG. X2.2 Reflected Temperature Uncertainty Contribution to Total Uncertainty

TABLE X2.2 Uncertainties for Atmospheric Absorption for the 8 to 14 µm Spectral Band

T (°C)	S	∂S/∂T (K^{-1})	Atmospheric Absorption (K)
-50	0.0017606	0.000046195	0.023
-25	0.0031919	0.000068911	0.028
0	0.0052311	0.000094630	0.033
23	0.0076966	0.000119945	0.039
50	0.0113476	0.000150582	0.045
100	0.0202920	0.000206805	0.059
200	0.0461160	0.000305968	0.090
300	0.0807067	0.000382129	0.127
400	0.1218801	0.000438476	0.167
500	0.1679132	0.000480126	0.210
750	0.2969221	0.000544734	0.327
1000	0.4378341	0.000579281	0.453

X3. DETECTOR TEMPERATURE DETERMINATION (5)

X3.1 A point of difficulty throughout in determining temperature uncertainty is that the value of T_d is not known to the user. It is measured internally by the instrument, but is not displayed on the readout. The best assumption is that T_d will be the same as, or close to, ambient temperature, and this may require some conditioning of the instrument before use. However, there are some situations where ensuring that $T_d = T_{amb}$ is not practicable. One is where the infrared thermometer is used for an extended period in front of a hot source (for example, during calibration at high temperatures), where the radiation from the source may heat the detector above ambient temperature. The second is where the infrared thermometer is used inside a walk-in freezer, where the ambient temperature is well below the specified operating temperature for the thermometer. In these cases, the thermometer can still be used successfully, but the detector shall be maintained above a defined temperature, usually above 0°C.

X3.2 Dependence on the detector temperature is removed if the instrumental emissivity is set to 1 (this is precluded in fixed emissivity instruments). On the other hand, relatively large errors in the estimate (guess) of the detector temperature can usually be tolerated without significant error in the reading.

X3.3 For adjustable emissivity instruments, the detector temperature can be inferred from two measurements of the same target using two different instrumental emissivity settings. The temperature and emissivity of the target and the ambient temperature do not need to be known. All that is required is that these values are constant during the two measurements. The detector temperature, T_d, can be calculated from the Eq X3.1

$$S(T_d) = \frac{\epsilon_{INSTR1} S(T_{MEAS1}) - \epsilon_{INSTR2} S(T_{MEAS2})}{\epsilon_{INSTR1} - \epsilon_{INSTR2}} \qquad (X3.1)$$

where:

$T_{MEAS1} - T_{MEAS2}$ = the two infrared thermometer readings corresponding to ε_{INSTR1} and ε_{INSTR2}, respectively, and

ε_{INSTR1} *and* ε_{INSTR2} = the emissivity settings used

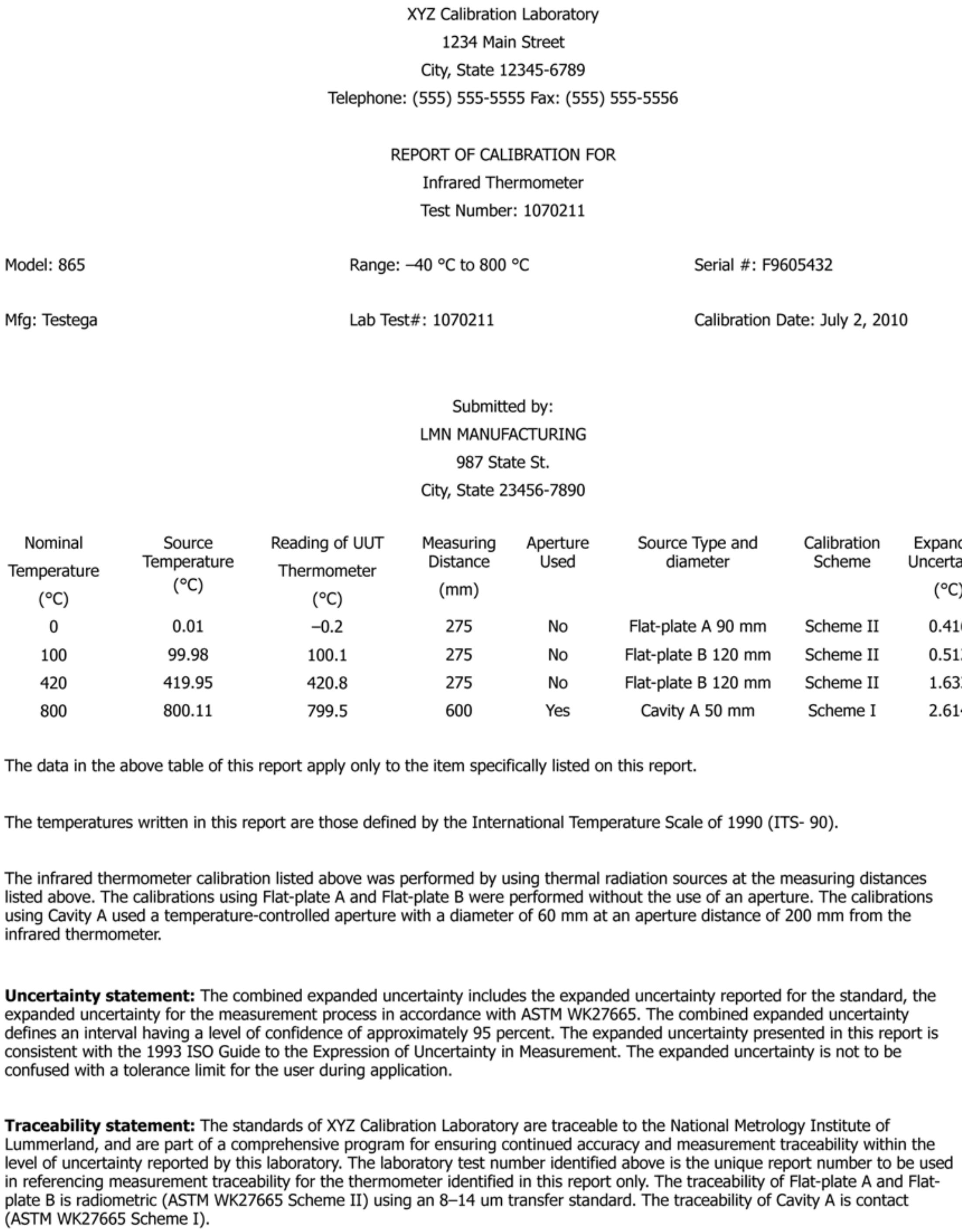
X3.4 The accuracy of calculations made with Eq X3.1 is best when ε_{INSTR1} and ε_{INSTR2} are widely spaced. Values of 0.5 and 1 are usually adequate.

X3.5 For example, two readings of a blackbody using an 8 to 14 µm thermometer might be T_{meas1} = 141.8°C when the instrumental emissivity is set to $\varepsilon_{instr1} = 1$, and T_{meas2} = 219.4°C when $\varepsilon_{instr2} = 0.5$. Substituting these values into Eq X3.1 gives T_d = 21.5°C.

X3.6 Calculations of this sort are useful for determining the expected variation of detector temperature as the conditions inside the laboratory change. While it is not possible to do this for fixed emissivity instruments, it may be possible to infer their behavior from measurements on similar adjustable emissivity instruments.

X4. SAMPLE REPORT FOR AN INFRARED THERMOMETER

See Fig. X4.1.



XYZ Calibration Laboratory
1234 Main Street
City, State 12345-6789
Telephone: (555) 555-5555 Fax: (555) 555-5556

REPORT OF CALIBRATION FOR
Infrared Thermometer
Test Number: 1070211

Model: 865	Range: –40 °C to 800 °C	Serial #: F9605432
Mfg: Testega	Lab Test#: 1070211	Calibration Date: July 2, 2010

Submitted by:
LMN MANUFACTURING
987 State St.
City, State 23456-7890

Nominal Temperature (°C)	Source Temperature (°C)	Reading of UUT Thermometer (°C)	Measuring Distance (mm)	Aperture Used	Source Type and diameter	Calibration Scheme	Expanded Uncertainty (°C)
0	0.01	–0.2	275	No	Flat-plate A 90 mm	Scheme II	0.416
100	99.98	100.1	275	No	Flat-plate B 120 mm	Scheme II	0.512
420	419.95	420.8	275	No	Flat-plate B 120 mm	Scheme II	1.633
800	800.11	799.5	600	Yes	Cavity A 50 mm	Scheme I	2.614

The data in the above table of this report apply only to the item specifically listed on this report.

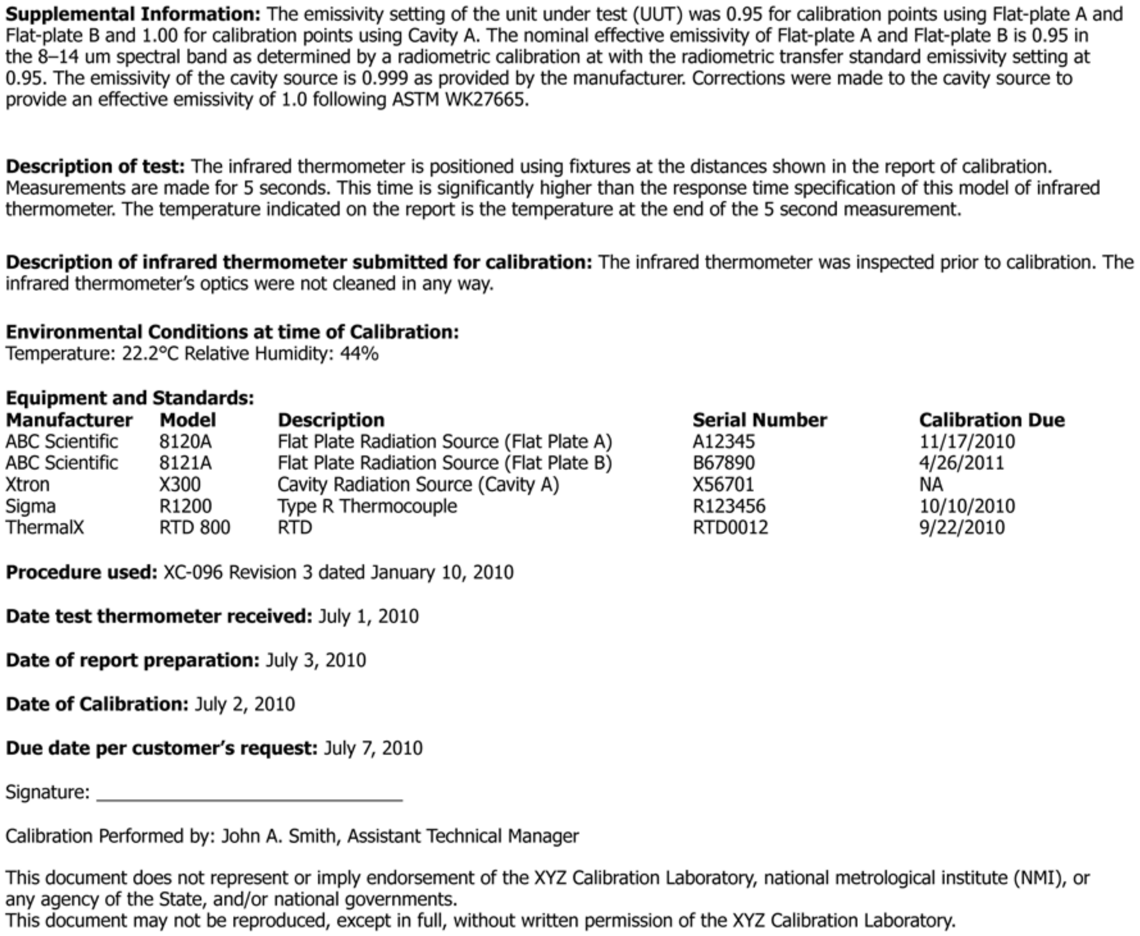
The temperatures written in this report are those defined by the International Temperature Scale of 1990 (ITS- 90).

The infrared thermometer calibration listed above was performed by using thermal radiation sources at the measuring distances listed above. The calibrations using Flat-plate A and Flat-plate B were performed without the use of an aperture. The calibrations using Cavity A used a temperature-controlled aperture with a diameter of 60 mm at an aperture distance of 200 mm from the infrared thermometer.

Uncertainty statement: The combined expanded uncertainty includes the expanded uncertainty reported for the standard, the expanded uncertainty for the measurement process in accordance with ASTM WK27665. The combined expanded uncertainty defines an interval having a level of confidence of approximately 95 percent. The expanded uncertainty presented in this report is consistent with the 1993 ISO Guide to the Expression of Uncertainty in Measurement. The expanded uncertainty is not to be confused with a tolerance limit for the user during application.

Traceability statement: The standards of XYZ Calibration Laboratory are traceable to the National Metrology Institute of Lummerland, and are part of a comprehensive program for ensuring continued accuracy and measurement traceability within the level of uncertainty reported by this laboratory. The laboratory test number identified above is the unique report number to be used in referencing measurement traceability for the thermometer identified in this report only. The traceability of Flat-plate A and Flat-plate B is radiometric (ASTM WK27665 Scheme II) using an 8–14 um transfer standard. The traceability of Cavity A is contact (ASTM WK27665 Scheme I).

FIG. X4.1 Sample Report for an Infrared Thermometer



Supplemental Information: The emissivity setting of the unit under test (UUT) was 0.95 for calibration points using Flat-plate A and Flat-plate B and 1.00 for calibration points using Cavity A. The nominal effective emissivity of Flat-plate A and Flat-plate B is 0.95 in the 8–14 um spectral band as determined by a radiometric calibration at with the radiometric transfer standard emissivity setting at 0.95. The emissivity of the cavity source is 0.999 as provided by the manufacturer. Corrections were made to the cavity source to provide an effective emissivity of 1.0 following ASTM WK27665.

Description of test: The infrared thermometer is positioned using fixtures at the distances shown in the report of calibration. Measurements are made for 5 seconds. This time is significantly higher than the response time specification of this model of infrared thermometer. The temperature indicated on the report is the temperature at the end of the 5 second measurement.

Description of infrared thermometer submitted for calibration: The infrared thermometer was inspected prior to calibration. The infrared thermometer's optics were not cleaned in any way.

Environmental Conditions at time of Calibration:
Temperature: 22.2°C Relative Humidity: 44%

Equipment and Standards:

Manufacturer	**Model**	**Description**	**Serial Number**	**Calibration Due**
ABC Scientific	8120A	Flat Plate Radiation Source (Flat Plate A)	A12345	11/17/2010
ABC Scientific	8121A	Flat Plate Radiation Source (Flat Plate B)	B67890	4/26/2011
Xtron	X300	Cavity Radiation Source (Cavity A)	X56701	NA
Sigma	R1200	Type R Thermocouple	R123456	10/10/2010
ThermalX	RTD 800	RTD	RTD0012	9/22/2010

Procedure used: XC-096 Revision 3 dated January 10, 2010

Date test thermometer received: July 1, 2010

Date of report preparation: July 3, 2010

Date of Calibration: July 2, 2010

Due date per customer's request: July 7, 2010

Signature: ______________________________

Calibration Performed by: John A. Smith, Assistant Technical Manager

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FIG. X4.1 Sample Report for an Infrared Thermometer *(continued)*

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