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Standard Test Methods for Radiation Thermometers (Single Waveband Type)¹

This standard is issued under the fixed designation E1256; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The test methods described in these test methods can be utilized to evaluate the following six basic operational parameters of a radiation thermometer (single waveband type):

	Section
Calibration Accuracy	7
Repeatability	8
Target Size	9
Response Time	10
Warm-Up Time	11
Long-Term Drift	12
Long-Term Stability	12

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 Definitions:

2.1.1 *blackbody, n*—the perfect or ideal source of thermal radiant power having a spectral distribution described by the Planck equation.

2.1.1.1 *Discussion*—The term blackbody is often used to describe a furnace or other source of radiant power which approximates the ideal.

2.1.2 *center wavelength, n*—a wavelength, usually near the middle of the band of radiant power over which a radiation thermometer responds, that is used to characterize its performance.

2.1.2.1 *Discussion*—The value of the center wavelength is usually specified by the manufacturer of the instrument.

2.1.3 *radiation thermometer, n*—a radiometer calibrated to indicate the temperature of a blackbody.

2.1.4 *radiometer, n*—a device for measuring radiant power that has an output proportional to the intensity of the input power.

2.1.5 *target plane, n*—the plane, perpendicular to the line of sight of a radiation thermometer, that is in focus for that instrument.

2.2 Definitions of Terms Specific to This Standard:

2.2.1 *reference temperature source, n*—a source of thermal radiant power of known temperature or emissivity, or both, used in the testing of radiation thermometers.

2.2.2 *target size, n*—the diameter of a circle in the target plane of a radiation thermometer that is centered on its line of sight and contains 99 % of the input radiant power received by that instrument.

2.2.3 *temperature resolution, n*—the minimum simulated or actual change in target temperature that gives a usable change in output or indication, or both.

3. Significance and Use

3.1 The purpose of these test methods is to establish consensus test methods by which both manufacturers and end users may make tests to establish the validity of the readings of their radiation thermometers. The test results can also serve as standard performance criteria for instrument evaluation or selection, or both.

3.2 The goal is to provide test methods that are reliable and can be performed by a sufficiently skilled end user or manufacturer in the hope that it will result in a better understanding of the operation of radiation thermometers and also promote improved communication between the manufacturers and the end users. A user without sufficient knowledge and experience should seek

¹ These test methods are under the jurisdiction of ASTM Committee E20 on Temperature Measurement and are the direct responsibility of Subcommittee E20.02 on Radiation Thermometry.

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assistance from the equipment makers or other expert sources, such as those found at the National Institute of Standards and Technology in Gaithersburg, Maryland.

3.3 Use these test methods with the awareness that there are other parameters, particularly spectral responserange limits and temperature resolution, which impact the use and characterization of radiation thermometers for which test methods have not yet been developed.

3.3.1 Temperature resolution is the minimum simulated or actual change in target temperature that results in a usable change in output or indication, or both. It is usually expressed as a temperature differential or a percent of full-scale value, or both, and usually applies to value measured. The magnitude of the temperature resolution depends upon a combination of four factors: detector noise equivalent power (NEP) or noise equivalent temperature, temperature difference (NETD), electronic signal processing, signal-to-noise characteristics (including amplification noise), and analog-to-digital conversion “granularity.”

3.3.2 Spectral responserange limits are the upper and lower limits to the wavelength band of radiant energy to which the instrument responds. These limits are generally expressed in micrometers (μm) and include the effects of all elements in the measuring optical path. At the spectral response limits, the transmission of the measuring optics is 5 % of peak transmission (see Fig. 1).

4. Apparatus

4.1 The following apparatus, set up as illustrated in Fig. 2, can be used to perform the standard tests for all six parameters.
 4.1.1 *Reference Temperature Source*—A blackbody (or other stable isothermal radiant source of high and known emissivity) with an opening diameter at least as large as that specified in these test methods.

NOTE 1—Typical examples include nearly isothermal furnaces with internal geometries, such as a sphere with an opening small relative to its radius, or a right circular cylinder with one end closed having a radius small relative to its length. Consult footnote² for greater detail.

4.1.2 *Temperature Indicator*—Either contact or radiometric, which accurately displays the temperature of the reference temperature source.

4.1.3 *Shutter Mechanism*—Of sufficient size so as to completely block the opening of the reference temperature source from the field of view of the test instrument. The shutter mechanism shall activate in a time interval that is short when compared with the response time of the test instrument.

4.1.4 *Iris Diaphragm*—Of sufficient size so that when fully open the iris diameter is greater than the opening of the reference temperature source. It shall be located with its opening concentric with and perpendicular to the line of sight of the radiation thermometer.

4.1.4.1 The side of the diaphragm facing the radiation thermometer should be blackened (nearly nonreflective) so as to minimize the effect of radiation reflected from the surrounding environment. In addition the iris should be shaded from sources of intense extraneous radiation. (See Note 9).

4.1.5 *Aperture Set*—If an iris diaphragm is not available, an aperture disc set of appropriate diameters can be used. Each aperture should be blackened and also mounted and protected from extraneous sources of radiation as discussed in 4.1.4.1.

4.1.6 *Data Acquisition Systems*—Of appropriate speed and storage capacity to measure and record the output signal of the radiation thermometer in the Response Time Test Method, Section 9.

4.1.7 *Power Supply*—Capable of supplying the proper voltage and frequency, if necessary, to the radiation thermometer.

² DeWitt, D. P., and Nutter, G. D., eds., “Theory and Practice of Radiation Thermometry,” John Wiley and Sons, New York, NY.

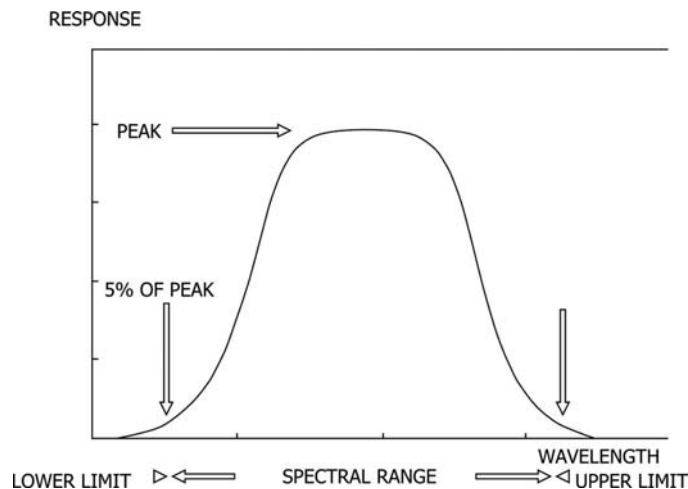


FIG. 1 Spectral Range Limits

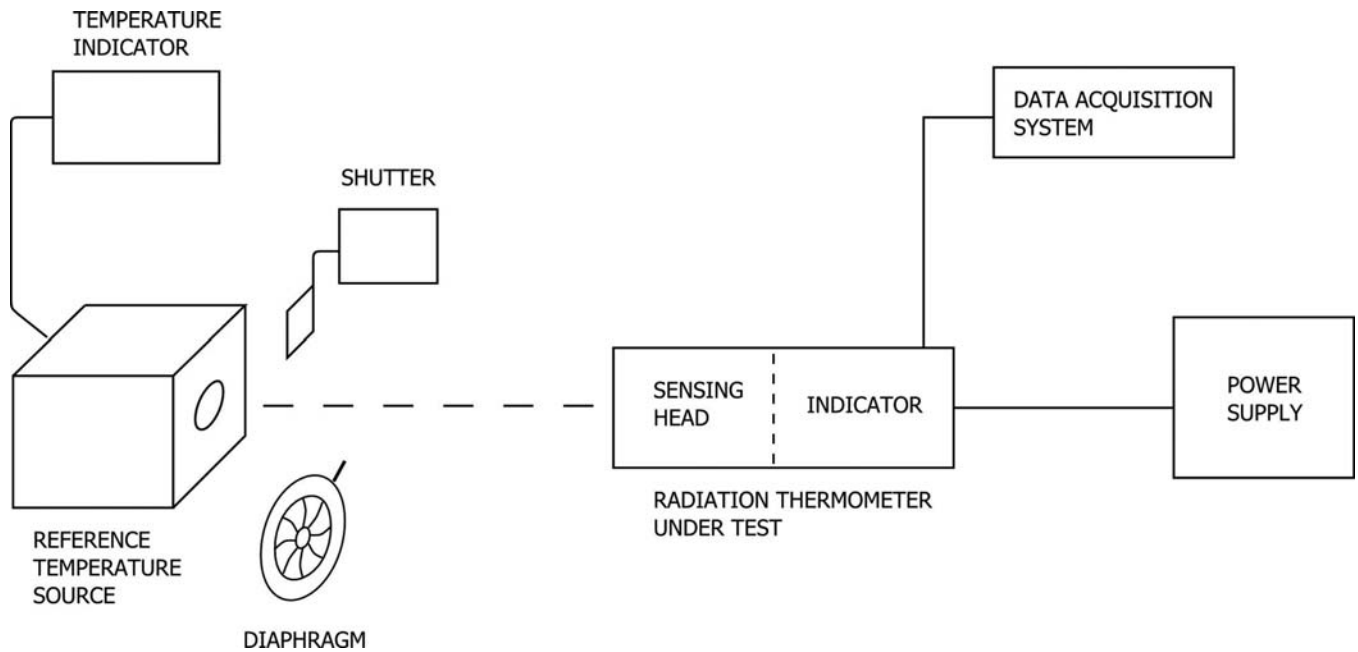


FIG. 2 Test Method Apparatus

5. Calibration Accuracy Test Method

5.1 *Summary*—This test method outlines the procedure to be used to evaluate the maximum deviation between the temperature indicated by the radiation thermometer and the known temperature of a reference temperature source, including the uncertainty of the reference temperature source relative to the current International Temperature Scale.

5.2 Test Conditions:

- 5.2.1 Rated supply voltage and frequency.
- 5.2.2 Prescribed warm-up period.
- 5.2.3 After execution of internal standardization check (if available).
- 5.2.4 Emissivity compensation set to one (1).
- 5.2.5 Minimum opening of the reference temperature source shall not obstruct the field of view of the radiation thermometer with the test aperture as specified by the manufacturer.
- 5.2.6 Laboratory ambient temperature range (20 to 25°C).
- 5.2.7 Manufacturer shall specify any special conditions such as atmospheric absorption effects, target distance, etc.
- 5.2.8 Manufacturer shall specify the output for determining the indicated temperature.

5.3 Test Method:

5.3.1 The radiation thermometer is sighted at the reference temperature source whose temperature is sequentially stabilized at three calibration points distributed uniformly over the measurement range of the instrument.

5.3.2 The temperature of the reference temperature source and the temperature indicated by the radiation thermometer are recorded, then the difference between the two values is calculated and recorded (see Fig. 3).

5.3.3 The test sequence is repeated twice for the same three calibration points, and an average temperature difference is calculated and recorded for each calibration point.

5.4 *Test Result*—The value for the calibration accuracy of the temperature indication of the radiation thermometer is taken to be the largest of the three average temperature differences determined in 5.3.2 plus or minus the uncertainty of the temperature of the reference temperature source relative to the current International Temperature Scale.

NOTE 2—The calibration accuracy is generally expressed as a temperature difference or a percent of full-scale value, or both.

NOTE 3—The value applies across the entire measurement range.

NOTE 4—If the reference temperature source is measured with other than a calibrated reference or secondary standard radiation thermometer, then the emissivity of the source enters into the calibration of the test radiation thermometer.

6. Procedure

- 6.1 Detailed directions for evaluation of each parameter listed in 1.1 are included in each parameter test method.
- 6.2 Each parameter test method is organized by: parameter term, summary, test conditions, test method, test result, and applicable notes.

7. Repeatability Test Method

7.1 *Summary*—This test method outlines the procedure to be used to evaluate the repeatability of the temperature indication of

Calibration Points	Run #1			Run #2			Run #3			Average Value	Difference
	T _{ref}	T ₁	ΔT ₁ (T _{ref} - T ₁)	T _{ref}	T ₂	ΔT ₂ (T _{ref} - T ₂)	T _{ref}	T ₃	ΔT ₃ (T _{ref} - T ₃)	$\frac{\Delta T_1 + \Delta T_2 + \Delta T_3}{3}$	ΔT _{max} - ΔT _{min}
Approx 10% of Span											
Approx 50% of Span											
Approx 90% of Span											

- Note 1 Uncertainty in temperature of reference temperature source ± _____ °C
- Note 2 Instrument span (See Note B below) _____ °C
- Note 3 Maximum Average Value _____ °C
- Note 4 Maximum difference _____ °C

- Note A This is only a sample worksheet. More replicates will increase the significance of the results.
- Note B For instruments with more than one range (span), each range is calibrated as if it were a separate instrument.
- Note C Special care must be taken not to infer too much significance from this test because of the small number of observations.

FIG. 3 Worksheet for Calibration Accuracy Test Method

a radiation thermometer for a number of consecutive measurements made under the same conditions over a specified interval of time.

- 7.2 Test Conditions:
 - 7.2.1 Rated supply of voltage and frequency.
 - 7.2.2 Prescribed warm-up period.
 - 7.2.3 After execution of internal standardization check (if available).
 - 7.2.4 Diameter of the reference temperature source opening shall be greater than the radiation thermometer target size, as specified by the manufacturer.
 - 7.2.5 Laboratory ambient temperature range (20 to 25°C).
 - 7.2.6 Emissivity compensation, if any, set to one (1).
 - 7.2.7 Manufacturer shall specify any special conditions such as response time, atmospheric absorption effects, target distance, etc.

- 7.3 Test Method:
 - 7.3.1 Once a day for twelve consecutive working days, the radiation thermometer is sighted at the reference temperature source whose temperature is stabilized at the approximate midpoint of the radiation thermometer calibration range.

NOTE 5—The selected reference temperature source temperature shall be reproduced for each of the twelve consecutive tests.

- 7.3.2 The temperature of the reference temperature source and the temperature(s) indicated by the radiation thermometer during each day's test are recorded.

- 7.3.3 The radiation thermometer shall be switched off after each series of measurements.

- 7.4 Test Result—The value for the repeatability of the readings of the radiation thermometer is taken to be the standard deviation of the twelve recorded readings.

$$S.D. = \sqrt{\frac{\sum_{i=1}^N (X_i - \bar{X})^2}{N - 1}} = \sqrt{\frac{\sum_{i=1}^N X_i^2 - \frac{(\sum_{i=1}^N X_i)^2}{N}}{N - 1}}$$

where:
 S.D. = standard deviation,
 N = number of measurements,
 X_i = value of the *i*th measurement, and
 $\bar{X} = \frac{\sum_{i=1}^N X_i}{N}$
 average of the twelve measurements = $\frac{\sum_{i=1}^N X_i}{N}$.

NOTE 6—The repeatability of the temperature indication is generally expressed as a temperature difference or a percent of full-scale value, or both.