



# Standard Test Method for Noise Equivalent Temperature Difference of Thermal Imaging Systems<sup>1</sup>

This standard is issued under the fixed designation E 1543; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the noise equivalent temperature difference (NETD;  $NE\Delta T$ ) of thermal imaging systems of the conventional forward-looking infrared (FLIR) or other types that utilize an optical-mechanical scanner; it does not include charge-coupled devices or pyroelectric vidicons.

1.2 Parts of this test method have been formulated under the assumption of a photonic detector(s) at a standard background temperature of 295°K (22°C). Besides nonuniformity, tests made at other background temperatures may result in impairment of precision and bias.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *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. Referenced Documents

2.1 *ASTM Standards:*

E 1213 Test Method for Minimum Resolvable Temperature Difference for Thermal Imaging Systems<sup>2</sup>

E 1316 Terminology for Nondestructive Examinations<sup>2</sup>

## 3. Terminology

3.1 *Definitions:*

3.1.1 *blackbody simulator*—a device that produces an emission spectrum closely approximating that emitted by a blackbody (surface with emissivity of 1.0), usually a cavity or a flat plate with a structured or coated surface having a stable and uniform temperature.

3.1.2 *dwelt time*—the time spent, during one frame, in scanning one angular dimension of a single pixel (picture element) of the image within the instantaneous field of view (IFOV) of a detector. Thus, for example, if a single pixel is scanned  $n$  times during one frame, the dwell time is given by  $n$  times the duration of a single scan of the pixel.

3.1.3 *FLIR*—an acronym for forward-looking infrared, originally implying airborne, now denoting any fast-frame thermal imaging system comparable to that of television and yielding real-time displays. Generally, these systems employ optical-mechanical scanning mechanisms.

3.1.4 See also Section J: Infrared Examination, of Terminology E 1316.

## 4. Summary of Test Method

4.1 The target is a blackbody source of uniform temperature that is viewed by the infrared thermal imaging system through an aperture of prescribed size. A specified temperature difference is established between the target and its background. Measurements are made of the peak-to-peak signal voltage from the target and the RMS noise voltage from the background, both across a standard reference filter, and of the target and background temperatures. From these measured values, the NETD is calculated.

## 5. Significance and Use

5.1 This test method gives an objective measure of the temperature sensitivity of a thermal imaging system (relative to a standard reference filter) exclusive of a monitor, with emphasis on the detector(s) and preamplifier.

NOTE 1—Test values obtained under idealized laboratory conditions may or may not correlate directly with service performance.

5.2 This test method affords a convenient means for periodically monitoring the performance of a given thermal imaging system.

5.3 NETD relates to minimum resolvable temperature difference as described in Test Method E 1213. Thus, an increase in NETD may be manifest as a loss of detail in imagery.

5.4 Intercomparisons based solely on NETD figures may be misleading.

<sup>1</sup>This test method is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.10 on Emerging NDT Methods.

Current edition approved Feb. 10, 2000. Published April 2000. Originally published as E 1543 – 93. Last previous edition E 1543 – 94.

<sup>2</sup>Annual Book of ASTM Standards, Vol 03.03.

NOTE 2—NETD depends on various factors such as spectral bandwidth and background temperature.

**6. Apparatus**

6.1 The apparatus, as shown in Fig. 1, consists of the following:

6.1.1 *Blackbody Simulator*, temporally stable and controllable to within 0.1°C.

6.1.2 *Target Plate*, containing an aperture several times larger dimensionally than the IFOV. The target plate should be at least ten times the dimension of the aperture in both the height and width. (The plate forms the target background; the aperture, in effect, becomes the target as the blackbody simulator is viewed through it.) The material and surface conditions of the target plate must be carefully considered. It is helpful for the back side of the target plate to be a highly reflective metallic surface to minimize the influence of the blackbody simulator on the temperature of the target background. The front surface of the target plate should appear to the infrared imaging system to have a high emissivity. One possibility would be to coat the viewed surface with a high emissivity paint or coating.

6.1.3 *Target Cover*, used to block completely the radiation emanating from the target. The target cover should have front and back surface properties similar to those of the target plate.

6.1.4 *Standard Reference Filter*, consisting of a single RC low-pass filter whose product  $RC$  is equal to twice the dwell time; see Fig. 2.

NOTE 3—If the resistance,  $R$ , is in ohms and the capacitance,  $C$ , is in farads,  $RC$  is in seconds.

NOTE 4—The purpose of the filter is to standardize and define a reference noise bandwidth, upon which the noise measurement depends in part.

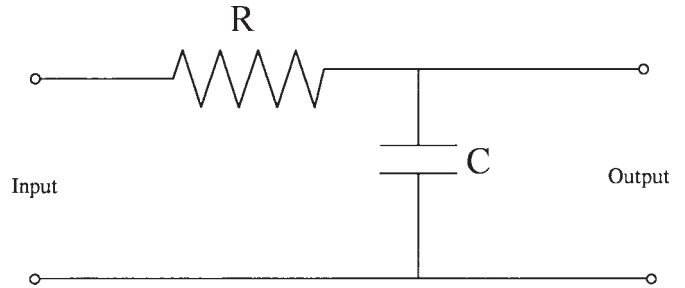


FIG. 2 Circuit Diagram of Standard Reference Filter

NOTE 5—If convenient, the filter may be a self-contained unit for external connection.

6.1.5 *Infrared Spot Radiometer* or equivalent radiometric instrument, calibrated with the aid of a blackbody source to an accuracy within 0.1°C.

6.1.6 *Digital Oscilloscope*.

6.1.7 *Digital True RMS Voltmeter*, with high crest factor (peak voltage/RMS voltage) so as not to attenuate any noise peaks, and bandwidth from approximately zero to at least  $1.6/RC$ . See 6.1.4 and X1.1.

**7. Procedure**

7.1 Mount the target plate at the blackbody simulator, with its aperture oriented the same as the IFOV of the imaging system and centered with the blackbody source, see Fig. 1 (a).

7.2 Connect the standard reference filter (input) to a point beyond the preamplifier and before any multiplexor, video sync pulse generator or pulse-width modulator.

7.3 The thermal imaging system, including the scanner, shall be in operation. (The monitor need not be connected.)

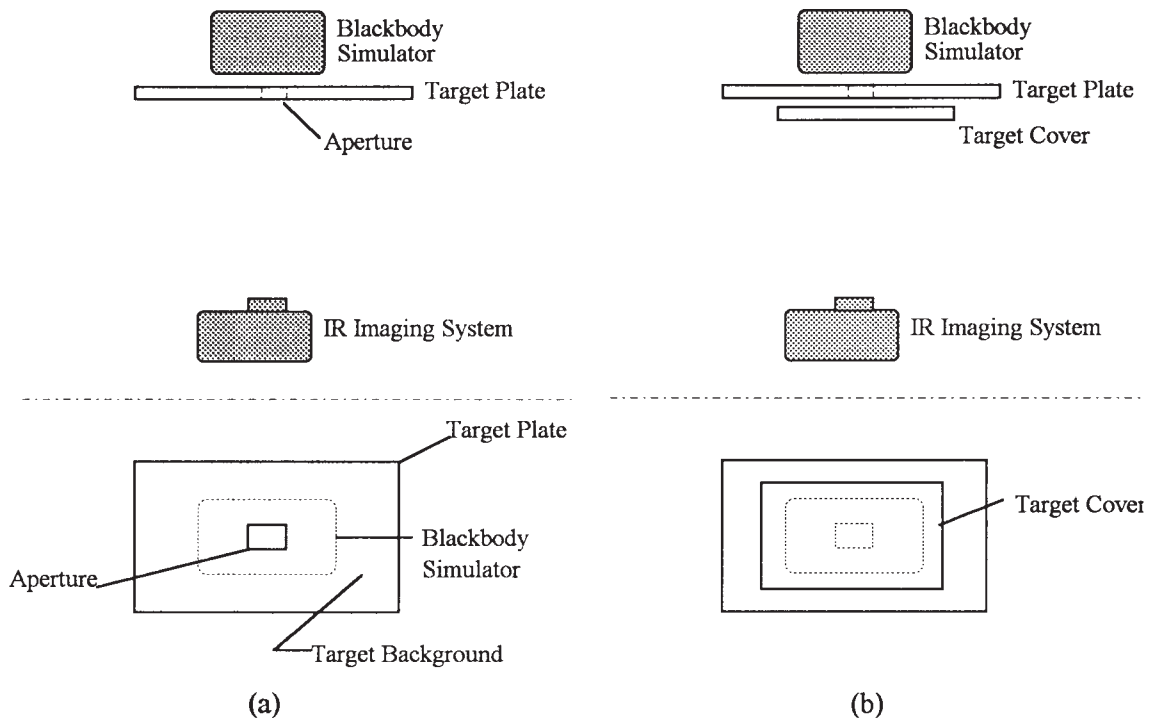


FIG. 1 Schematic of NETD Test Configuration; ( a ) When Measuring Signal and ( b ) When Measuring Noise

7.4 Set the blackbody simulator target temperature to roughly 7 or 8°C above the ambient temperature; the recommended ambient temperature is 22°C, controlled within ± 1°C.

7.5 With the spot radiometer at a normal distance of 1 m to the target, measure and record the target temperature,  $T$ .

7.6 Replace the radiometer with the thermal imaging system at the same location.

7.7 Connect the standard reference filter output to the oscilloscope. Measure and record the peak-to-peak signal voltage,  $S$ , between the signals from the background and the signals from the target. Be certain that the range and level controls of the infrared imager are set so that both the target and background signals are within the working range of the instrument.

7.8 Place the target cover over the entire aperture; see Fig. 1(b).

7.9 Replace the oscilloscope with the RMS voltmeter. Measure and record the RMS noise voltage,  $N$ . The range and level control settings on the infrared imager should not be adjusted between the signal measurement in 7.7 and the noise measurement in 7.9.

7.10 Replace the thermal imaging system with the spot radiometer at the same location. Measure the apparent target background temperature. Record the actual target background temperature,  $T_B$ , correcting for emissivity, if warranted. The desired background temperature is 22°C.

7.11 The difference,  $T - T_B$ , should be between 5 and 10°C; otherwise adjust the blackbody simulator target temperature accordingly and repeat 7.5 through 7.11.

7.12 Calculate the NETD; see 8.1.

7.13 With the spot radiometer (or equivalent radiometric instrument) measure the temperature uniformities of the target and of the target background. The required temperature uniformities are ± 0.05°C for the target and ± 0.1°C for the target background.

7.14 Similarly, measure the temperature stabilities of the target and the target background. The target must not vary by more than ± 0.05°C for the time interval from the temperature measurement,  $T$ , to the signal measurement,  $S$ . The target background must not vary by more than ± 0.1°C for the duration of the entire test.

7.15 Inclusion of 7.13 and 7.14 shall be required for the first three tests made with a given installation. Subsequent tests may omit these steps where deemed warranted; for example, after no significant change in NETD is observed.

## 8. Calculation

8.1 Calculate the noise equivalent temperature difference, NETD, as follows:

$$NETD = \frac{T - T_B}{S/N} (\text{°C}) \quad (1)$$

where:

$T$  = target temperature (°C),

$T_B$  = target background temperature (°C), and

$S/N$  = signal to noise ratio (dimensionless).

8.2 Calculate the noise equivalent bandwidth of the reference filter (reference noise bandwidth),  $\Delta f_R$ , as follows (see X1.2):

$$\Delta f_R = \frac{1}{4RC} (\text{Hz}) \quad (2)$$

where:

$R$  = filter resistance (ohms), and

$C$  = filter capacitance (farads).

## 9. Report

9.1 Report the following information:

9.1.1 NETD,

9.1.2 Background temperature,

9.1.3 Reference noise bandwidth, and

9.1.4 Spectral bandwidth.

## 10. Precision and Bias

10.1 Insufficient data are available on which to base a precision and bias statement.

## 11. Keywords

11.1 infrared imaging systems; noise equivalent temperature difference; nondestructive testing; thermal imaging systems; thermography

APPENDIX

(Nonmandatory Information)

X1. MATHEMATICAL DERIVATIONS RELATING TO THE STANDARD REFERENCE FILTER

X1.1 *Characteristic Frequency*—The frequency response of the standard reference filter is sketched in Fig. X1.1, where  $R/R_o$  is the ratio of output-to-input responsivity, and  $\omega$  is the

angular frequency ( $\omega = 2\pi f$ ). The frequency at which  $R/R_o$  equals 0.707 is the characteristic frequency, given by:

$$\omega_c = \frac{1}{RC} \text{ or } f_c = \frac{1}{2\pi RC} \tag{X1.1}$$

and:

$$10f_c = \frac{10}{2\pi RC} = \frac{1.6}{RC} \tag{X1.2}$$

X1.2 *Noise Equivalent Bandwidth*—For a system characterized by exponential decay time, as above, the noise equivalent bandwidth is given by:

$$\Delta f_R = \int_0^\infty \frac{df}{1 + (2\pi f\tau)^2} = \frac{1}{4\tau} \tag{X1.3}$$

where:

$$\tau = RC.$$

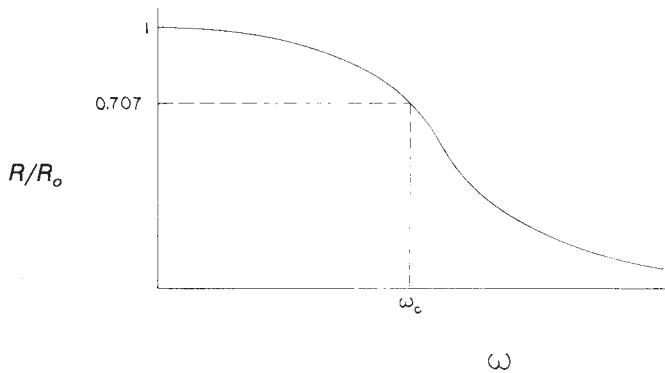


FIG. X1.1 Frequency Response of the Standard Reference Filter

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