National Fire Protection Association

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M E M O R A N D U M

TO: NFPA Technical Committee on Electronic Safety Equipment

FROM: Stacey Van Zandt

DATE: February 9, 2011

SUBJECT: NFPA 1801 ROP TC Letter Ballot (A2012)

The ROP letter ballot for NFPA 1801 is attached. The ballot is for formally voting on whether or not you concur with the committee's actions on the proposals. Reasons must accompany all negative and abstention ballots.

Please do not vote negatively because of editorial errors. However, please bring such errors to my attention for action.

Please complete and return your ballot as soon as possible but no later than **Friday, February 25, 2011 at 5:00 PM ET.** As noted on the ballot form, please return the ballot to Stacey Van Zandt either via e-mail to svanzandt@nfpa.org or via fax to 617-984-7056. You may also mail your ballot to the attention of Stacey Van Zandt at NFPA, 1 Batterymarch Park, Quincy, MA 02169.

The return of ballots is required by the Regulations Governing Committee Projects.

Attachments: Proposals
Preprint
Letter Ballot

1801-1 Log #2 FAE-ELS **Final Action: Accept in Principle**
(Table 4.3.9)

Submitter: Landon Borders, Bullard
Recommendation: Revise table as follows:

****Insert Table 4.3.9 Here****

Substantiation: Remove the FOV test from specimens 1-3. This is redundant and unnecessary since it will be tested on specimens 7-9. Modify specimen requirements for the vibration test to be consistent with the Heat Resistance specimen requirements.
Committee Meeting Action: Accept in Principle
Revise Table 4.3.9 as follows:

****Insert Table 4.3.9 Here****

Committee Statement: This is a more effective testing process to run the FOV test earlier rather than later.

Table 4.3.9 Test Matrix for Thermal Imagers

Test Order	Specimens 1–3	Specimens 4–6	Specimens 7–9	Specimens 10–12	Specimens 13–15	Specimens 16–18
1	~~Field of View Measurement Section 8.11 Specimens 1–3~~	Cable Pullout Test Section 8.9 Specimens 4–6	Field of View Measurement Section 8.11 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 10	Vibration Test Section 8.2 Specimens 13–~~15~~	Durability Test Section 8.13 Specimens 16–18
2	Image Recognition Test Section 8.1 Specimens 1–3	Impact Acceleration Resistance Test — Ambient Section 8.3 Specimen 4	Corrosion Test Section 8.4 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 11	Vibration Test Section 8.2 Specimens ~~13–15~~ 14	Product Label Durability Test Section 8.8 Specimens 16–18
3	Image Color and Effective Temperature Range Test Section 8.10 Specimens 1–3	Impact Acceleration Resistance Test — Cold Section 8.3 Specimen 5	Product Label Durability Test Section 8.8 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 12	Vibration Test Section 8.2 Specimens ~~13–~~15	—
4	Thermal Sensitivity Test Section 8.12 Specimens 1–3	Impact Acceleration Resistance Test — Elevated Temperature Section 8.3 Specimen 6	—	Product Label Durability Test Section 8.8 Specimens 10–12	—	—
5	Heat and Flame Test Section 8.7 Specimen 1–3	—	—	—	—	—

Table 4.3.9 Test Matrix for Thermal Imagers

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1	Field of View Measurement Section 8.11 Specimens 1-3	Cable Pullout Test Section 8.9 Specimens 4–6	Field of View Measurement Section 8.11 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 10	Vibration Test Section 8.2 Specimen 13	Durability Test Section 8.13 Specimens 16–18
2	Image Recognition Test Section 8.1 Specimens 1–3	Impact Acceleration Resistance Test — Ambient Section 8.3 Specimen 4	Corrosion Test Section 8.4 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 11	Vibration Test Section 8.2 Specimen 14	Product Label Durability Test Section 8.8 Specimens 16–18
3	Image Color and Effective Temperature Range Test Section 8.10 Specimens 1–3	Impact Acceleration Resistance Test — Cold Section 8.3 Specimen 5	Product Label Durability Test Section 8.8 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 12	Vibration Test Section 8.2 Specimens 15	—
4	Thermal Sensitivity Test Section 8.12 Specimens 1–3	Impact Acceleration Resistance Test — Elevated Temperature Section 8.3 Specimen 6	—	Product Label Durability Test Section 8.8 Specimens 10–12	—	—
5	Heat and Flame Test Section 8.7 Specimen 1–3	—	—	—	—	—

1801-2 Log #CP1 FAE-ELS Final Action: Accept
(Chapters 6, 7 and 8)

Submitter: Technical Committee on Electronic Safety Equipment,
Recommendation: Revise text to read as follows:

1. Insert a new 6.6.4.4.3 to read as follows:

6.6.4.4.3 The internal electronics overheat indicator shall be a flashing indicator consisting of a solid red thermometer-shaped image within a transparent equilateral triangle having a red border as shown in Figure 6.6.4.

2. Revise 6.6.4.7.2 to read as follows:

6.6.4.7.2 ~~The temperature measurement zone~~ The TI BASIC PLUS operational format indicator shall be an indicator consisting of an solid green "plus sign" (+) enclosed in a transparent square box with a green border as shown in Figure 6.6.4. ~~box or box corners and shall be displayed in the viewing screen. The temperature measurement zone box or box corners shall be the color green.~~

3. Revise 7.1.4 to read as follows:

7.1.4 Thermal imagers shall be tested for effective temperature range as specified in Section 8.10, Image Color and Effective Temperature Range Test, and shall have all *PIQ* values be greater than or equal to 0.80. ~~mean pixel intensity of the hot region of interest at 550°C (1022°F), i550, shall be greater than the sum of the mean pixel intensity of the hot region of interest at 500°C (932°F), i500, and the standard deviation of the pixel intensities of the hot region of interest at 500°C (932°F), iσ500.~~

4. Delete 8.1.4.2.1 and 8.1.4.2.2 in their entirety and renumber remaining paragraphs.

5. Revise 8.1.6.7 to read as follows:

8.1.6.7 A minimum of 10 uncompressed color images at a minimum bit depth of 16 bits shall be captured from the visible spectrum camera at a rate of one image every 3 seconds. ~~, ± 0.1 second, at each nominal measurement temperature. The image having the lowest contrast shall be excluded.~~

6. Revise 8.1.6.11.1 to read as follows:

8.1.6.11.1 The pixels selected to calculate *Ci*, *CTFi*, and ii shall be located along a baseline that is perpendicular to the centerline of the converging lines of the stencil pattern, as shown in Figure 8.1.6.11.1(a) and (b). Along these lines, all pixels between the maxima of the leftmost and rightmost lines of the stencil pattern shall be used.

Insert new Figure 8.1.6.11.1 (a), and renumber existing Figure 8.1.6.11.1 as Figure 8.1.6.11.1(b).

[INSERT NEW FIGURE 8.1.6.11.1(a) FROM TIA LOG NO. 1018]

7. Revise 8.1.6.12 to read as follows:

8.1.6.12 CTFi shall be calculated at least at each indexed baseline as specified in Equation 8.1.6.12, where *Imax* and *Imin* are the averaged maximum and minimum pixel intensity values, respectively, for each of the hot and cold regions along the baseline. CTF1 shall be defined as the maximum CTF value calculated between indices 1 and 2, inclusive.

8. Revise text in 8.1.6.19 to read as follows, equation remains unchanged:

8.1.6.19 The image quality probability (*PIQ*) shall be calculated for the spatial resolution procedure as specified in Equation 8.1.6.19, where *C* is the ~~CTF1 value~~ average of the CTF1's from both sets of lines calculated at index 1 in 8.1.6.13, *B* is the average brightness calculated in 8.1.6.14, *SR* is the spatial resolution calculated in 8.1.6.18, and *NU* is the NU(30) value calculated in 8.1.5.16.

9. Revise 8.10.4.3.1 to read as follows:

8.10.4.3.1 The surface labeled T_{hot} shall range in temperature from ~~ambient~~ 50° C (122° F) to 550° C (1022° F) and shall fill at least 50 percent of the FOV. The radiation source producing the T_{hot} surface shall be a blackbody and shall have an emissivity of 0.95, ± 0.03. The ~~source target~~ blackbody shall be calibrated at least every 6 months. ~~The nonuniformity of the blackbody shall not exceed 0.02.~~ The blackbody temperature accuracy shall be ± 0.05° C (± 1° F). The stability of the ~~emitting surface~~ blackbody temperatures shall ~~be~~ not exceed 0.15° C. The nonuniformity of the ~~emitting surface~~ blackbody shall not exceed 0.02 using the method in 8.1.5.1~~3~~4 as ~~su~~applied to temperature measurements of the emitting surface of the blackbody.

10. Revise 8.10.5.8 to read as follows:

8.10.5.8 The image capturing software and hardware shall permit 16-bit uncompressed color images to be downloaded from the visible spectrum camera to a computer or memory at a rate of one image every ~~3 seconds, ± 0.1 second;~~ 2° C ± 0.1° C (3.6° F ± 0.2° F) as T_{hot} increases from ambient to 550° C (1022° F) at a rate of not greater than 15° C (27° F) per minute.

11. Revise 8.10.6.7 to read as follows:

8.10.6.7 The color yellow shall be defined as having a hue between 45 and 69 degrees, a luminosity between 0.5 and ~~0.7~~ 0.9, and a color saturation greater than 0.2.

12. Revise 8.10.6.8 to read as follows:

8.10.6.8 The color orange shall be defined as having a hue between 24 and 32 degrees, a luminosity between 0.5 and ~~0.7~~ 0.9, and a color saturation greater than 0.1.

13. Revise 8.10.6.9 to read as follows:

8.10.6.9 The color red shall be defined as having a hue between 344 and 15 degrees, a luminosity between 0.5 and ~~0.7~~ 0.9, and a color saturation ~~between 0.1 and 0.4~~ greater than 0.4.

14. Revise 8.10.6.10 to read as follows:

8.10.6.10 The color dark red shall be defined as having a hue between 344 and 15 degrees, a luminosity between 0.5 and 0.7, and a color saturation ~~greater than 0.4~~ between 0.1 and 0.4.

15. Delete 8.10.7.7 in its entirety

16. Revise 8.10.8 to read as follows:

8.10.8 Report. *TY*, *TO*, *TR*, and *PIQ* shall be reported and recorded.

17. Revise 8.12.4.6 to read as follows:

8.12.4.6 The emitting surface of the source targets shall be equal in size, ± 10 percent, as viewed on the thermal imager's display. ~~The combined area of the emitting surfaces of the source targets shall fill at least 40 percent of the thermal imager's FOV.~~

Substantiation: The recommendation is the text of TIA Log No. 1018) which was submitted to the NFPA Standards Council for approval at its February 28, 2011 meeting.

The substantiation's for each change are as follows (from the TIA):

6.6.4.4.3 refers to the internal electronics heat indicator. There is no description of the indicator in the current document however it exists in the current document in Figure 6.6.4. It was proposed to be deleted as per ROP-54 submitted by Kovac whose recommendation was to delete the entire symbol. The committee action on ROP-54 was accepted in principal as it included many items in one submission. As a result the internal electronics overheat indicator remains in the current edition of NFPA 1801-2010, but is not described.

6.6.4.7.2 There is no written description of the TI BASIC PLUS operational format indicator in the standard as it is currently written. This change is requested to remain consistent with the written descriptions of all other icons and indicators that exist in the standard as pictured in Figures 6.6.3 and 6.6.4. Also, 6.6.4.7.1 indicates that the TI BASIC PLUS operational format indicator is a requirement, 6.6.4.7.4 indicates when the TI BASIC PLUS operational format indicator shall be displayed, and TI BASIC PLUS operational format indicator is pictured in figures 6.6.3 and 6.6.4

7.1.4 The parts of the Effective Temperature Range Test that involve testing for pixel saturation should be removed because they result in erroneous information.

8.1.6.7 This test is only done at one temperature so the text is not relevant.

8.1.6.10.1 More exact definition of the pixels to be used to calculate the parameters Ci, CTFi, and ì. Necessary to give reproducible results. Figure 8.1.6.10.1(a) was added to give a visual representation of the description in 8.1.6.10.1.

8.1.6.12 The meaning of CTF1 should be included in this paragraph to provide additional relevant information.

8.1.6.19 The meaning of the C value should be included in this paragraph to provide additional relevant information.

8.10.4.3.1 The apparatus for the effective temperature range test requires that the stability of the blackbody temperatures shall not exceed the specified temperature.

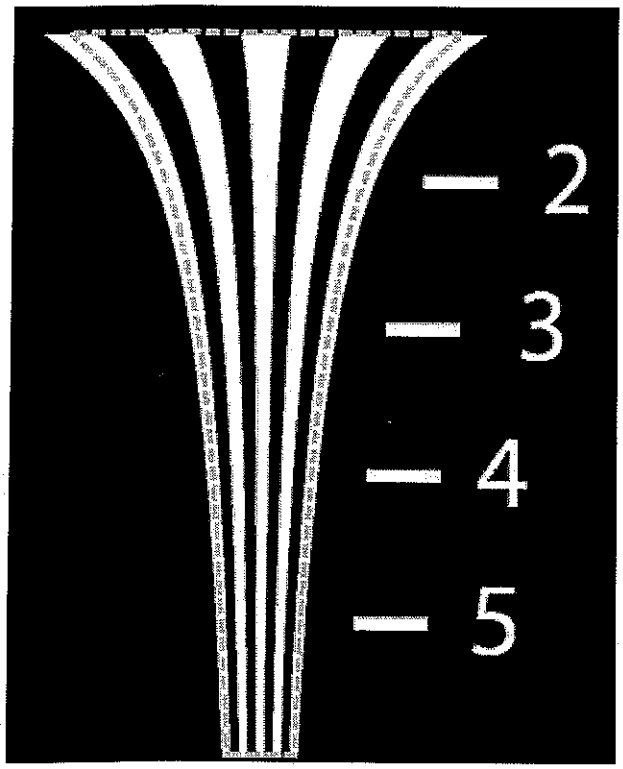
8.10.5.8 The procedure for testing image capturing software and hardware requires a download rate as specified.

8.10.6.7, 8.10.6.8, 8.10.6.9, 8.10.6.10 In the image color procedure this color is defined as having a luminosity as specified.

8.10.7.7 and 8.10.8 The parts of the Effective Temperature Range Test that involve testing for pixel saturation should be removed because they result in erroneous information.

8.12.4.6 The reference to the combined area of the emitting surface is incorrect, and should be deleted.

Committee Meeting Action: Accept



1801-2, Log # CP1

1801-3 Log #3 FAE-ELS **Final Action: Reject**
(7.1.7)

Submitter: Landon Borders, Bullard
Recommendation: Delete the following text:
~~7.1.7 Thermal imagers shall be tested for ingress protection (IP) rating as specified in IEC 60529, Degrees of protection provided by enclosures (IP Code), and shall have a rating of IP6X.~~
Substantiation: Testing for an IP rating of IP6X is unnecessary. The thermal imager is sufficiently tested for ingress during the Durability Test described in section 8.13, specifically during the dunk test described in sections 8.13.5.7, 8.13.5.7.2 and 8.13.5.8.3.
Committee Meeting Action: Reject
Committee Statement: It is the intent of the technical committee to test for dust. The IP6X test is testing for a different condition than the dunk test, so both tests need to remain in the standard.

1801-4 Log #CP2 FAE-ELS **Final Action: Accept**
(8.1.5.12)

Submitter: Technical Committee on Electronic Safety Equipment,
Recommendation: Revise 8.1.5.12 to read as follows:
8.1.5.12 A rectangular region of interest, encompassing at least 90 percent of the source target image <u>area</u> but excluding pixels...". (rest of paragraph to remain as written in 2010 edition).

Substantiation: Clarifies the definition of the region of interest.
Committee Meeting Action: Accept

1801-5 Log #4 FAE-ELS **Final Action: Accept in Principle**
(8.1.6.4.1)

Submitter: Landon Borders, Bullard
Recommendation: Revise text to read as follows:
~~The spatial resolution source target for o~~<u>O</u>ne randomly chosen specimen shall be rotated 180 degrees, such that the lower indices appear on the right side of the ~~spatial resolution source target~~ <u>specimen's display</u>. All other components of the equipment setup shall remain unchanged.
Substantiation: It is impractical to rotate the spatial resolution target due to its size and weight. Rotating the thermal imager 180 degrees accomplishes the same intent.
Committee Meeting Action: Accept in Principle
Revise text in 8.1.6.4.1 to read as follows:
8.1.6.4.1 For one randomly chosen specimen either the spatial resolution source target or the specimen shall be rotated 180 degrees, such that the lower indices appear on the right side of the specimen's display. All other components of the equipment setup shall remain unchanged.
Committee Statement: The proposed revised text allows the test lab the option of rotating the specimen or the target.

1801-6 Log #5 FAE-ELS Final Action: Accept
(8.1.6.11)

Submitter: Landon Borders, Bullard
Recommendation: Revise text to read as follows:
The captured images shall be rotated ~~45 degrees~~ such that the centerline of the converging lines of interest is vertical. The contrast transfer function *(CTF)* and the mean pixel intensity (μ) of the two sets of converging lines of the stencil pattern in the captured images shall be calculated at each of the numbered indices, beginning at 1 and ending at 9. ~~A~~ rRegions of interest that encloses each of the two sets of converging lines of the stencil pattern shall be used to select pixels for analysis.
Substantiation: The intent is to rotate the converging lines such that the center line is vertical. This is not necessarily accomplished by rotating the image 45 degrees.
There is more than one region of interest, so the last sentence should be pluralized.
Committee Meeting Action: Accept

1801-7 Log #6 FAE-ELS **Final Action: Accept in Principle**
(8.1.6.20)

Submitter: Landon Borders, Bullard
Recommendation: Revise text to read as follows:
The image quality probability *(PIQ)* shall be calculated for the nonuniformity procedure at setpoint temperatures of 1°C, 30°C, 100°C, 160°C, and 260°C (34°F, 86°F, 212°F, 320°F, and 500°F) as specified in Equation 8.1.6.19, where C is the CTF calculated at index 1 in 8.1.16.12, B is the average ~~brightness~~ mean pixel intensity μ calculated ~~in 8.1.6.14~~ in 8.1.5.14b for NU(1), NU(1), NU(30), NU(100), NU(160), and NU(260), SR is the spatial resolution calculated in 8.1.6.18, and UN is the nonuniformity value calculated in 8.1.5.16, NU(1), NU(30), NU(100), NU(160), and NU(260).
Substantiation: The image quality probability "B" coefficient calculation was improperly reported in the 1st edition for the uniformity procedure.
Committee Meeting Action: Accept in Principle
Revise text to read as follows:
8.1.6.20 The image quality probability *(PIQ)* shall be calculated for the nonuniformity procedure at setpoint temperatures of 1°C, 30°C, 100°C, 160°C, and 260°C (34°F, 86°F, 212°F, 320°F, and 500°F) as specified in Equation 8.1.6.19, where C is the CTF_1 value calculated in 8.1.6.12, B is the average ~~brightness~~ mean pixel intensity μ calculated ~~in 8.1.6.14~~ in 8.1.5.14b for NU(1), NU(30), NU(100), NU(160), and NU(260), SR is the spatial resolution calculated in 8.1.6.18, and NU is the nonuniformity value calculated in 8.1.5.16 for NU(1), NU(30), NU(100), NU(160), and NU(260), respectively.
Committee Statement: The committee accepted the proposal in principle and revised the text to include language that clarifies the values used for brightness in the PIQ calculation.

1801-8 Log #CP3 FAE-ELS **Final Action: Accept**
(Figure 8.10.4.3)

Submitter: Technical Committee on Electronic Safety Equipment,
Recommendation: In Figure 8.10.4.3, change the temperature from 30°C to 50°C. Also, move side dotted lines so that they go down the middle of the white bars on either side of the Figure.
Substantiation: To make Figure consistent with text.
Committee Meeting Action: Accept

1801-9 Log #7 FAE-ELS **Final Action: Reject**
(8.10.4.3.1)

Submitter: Landon Borders, Bullard
Recommendation: Revise text to read as follows:
The surface labeled 7hot shall range in temperature from ~~ambient~~ 50°C (122°F) to 550°C (1022°F) and shall fill at least 50 percent of the FOV. The radiation source producing the 7hot surface shall be a blackbody and shall have an emissivity of 0.95, ±0.03. The source target shall be calibrated at least every 6 months. The nonuniformity of the blackbody shall not exceed 0.02. The blackbody temperature accuracy shall be ±0.5°C (±1°F). The stability of the emitting surface temperatures shall be 0.15°C. The nonuniformity of the blackbody.
Substantiation: Blackbodies that meet the performance criteria detailed in this test are not typically designed for calibration below 50°C. The certified laboratories cannot perform tests using equipment operated outside of its calibrated range.
Committee Meeting Action: Reject
Committee Statement: This is part of a Tentative Interim Amendment going before the NFPA Standards Council in February 2011 which has also been added as a committee proposal.

1801-10 Log #CP4 FAE-ELS **Final Action: Accept**
(8.10.4.3.1)

Submitter: Technical Committee on Electronic Safety Equipment,
Recommendation: Revise first sentence to read in 8.10.4.3.1 to read as follows:
8.10.4.3.1 "...shall fill at least 50 percent of the area of the FOV." (Remaining paragraph text stays).
Substantiation: This proposed change clarifies the region of interest.
Committee Meeting Action: Accept

1801-11 Log #8 FAE-ELS **Final Action: Accept**
(8.10.5.5)

Submitter: Landon Borders, Bullard
Recommendation: Revise text to read as follows:
8.10.5.5 All surface temperatures in the FOV shall be ~~adjusted to~~ set at the assigned temperatures and shall be allowed to come to steady-state prior to starting the test.
Substantiation: Add clarification that the blackbodies must be steady state prior to the test and not during the test.
Committee Meeting Action: Accept

1801-12 Log #CP5 FAE-ELS **Final Action: Accept**
(8.10.6.1, 8.10.7.1)

Submitter: Technical Committee on Electronic Safety Equipment,
Recommendation: Move 8.10.6.1 to a new paragraph 8.10.5.11.
Delete 8.10.7.1. Renumber existing paragraphs in 8.10.6 and 8.10.7.
Substantiation: Procedure required in 8.10.7.1 is redundant. Test procedure is more applicable under the General Procedure in 8.10.5.
Committee Meeting Action: Accept

1801-13 Log #CP6 FAE-ELS Final Action: Accept
(8.10.7.3)

Submitter: Technical Committee on Electronic Safety Equipment,
Recommendation: Revise first sentence in 8.10.7.3 to read as follows:
8.10.7.3 The bar contrast, *C*, shall be calculated for the bar region of interest of ~~for~~ each image as specified...".
(Remainder of paragraph to remain as written in the 2010 edition).
Substantiation: More specifically define and clarify the region of interest.
Committee Meeting Action: Accept

1801-14 Log #1 FAE-ELS Final Action: Accept
(B.1.2.3)

Submitter: John F. Bender, Underwriters Laboratories Inc.
Recommendation: Revise text to read as follows:
B.1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096
UL 1642, Standard for Lithium Batteries, 2005, Revised 2009.
UL 2054, Standard for Household and Commercial Batteries, 2004, Revised 2009.
Substantiation: Update referenced standards to most recent revisions.
Committee Meeting Action: Accept

NFPA 1801
Standard on
Thermal Imagers for the Fire Service

2012 Edition Preprint

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Information on referenced publications can be found in Chapter 2 and Annex B.

Chapter 1 Administration

1.1 Scope.

1.1.1 This standard shall specify the design, performance, testing, and certification requirements for thermal imagers used by fire service personnel during emergency incident operations.

1.1.2 This standard shall specify requirements for new thermal imagers for the fire service.

1.1.3 This standard shall not specify requirements for thermal imagers manufactured prior to the effective date of this standard.

1.1.4 This standard shall not specify requirements for thermal imagers manufactured to any other standards or other requirements.

1.1.5* Any accessories or enhancements built into, attached to, or sold with the thermal imager by the thermal imager manufacturer for later attachment shall be tested with the thermal imager with those accessories and enhancements installed or attached, as specified in 4.3.9.4, to ensure the performance and functions of the thermal imager.

1.1.6 This standard shall not be construed as addressing all of the safety concerns, if any, associated with the use of this standard by testing facilities. It shall be the responsibility of the persons and organizations that use this standard to establish safety and health practices and to determine the applicability of regulatory limitations prior to use of this standard for designing, manufacturing, and testing.

1.1.7 Nothing herein shall restrict any jurisdiction or manufacturer from exceeding these minimum requirements.

1.2 Purpose.

1.2.1 The purpose of this standard shall be to establish minimum requirements for thermal imagers manufactured for fire service use.

1.2.2 Controlled laboratory tests used to determine compliance with the performance requirements of this standard shall not be deemed as establishing performance levels for all situations, environments, and conditions to which thermal imagers could be exposed.

1.2.3 This standard shall not be interpreted or used as a detailed manufacturing or purchase specification, but it shall be permitted to be referenced in purchase specifications as minimum requirements.

1.3 Application.

1.3.1 This standard shall apply to all thermal imagers used by fire service personnel during an emergency incident.

1.3.2 This standard shall apply to the design, performance, manufacturing, testing, and certification of new thermal imagers used by fire service personnel.

1.3.3 This standard shall not apply to any thermal imager manufactured in accordance with other standards. However, manufacturers shall be permitted to have noncompliant thermal imagers modified to meet the requirements of this standard and become certified as compliant with this standard.

1.3.4* This standard shall not apply to accessories and enhancements that could be built into or attached to a certified thermal imager before or after purchase but that are not necessary for the thermal imager to meet the requirements of this standard. Any accessories or enhancements built into, attached to, or sold with the thermal imager by the thermal imager manufacturer for later attachment shall be tested with the thermal imager with those accessories and enhancements installed or attached, as specified in 4.3.9.4, to ensure the performance and functions of the thermal imager.

1.3.5 This standard shall not apply to criteria for use of thermal imagers by the fire service.

1.4 Units.

1.4.1 In this standard, values for measurement are followed by an equivalent in parentheses, but only the first stated value shall be regarded as the requirement.

1.4.2 Equivalent values in parentheses shall not be considered as the requirement because those values are approximate.

Chapter 2 Referenced Publications

2.1 General.

The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting,* 2007 edition.

2.3 Other Publications.

2.3.1 ANSI Publications.

American National Standards Institute, Inc., 25 West 43d Street, 4th Floor, New York, NY 10036.

ANSI/ISA-12.12.01, *Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations,* 2007.

2.3.2 ASTM Publications.

ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM B 117, *Standard Test Method for Salt Spray (Fog) Testing*, 1985.

ASTM D 1003, *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics,* 2000.

2.3.3 ISO/IEC Publications.

International Standards Organization, 1 rue de Varembé, Case Postale 56, CH-1211 Genéve 20, Switzerland.

IEC 60529, *Degrees of protection provided by enclosures (IP Code)* Ed. 2.1 b:2001.

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*, 2005.

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial, and light-industrial environments,* 2007.

ISO 27, *Guidelines for corrective action to be taken by a certification body in the event of misuse of its mark of conformity*, 1983.

ISO 65, *General requirements for bodies operating product certification systems*, 1998.

ISO 9001, *Quality management systems – Requirements*, 2008.

ISO 17011, *Conformity assessment – General requirements for accreditation bodies accrediting conformity assessment bodies*, 2004.

ISO 17025, *General requirements for the competence of testing and calibration laboratories*, 2005/Cor 1: 2006.

ISO 17493, *Clothing and equipment for protection against heat – Test method for convective heat resistance using a hot air circulating oven*, 2000.

ISO/IEC 17021, *Conformity assessment – Requirements for bodies providing audit and certification of management systems*, 2006.

2.3.4 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections. (Reserved)

Chapter 3 Definitions

3.1 General.

The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's*

Collegiate Dictionary, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3* General Definitions.

3.3.1 Assembly. Processes including, but not limited to, sewing, gluing, laminating, tacking, or other means of attaching whereby materials or component parts are put together to form a portion of the compliant product or the complete compliant product.

3.3.2 Blackbody. An object that absorbs all electromagnetic radiation that falls onto it; no radiation passes through the object, and none is reflected.

3.3.3 Certification Organization. An independent third-party organization that determines product compliance with the requirements of this standard using product testing and evaluation and that administers a labeling, listing, and follow-up program.

3.3.4 Certification/Certified. A system whereby a certification organization determines that a manufacturer has demonstrated the ability to produce a product that complies with the requirements of this standard, authorizes the manufacturer to use a label on listed products that comply with the requirements of this standard, and establishes a follow-up program conducted by the certification organization as a check on the methods the manufacturer uses to determine continued compliance of labeled and listed products with the requirements of this standard.

3.3.5 Compliance/Compliant. Meeting or exceeding all applicable requirements of this standard.

3.3.6 Compliant Product. Equipment that is certified to the applicable NFPA standard.

3.3.7 Component. Any material, part, or subassembly used in the construction of the compliant

product.

3.3.8 Drip. To run or fall in drops or blobs.

3.3.9 Emissivity. The ratio of the radiation emitted by a surface to the radiation emitted by a blackbody at the same temperature.

3.3.10 Failure Mode and Effects Analysis (FMEA). A risk assessment technique for systematically identifying potential failures in a system or a process.

3.3.11 Follow-Up Program. The sampling, inspections, tests, or other measures conducted by the certification organization on a periodic basis to determine the continued compliance of labeled and listed products that are being produced by the manufacturer to the requirements of this standard.

3.3.12 Haze. Light that is scattered as a result of passing through a transparent object.

3.3.13 Icon. A symbol that represents an option, program, or system status.

3.3.14 Luminance. A photometric measure of the amount of light that passes through or is emitted from a particular area.

3.3.15 Manufacturer. The entity that directs and controls any of the following: compliant product design, compliant product manufacturing, or compliant product quality assurance; also, the entity that assumes liability for the compliant product or provides the warranty for the compliant product.

3.3.16 Melt. A response to heat by a material resulting in evidence of flowing or dripping.

3.3.17 Pixel Saturation. Incident energy that causes a sensor to respond at its maximum value.

3.3.18 Power Source Indicator. A visual signal displayed on a thermal imager that indicates the status of the power supply.

3.3.19 Product. See 3.3.6, Compliant Product.

3.3.20* Product Label. A marking provided by the manufacturer for each compliant product containing compliance statements, certification statements, manufacturer, model information, or similar data.

3.3.21 Resolution. Separation or division into constituent or elementary parts as expressed by the number of pixels in the displayed image.

3.3.22 Sample. Equipment or equipment components that are randomly selected from the manufacturer’s production line, from the manufacturer’s inventory, or from the open market.

3.3.23 Sensitivity. The degree of response of a receiver or instrument to an incoming signal or to a change in the incoming signal.

3.3.23.1 Low Sensitivity. The least thermally sensitive operational mode, used to increase the thermal imager’s temperature range.

3.3.24 Sensitivity Mode. An operational function that relates to the degree to which temperature differences are resolved.

3.3.25 Specimen. The item that undergoes testing; the conditioned equipment or equipment component that is tested. Specimens are taken from samples. *(See also 3.3.22, Sample.)*

3.3.26 Temperature Measurement Zone. A transparent green square that aids in aiming a thermal imager for temperature measurements.

3.3.27 White-Hot Polarity. A display methodology whereby a grayscale image is created based on the fact that the warmest object in the field of view is the whitest object.

Chapter 4 Certification

4.1 General.

4.1.1 For the process of certification of thermal imagers as being compliant with NFPA 1801, all such thermal imagers shall meet the requirements of Section 4.1, General; Section 4.2, Certification Program; Section 4.3, Inspection and Testing; Section 4.4, Annual Verification of Product Compliance; Section 4.5, Manufacturers' Quality Assurance Program; Section 4.6, Hazards Involving Compliant Product; Section 4.7, Manufacturers' Investigation of Complaints and Returns; and Section 4.8, Manufacturers' Safety Alert and Product Recall Systems.

4.1.2 All certification shall be performed by a certification organization that meets at least the requirements specified in Section 4.2, Certification Program, and that is accredited for personal protective equipment in accordance with ISO 65, *General requirements for bodies operating product certification systems*. The accreditation shall be issued by an accreditation body operating in accordance with ISO 17011, *General requirements for accreditation bodies accrediting conformity assessment bodies*.

4.1.3 Manufacturers shall not claim compliance with portions or segments of the requirements of this standard and shall not use the NFPA name or the name or identification of this standard, NFPA 1801, in any statements about their respective product(s) unless the product(s) is certified as compliant to this standard.

4.1.4 Where thermal imagers are compliant, the product shall be labeled and listed.

4.1.5 Where thermal imagers are compliant, the product shall also have a product label that meets the requirements specified in Section 5.1, Product Label Requirements.

4.1.6 The certification organization's label, symbol, or identifying mark shall be attached to the product label, shall be part of the product label, or shall be immediately adjacent to the product label.

4.2 Certification Program.

4.2.1 The certification organization shall not be owned or controlled by manufacturers or vendors of the product being certified.

4.2.2 The certification organization shall be primarily engaged in certification work and shall not have a monetary interest in the product's ultimate profitability.

4.2.3 The certification organization shall be accredited for personal protective equipment in accordance with ISO 65, *General requirements for bodies operating product certification systems*. The accreditation shall be issued by an accreditation body operating in accordance with ISO 17011, *General requirements for accreditation bodies accrediting conformity assessment bodies.*

4.2.4 The certification organization shall refuse to certify products to this standard that do not comply with all applicable requirements of this standard.

4.2.5 The contractual provisions between the certification organization and the manufacturer shall specify that certification is contingent on compliance with all applicable requirements of this standard.

4.2.5.1 The certification organization shall not offer or confer any conditional, temporary, or partial certifications.

4.2.5.2 Manufacturers shall not be authorized to use any label or reference to the certification

organization on products that are not compliant with all applicable requirements of this standard.

4.2.6 The certification organization shall have laboratory facilities and equipment available for conducting proper tests to determine product compliance.

4.2.6.1 The certification organization laboratory facilities shall have a program in place and functioning for calibration of all instruments, and procedures shall be in use to ensure proper control of all testing.

4.2.6.2 The certification organization laboratory facilities shall follow good practice regarding the use of laboratory manuals, form data sheets, documented calibration and calibration routines, performance verification, proficiency testing, and staff qualification and training programs.

4.2.7 The certification organization shall require the manufacturer to establish and maintain a quality assurance program that meets the requirements of Section 4.5, Manufacturers' Quality Assurance Program.

4.2.7.1 The certification organization shall require the manufacturer to have a product recall system specified in Section 4.8, Manufacturers' Safety Alert and Product Recall Systems, as part of the manufacturers' quality assurance program.

4.2.7.2 The certification organization shall audit the manufacturer's quality assurance program to ensure that the quality assurance program provides continued product compliance with this standard.

4.2.8 The certification organization and the manufacturer shall evaluate any changes affecting the form, fit, or function of the compliant product to determine its continued certification to this standard.

4.2.9 The certification organization shall have a follow-up inspection program of the manufacturer's facilities of the compliant product with at least two random and unannounced visits per 12-month period to verify the product's continued compliance.

4.2.9.1 As part of the follow-up inspection program, the certification organization shall select sample compliant product at random from the manufacturer's production line, from the manufacturer's in-house stock, or from the open market.

4.2.9.2 Sample product shall be evaluated by the certification organization to verify the product's continued compliance in order to ensure that the materials, components, and manufacturing quality assurance systems are consistent with the materials, components, and manufacturing quality assurance that were inspected and tested by the certification organization during initial certification and recertification.

4.2.9.3 The certification organization shall be permitted to conduct specific testing to verify the product's continued compliance.

4.2.9.4 For products, components, and materials where prior testing, judgment, and experience of the certification organization have shown results to be in jeopardy of not complying with this standard, the certification organization shall conduct more frequent testing of sample product, components, and materials acquired in accordance with 4.2.9.1 against the applicable requirements of this standard.

4.2.10 The certification organization shall have in place a series of procedures, as specified in Section 4.6, Hazards Involving Compliant Product, that address reports of situations in which a compliant product is subsequently found to be hazardous.

4.2.11 The certification organization's operating procedures shall provide a mechanism for the

manufacturer to appeal decisions. The procedures shall include the presentation of information from both sides of a controversy to a designated appeals panel.

4.2.12 The certification organization shall be in a position to use legal means to protect the integrity of its name and label. The name and label shall be registered and legally defended.

4.3 Inspection and Testing.

4.3.1 For both initial certification and recertification of compliant products, the certification organization shall conduct both inspection and testing as specified in this section.

4.3.2 All inspections, evaluations, conditioning, and testing for certification or for recertification shall be conducted by a certification organization's testing laboratory that is accredited in accordance with the requirements of ISO 17025, *General requirements for the competence of testing and calibration laboratories*.

4.3.2.1 The certification organization's testing laboratory's scope of accreditation to ISO 17025, *General requirements for the competence of testing and calibration laboratories*, shall encompass testing of personal protective equipment.

4.3.2.2 The accreditation of a certification organization's testing laboratory shall be issued by an accreditation body operating in accordance with ISO 17011, *General requirements for accreditation bodies accrediting conformity assessment bodies*.

4.3.3 A certification organization shall be permitted to utilize conditioning and testing results conducted by a product or component manufacturer for certification or recertification, provided the manufacturer's testing laboratory meets the requirements specified in 4.3.3.1 through 4.3.3.5.

4.3.3.1 The manufacturer's testing laboratory shall be accredited in accordance with the requirements of ISO 17025, *General requirements for the competence of testing and calibration laboratories*.

4.3.3.2 The manufacturer's testing laboratory's scope of accreditation to ISO 17025, *General requirements for the competence of testing and calibration laboratories*, shall encompass testing of personal protective equipment.

4.3.3.3 The accreditation of a manufacturer's testing laboratory shall be issued by an accreditation body operating in accordance with ISO 17011, *General requirements for accreditation bodies accrediting conformity assessment bodies*.

4.3.3.4 The certification organization shall approve the manufacturer's testing laboratory.

4.3.3.5 The certification organization shall determine the level of supervision and witnessing of the conditioning and testing for certification or recertification conducted at the manufacturer's testing laboratory.

4.3.4 Sampling levels for testing and inspection shall be established by the certification organization and the manufacturer to ensure a reasonable and acceptable reliability at a reasonable and acceptable confidence level that products certified to this standard are compliant, unless such sampling levels are specified herein.

4.3.5 Inspection and evaluation by the certification organization shall include a review of all product labels to ensure that all required label attachments, compliance statements, certification statements, and other product information are at least as specified for thermal imagers in Section 5.1, Product Label Requirements.

4.3.6 Inspection and evaluation by the certification organization shall include an evaluation of

any symbols and pictorial graphic representations used on product labels or in user information, as permitted in 5.1.5, to ensure that the symbols are clearly explained in the product's user information package.

4.3.7 Inspection and evaluation by the certification organization shall include a review of the user information required by Section 5.2, User Information, to ensure that the information has been developed and is available.

4.3.8 Inspection and evaluation by the certification organization for determining compliance with the design requirements specified in Chapter 6 shall be performed on whole or complete products.

4.3.9 Testing to determine compliance of the thermal imager, and the components that are necessary for the proper operation of the thermal imager, with the performance requirements specified in Chapter 7 shall be conducted by the certification organization in accordance with the specified testing requirements of Chapter 8. The order of testing shall be conducted as specified in Table 4.3.9.

Table 4.3.9 Test Matrix for Thermal Imagers

Test Order	Specimens 1–3	Specimens 4–6	Specimens 7–9	Specimens 10–12	Specimens 13–15	Specimens 16–18
1	Field of View Measurement Section 8.11 Specimens 1–3	Cable Pullout Test Section 8.9 Specimens 4–6	Field of View Measurement Section 8.11 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 10	Vibration Test Section 8.2 Specimen 13	Durability Test Section 8.13 Specimens 16–18
2	Image Recognition Test Section 8.1 Specimens 1–3	Impact Acceleration Resistance Test — Ambient Section 8.3 Specimen 4	Corrosion Test Section 8.4 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 11	Vibration Test Section 8.2 Specimen 14	Product Label Durability Test Section 8.8 Specimens 16–18
3	Image Color and Effective Temperature Range Test Section 8.10 Specimens 1–3	Impact Acceleration Resistance Test — Cold Section 8.3 Specimen 5	Product Label Durability Test Section 8.8 Specimens 7–9	Heat Resistance Test Section 8.6 Specimen 12	Vibration Test Section 8.2 Specimen 13–15	—
4	Thermal Sensitivity Test Section 8.12 Specimens 1–3	Impact Acceleration Resistance Test — Elevated Temperature Section 8.3 Specimen 6	—	Product Label Durability Test Section 8.8 Specimens 10–12	—	—
5	Heat and Flame Test Section 8.7 Specimen 1–3	—	—	—	—	—

4.3.9.1 Testing shall be performed on new thermal imager product.

4.3.9.2 Testing shall be performed on specimens representative of materials and components used in the actual construction of the compliant product.

4.3.9.3 The certification organization also shall be permitted to use sample materials cut from a representative product.

4.3.9.4 Where any accessories, enhancements, or both are built into, attached to, or detachable from the thermal imager, the certification organization shall inspect and evaluate the thermal imager as specified in Chapter 6 and shall test the thermal imager as specified in Chapter 8, and the thermal imager shall meet all the performance requirements specified in Chapter 7 with those accessories and enhancements installed or attached to ensure that the performance and functions of the thermal imager are not reduced or otherwise negatively affected.

4.3.10 The certification organization shall accept from the manufacturer, for evaluation and testing for certification, only product or product components that are the same in every respect as the actual final product or product component.

4.3.11 The certification organization shall not allow any modifications, pretreatment, conditioning, or other such special processes of the product or any product component prior to the product's submission for evaluation and testing by the certification organization.

4.3.12 The certification organization shall not allow the substitution, repair, or modification, other than as specifically permitted herein, of any product or any product component during testing.

4.3.13 The certification organization shall not allow test specimens that have been conditioned and tested for one method to be reconditioned and tested for another test method unless specifically permitted in the test method.

4.3.14 Material changes in the form, fit, or function of a compliant product shall necessitate new inspection and testing to verify compliance to all applicable requirements of this standard that the certification organization determines can be affected by such change. This recertification shall be conducted before labeling the modified product as being compliant with this standard.

4.3.15 The manufacturer shall maintain all design, performance, inspection, and test data from the certification organization used in the certification of the manufacturer's compliant product. The manufacturer shall provide such data, upon request, to the purchaser or authority having jurisdiction.

4.4 Annual Verification of Product Compliance.

4.4.1 All thermal imagers that are certified as compliant with this standard shall undergo recertification on an annual basis. This recertification shall include the following:

(1) Inspection and evaluation to all design requirements as required by this standard on all manufacturer models and components

(2) Testing to all performance requirements as required by this standard on all manufacturer models and components within the following protocol:

  (a) Where a test method incorporates testing both before and after preconditioning and the test generates quantitative results, recertification testing shall be limited to the conditioning that yielded the worst case test result during the initial certification for the model or component.

  (b) Where a test method requires testing of three specimens, a minimum of one

specimen shall be tested for annual recertification.

(c) Where a test method requires testing of five or more specimens, a minimum of two specimens shall be tested for annual recertification.

4.4.2 Samples of manufacturer models and components for recertification acquired from the manufacturer or a component supplier during random and unannounced visits as part of the follow-up inspection program in accordance with 4.2.9 shall be permitted to be used toward annual recertification.

4.4.3 The manufacturer shall maintain all design and performance inspection and test data from the certification organization used in the recertification of manufacturer models and components. The manufacturer shall provide such data, upon request, to the purchaser or authority having jurisdiction.

4.5 Manufacturers' Quality Assurance Program.

4.5.1 The manufacturer shall provide and operate a quality assurance program that meets the requirements of this section and that includes a product recall system as specified in 4.2.7.1 and Section 4.8, Manufacturers' Safety Alert and Product Recall Systems.

4.5.2 The operation of the quality assurance program shall evaluate and test compliant product production to the requirements of this standard to ensure that production remains in compliance.

4.5.3 The manufacturer shall be registered to ISO 9001, *Quality management systems – Requirements.*

4.5.3.1 Registration to the requirements of ISO 9001, *Quality management systems – Requirements,* shall be conducted by a registrar that is accredited for personal protective equipment in accordance with ISP/IEC 17021, *Conformity assessment – Requirements for bodies providing audit and certification of management systems*.

4.5.3.2 The scope of the ISO registration shall include at least the design and manufacturing systems management for the personal protective equipment being certified.

4.5.3.3 The registrar shall affix the accreditation mark on the ISO registration certificate.

4.5.4 Any entity that meets the definition of *manufacturer* specified in 3.3.15 and therefore is considered to be the "manufacturer" but that does not manufacture or assemble the compliant product shall meet the requirements specified in Section 4.5.

4.5.5 Where the manufacturer uses subcontractors in the construction or assembly of the compliant product, the locations and names of all subcontractor facilities shall be documented, and the documentation shall be provided to the manufacturer's ISO registrar and the certification organization.

4.6 Hazards Involving Compliant Product.

4.6.1 The certification organization shall establish procedures to be followed where situation(s) are reported in which a compliant product is subsequently found to be hazardous. These procedures shall comply with the provisions of ISO 27, *Guidelines for corrective action to be taken by a certification body in the event of misuse of its mark of conformity*, and as modified herein.

4.6.2 Where a report of a hazard involved with a compliant product is received by the certification organization, the validity of the report shall be investigated.

4.6.3 With respect to a compliant product, a hazard shall be a condition, or create a situation, that

results in exposing life, limb, or property to a dangerous or imminently dangerous condition.

4.6.4 Where a specific hazard is identified, the determination of the appropriate action for the certification organization and the manufacturer to undertake shall take into consideration the severity of the hazard and its consequences to the safety and health of users.

4.6.5 Where it is established that a hazard is involved with a compliant product, the certification organization shall determine the scope of the hazard, including products, model numbers, serial numbers, factory production facilities, production runs, and quantities involved.

4.6.6 The certification organization's investigation shall include, but not be limited to, the extent and scope of the problem as it might apply to other compliant product or compliant product components manufactured by other manufacturers or certified by other certification organizations.

4.6.7 The certification organization shall also investigate reports of a hazard where compliant product is gaining widespread use in applications not foreseen when the standard was written, such applications in turn being ones for which the product was not certified, and no specific scope of application has been provided in the standard, and no limiting scope of application was provided by the manufacturer in written material accompanying the compliant product at the point of sale.

4.6.8 The certification organization shall require the manufacturer of the compliant product or the manufacturer of the compliant product component if applicable, to assist the certification organization in the investigation and to conduct its own investigation as specified in Section 4.7, Manufacturers' Investigation of Complaints and Returns.

4.6.9 Where the facts indicating a need for corrective action are conclusive and the certification organization's appeal procedures referenced in 4.2.11 have been followed, the certification organization shall initiate corrective action immediately, provided there is a manufacturer to be held responsible for such action.

4.6.10 Where the facts are conclusive and corrective action is indicated, but there is no manufacturer to be held responsible, such as when the manufacturer is out of business or the manufacturer is bankrupt, the certification organization shall immediately notify relevant governmental and regulatory agencies and issue a notice to the user community about the hazard.

4.6.11 Where the facts are conclusive and corrective action is indicated, the certification organization shall take one or more of the following corrective actions:

(1) Parties authorized and responsible for issuing a safety alert shall be notified when, in the opinion of the certification organization, such a safety alert is necessary to inform the users.

(2) Parties authorized and responsible for issuing a product recall shall be notified when, in the opinion of the certification organization, such a recall is necessary to protect the users.

(3) The mark of certification shall be removed from the product.

(4) Where a hazardous condition exists and it is not practical to implement the corrective actions in 4.6.11(1), 4.6.11(2), or 4.6.11(3) or where the responsible parties refuse to take corrective action, the certification organization shall notify relevant governmental and regulatory agencies and issue a notice to the user community about the hazard.

4.6.12 The certification organization shall provide a report to the organization or individual identifying the reported hazardous condition and notify that organization or individual of the corrective action indicated or that no corrective action is indicated.

4.6.13 Where a change to an NFPA standard(s) is felt to be necessary, the certification

organization shall also provide a copy of the report and indicated corrective actions to the NFPA and shall also submit either a Public Proposal for a proposed change to the next revision of the applicable standard or a proposed Temporary Interim Amendment (TIA) to the current edition of the applicable standard.

4.7 Manufacturers' Investigation of Complaints and Returns.

4.7.1 Manufacturers shall provide corrective action in accordance with ISO 9001, *Quality management systems – Requirements*, for investigating written complaints and returned products.

4.7.2 Manufacturers' records of returns and complaints related to safety issues shall be retained for at least 5 years.

4.7.3 Where the manufacturer discovers, during the review of specific returns or complaints, that a compliant product or compliant product component can constitute a potential safety risk to end users and is possibly subject to a safety alert or product recall, the manufacturer shall immediately contact the certification organization and provide all information about its review to assist the certification organization with the investigation.

4.8 Manufacturers' Safety Alert and Product Recall Systems.

4.8.1 Manufacturers shall establish a written safety alert system and a written product recall system that describes the procedures to be used in the event that they decide or are directed by the certification organization to either issue a safety alert or conduct a product recall.

4.8.2 The manufacturers' safety alert and product recall systems shall provide the following:

(1) The establishment of a coordinator and responsibilities by the manufacturer for the handling of safety alerts and product recalls

(2) A method of notifying all dealers, distributors, purchasers, users, and the NFPA about the safety alert or product recall that can be initiated within 1 week following the manufacturer's decision to issue a safety alert or to conduct a product recall or after the manufacturer has been directed by the certification organization to issue a safety alert or conduct a product recall

(3) Techniques for communicating accurately and understandably the nature of the safety alert or product recall and, in particular, the specific hazard or safety issue found to exist

(4) Procedures for removing product that is recalled and for documenting the effectiveness of the product recall

(5) A plan for repairing or replacing product or for compensating purchasers for returned product

Chapter 5 Product Labeling and Information

5.1 Product Label Requirements.

5.1.1 Each compliant thermal imager shall have a product label permanently and conspicuously attached to the complete assembled product.

5.1.2 Multiple label pieces shall be permitted in order to carry all statements and information required to be on the product label; however, all label pieces that the product label comprises shall be located adjacent to each other.

5.1.3 The certification organization's label, symbol, or identifying mark shall be attached to the

product label or be part of the product label and shall be placed in a conspicuous location. All letters shall be at least 1.5 mm (1/32 in.) in height, and the label, symbol, or identifying mark shall be at least 6 mm (¼ in.) in height. The font Arial in capital letters shall be used for all label lettering.

5.1.4 All worded portions of the required product label shall be at least in English.

5.1.5 Symbols and other pictorial graphic representations shall be permitted to be used to supplement worded statements on the product label(s).

5.1.6 The following compliance statement shall be legibly printed on the product label.

"THIS THERMAL IMAGER MEETS THE REQUIREMENTS OF NFPA 1801, STANDARD ON THERMAL IMAGERS FOR THE FIRE SERVICE, 2010 EDITION.

DO NOT REMOVE THIS LABEL!"

5.1.7 Each thermal imager shall be marked directly with the serial number and the year and month of manufacture.

5.1.8 All rechargeable power sources provided by the thermal imager manufacturer shall be marked with a serial number and the year and date of manufacture.

5.2 User Information.

5.2.1 The manufacturer shall provide with each product at least the informational material and user instructions specified in Section 5.2.

5.2.2 At the time of purchase, the manufacturer shall provide to the purchaser an information sheet with each product that documents at least the following:

(1) Date of manufacture
(2) Model number
(3) Serial number
(4) Lot number, if applicable

5.2.3 Information and materials regarding pre-operational use shall be provided on at least the following areas.

(1) Safety considerations
(2) Pre-use checks
(3) Limitations of use
(4) Power source requirements, type, and brand
(5) Estimated operation time on fully charged power source in each available mode
(6) Low-power source signals and power supply replacement, where applicable
(7) Charging and recharging procedures
(8) Marking recommendations and restrictions
(9) Warranty information
(10) Recommended storage practices
(11) Mounting on/in vehicles or fire apparatus
(12) Explanation and identification of the features and functions of TI BASIC/TI BASIC

PLUS

(13) Symbols and functions with associated temperature references in available operating modes

(14) If equipped with a temperature bar, adequate description of the use of the temperature bar

(15) If equipped with a numeric temperature indicator, adequate description of the use of the numeric temperature indicator

(16) If equipped with colorization, adequate description of the temperature thresholds for colorization

5.2.4 Information and operational materials regarding periodic inspections shall be provided on at least inspection frequency and details.

5.2.5 Information and operational materials regarding proper operational use shall be provided.

5.2.6 Information and operational materials regarding periodic maintenance and cleaning shall be provided on at least the following areas:

(1) Cleaning instructions and precautions

(2) Disinfecting procedures

(3) Maintenance frequency and details

(4) Guidelines for service and repair

5.2.7 Information and operational materials regarding replacement and retirement considerations for thermal imagers and components shall be provided.

Chapter 6 Design Requirements

6.1 General Design Requirements.

6.1.1 All thermal imagers shall have at least the applicable design requirements specified in this chapter when inspected and evaluated by the certification organization as specified in Section 4.3, Inspection and Testing.

6.1.2* All thermal imagers shall be capable of continuously operating for a minimum of 120 minutes in TI BASIC mode without the power source being changed or recharged.

6.1.3 When powered on, all thermal imagers shall continuously detect and display as an image that portion of the electromagnetic spectrum occurring in the 8.0–14.0 micron range and shall include all components necessary for the intended proper operation of the thermal imager.

6.1.4 All operational selection devices, including but not limited to switches, card readers, and keys, shall be rated for a service life of not less than 50,000 cycles.

6.1.5 All operational selection devices shall be designed to prevent unintentional activation, deactivation, and change of operation.

6.1.6 All operational selection devices shall be capable of being switched by a gloved hand. The gloves used for this function test shall be certified as compliant with the structural fire-fighting glove requirements of NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*.

6.1.7 All thermal imagers shall be provided with a method of attaching the thermal imager to the user, and the method of attachment shall not degrade the function or performance of the thermal

imager.

6.2 Power Button.

6.2.1 The thermal imager shall have a power–on/off button that cycles the thermal imager's power. The power button shall be located in an easily accessible area of the thermal imager.

6.2.1.1 The power–on/off button shall be capable of being switched by a gloved hand. The gloves used for this function test shall comply with structural fire-fighting glove requirements of NFPA 1971, *Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*.

6.2.2 The power button shall be green in color. No other button(s) on the outside of the thermal imager shall be green in color.

6.2.3 The power button shall only turn the thermal imager "on," turn the thermal imager "off," and revert the thermal imager to the TI BASIC operational format from TI BASIC PLUS operational format.

6.2.4 When the thermal imager is off, the activation of the power–on/off button shall always power up the thermal imager in the TI BASIC operational format.

6.2.5 Where the power button is used to power up the thermal imager, the power-on process shall require the power button to be pressed and held for no more than 1 second.

6.2.5.1 Automatic activation of the power-up process shall be permitted.

6.2.5.2 Both the power button activation and the automatic activation shall present a useful thermal image on the display in 60 seconds or less.

6.2.6 The power–on/off button shall be protected from accidental change of operation and impact damage.

6.3 Failure Mode and Effects Analysis (FMEA) for Thermal Imagers.

6.3.1* An FMEA shall be applied throughout the development process.

6.3.2 The FMEA shall address thermal imager systems and shall identify and prioritize those critical failures that could have a serious effect on the safety and reliability of a thermal imager in the anticipated operating environments.

6.3.3 The FMEA shall tabulate potential failure modes and their effects on the performance of a thermal imager. The failure mode shall describe how the system might fail.

6.3.4* The thermal imager manufacturer shall use FMEA to address the reduction of risk of random and systematic failures of thermal imagers by using As Low As Reasonably Practical (ALARP) region activities, shown in Figure 6.3.4. The thermal imager manufacturer shall include the risk priority number (RPN) corresponding to the upper limit of the ALARP region in the FMEA report.

****INSERT EXISTING FIGURE 6.3.4 FROM 2010 EDITION****

FIGURE 6.3.4 ALARP Region Activities.

6.3.5 Where a thermal imager system RPN as determined by the manufacturer is above the upper limit of the ALARP region as determined by the manufacturer, one or more of the practices specified in 6.3.5.1 shall be permitted.

6.3.5.1 Verification of the manufacturers' design and testing practices shall include documentation of at least temperature, vibration, and wetness exposure data; hours of operation;

and management of change information.

6.3.6 The FMEA report shall be provided to the certification organization.

6.4 TI BASIC Operational Format.

6.4.1 All thermal imagers shall have at least the TI BASIC operational format and shall be permitted to also have a TI BASIC PLUS operational format as specified in Section 6.5, TI BASIC PLUS Operational Format.

6.4.2* When the thermal imager is initially powered on or restarted from the TI BASIC PLUS operational format, the thermal imager shall revert back to the TI BASIC operational format.

6.4.3 TI BASIC operational format functions shall include the following:

(1) Grayscale imagery with white-hot polarity

(2) Power source status

(3) Internal electronics overheat indicator

(4) Thermal imager “on” indicator

6.4.4 In addition to the requirements specified in 6.4.3, the TI BASIC operational format shall be permitted to also include the following:

(1) Heat indicating color and, if so equipped with heat indicating color, a color reference bar

(2) Temperature bar

(3) Numeric temperature measurement indicator

6.5 TI BASIC PLUS Operational Format.

6.5.1 TI BASIC PLUS operational format shall have at least the TI BASIC functions specified in 6.4.3, and any or all of the TI BASIC functions listed in 6.4.4 shall also be permitted.

6.5.2* TI BASIC PLUS operational format shall be permitted to have additional functions, enhancements, and innovations beyond TI BASIC, provided by the manufacturer, that require additional or specialized instruction or training in addition to the TI BASIC operational format training.

6.5.3 TI BASIC PLUS functions shall not result in failure to provide TI BASIC functions specified in 6.4.3, in whole or in part.

6.5.4 TI BASIC PLUS shall switch to TI BASIC by either of the following two methods: cycling the thermal imager’s power by pushing the green power–on/off button or pushing the green power–on/off button one time for no more than 1 second while the thermal imager is on.

6.5.5* TI BASIC PLUS shall be designed to limit access and shall have an alternative method of selecting the operational format other than that of TI BASIC.

6.6 Thermal Imager Viewing Area.

6.6.1 The thermal imager shall have a viewing area that contains operational information for the thermal imager user.

6.6.2 The viewing area shall consist of three vertical sections and shall include a maximum distance of 25 mm (1 in.) directly above, below, and on the sides of the display. The region consisting of a maximum distance of 25 mm (1 in.) directly above, below, and on the sides of the display shall be part of the viewing area.

6.6.3 Each of the three vertical sections shall be reserved to contain specific thermal imager additional information, alarm and operational indicators, and temperature sensing indicators as shown in Figure 6.6.3 and specified in 6.6.3.1 through 6.6.3.3.

****INSERT EXISTING FIGURE 6.6.3 FROM 2010 EDITION ***

FIGURE 6.6.3 Thermal Imager Viewing Areas and Icon Layout.

6.6.3.1 Additional Information Area, Left Vertical Section. The left vertical section shall be reserved for additional information in both the TI BASIC and TI BASIC PLUS operational formats utilizing standard icons/symbols and locations and shall include the following:

(1) Low sensitivity mode indicator

(2) TI BASIC PLUS activation, if so equipped

(3) Activation and status of optional TI BASIC PLUS features and functions, if so equipped

6.6.3.2 Alarm and Operational Indicator Area, Center Vertical Section. The center column of the display plane shall be reserved for the alarm and operational indicators and shall include the following:

(1) Power source status

(2) Temperature measurement zone, if so equipped

(3) Internal electronics overheat indicator

6.6.3.3 Temperature Sensing Indicators Area, Right Vertical Section. The right vertical viewing area shall be reserved for temperature sensing indicators and heat color reference bar(s).

6.6.4 Icon and Symbol Design. The icons for the TI BASIC and TI BASIC PLUS functions shall be as shown in Figure 6.6.4 and as specified in 6.6.4.1 through 6.6.4.8.

****INSERT EXISTING FIGURE 6.6.4 FROM THE 2010 EDITION ****

FIGURE 6.6.4 Icon Designs and Descriptions.

6.6.4.1 Temperature Sensing Indicators.

6.6.4.1.1 All thermal imagers equipped with spot temperature measurement shall have a visual temperature measurement zone indicator to provide the user an approximate location from which the temperature is being reported.

6.6.4.1.2 The temperature measurement zone indicator shall consist of a transparent square box or box corners with a green border as shown in Figure 6.6.4.

6.6.4.1.3 The temperature measurement zone indicator shall be positioned in the center of the center vertical viewing area (alarm and operational indicators) as shown in Figure 6.6.4.

6.6.4.1.4 Where the thermal imager is equipped with temperature measurement, the viewing area shall include a numeric temperature indicator, a temperature bar, or both.

6.6.4.1.5 The temperature bar shall be solid green in color. The temperature bar shall be calibrated to show four divided increments. The approximate temperature at each division shall be shown next to the temperature bar as shown in Figure 6.6.3 and 6.6.4. The temperature measurement bar shall be positioned in the right vertical viewing are (temperature sensing indicators) as shown on Figure 6.6.4.

6.6.4.1.6 The numeric temperature indicator shall display the approximate temperature emitted by an object targeted within the temperature measurement zone indicator as shown in Figure 6.6.4.

The numeric temperature indicator shall be positioned in the lower right vertical viewing area. This icon shall be readable green numerals followed by an “F” for Fahrenheit or “C” for Celsius superimposed on a black background.

6.6.4.1.7 Where the thermal imager is equipped with heat indicating color capability, the right vertical section of the viewing area shall include a heat color reference bar that shall include the hear color reference scale as described in 6.6.4.1.11.

6.6.4.1.8 Where equipped with heat indicating color capability, the heat color reference bar shall be located adjacent to the temperature bar, if equipped, and shall permit the user to interpret the approximate temperature reading displayed by the temperature bar as shown in Figure 6.6.4.

6.6.4.1.8.1 Where equipped with both the heat color reference bar and the temperature measurement bar, the heat color reference bar and the temperature measurement bar shall utilize only one set of temperature graduations.

6.6.4.1.8.2 Where equipped with only a heat color reference bar, the heat color reference bar shall have a graduation corresponding to the temperature settings of the thermal imager.

6.6.4.1.9 The temperature bar indicator shall be solid green in color. The temperature bar shall be calibrated to show four divided increments. Where a heat color reference bar is provided, the temperature bar shall advance vertically along the heat color reference bar in reference to the approximate temperature of the LWIR energy emitted by an object targeted by the temperature measurement zone.

6.6.4.1.10 The heat color reference bar shall be a vertical icon representing the entire dynamic range of the thermal imager in its current sensitivity mode and shall be divided into at least four temperature increments.

6.6.4.1.11 In the TI BASIC mode, the heat color reference bar shall have a color scale that includes only the following colorization:

(1) Transparent—at the bottom of the heat color reference bar before color indication begins

(2) Yellow—at the low end of the heat color reference bar

(3) Orange—in the middle of the heat color reference bar

(4) Red—at the high end of the heat color reference bar

6.6.4.1.11.1 When the thermal imager is operating in the TI BASIC mode and is equipped with automatic temperature indicating colorization, the colors, as specified in 6.6.4.1.11, shall correspond to approximate temperature ranges determined by the manufacturer.

6.6.4.1.11.2 The automatic temperature indicating color shall correspond to the colors on the heat color reference scale.

6.6.4.1.12 The heat color reference bar shall be legible, shall extend to at least 75 percent of the height of the thermal imager display, and shall be dynamic in that it will change if necessary to correspond to the temperatures set by the manufacturer in whatever sensitivity mode the thermal imager is in.

6.6.4.1.13 Whenever any change occurs in the scale of the color reference bar, a green triangle shall be displayed above and connected to the color reference bar as shown in Figure 6.6.4.

6.6.4.2 Automatic Heat Indicating Colorization.

6.6.4.2.1 Where the thermal imager is equipped with automatic heat indicating colorization, the TI BASIC and TI BASIC PLUS operational formats shall include colorization corresponding to

approximate temperatures determined and set by the manufacturer with an associated dynamic heat color reference bar.

6.6.4.2.2 Colorization shall overlay the grayscale thermal images produced by the thermal imager. Details within the thermal image and within the colorized area shall remain resolvable by the user other than at saturation.

6.6.4.2.3 The colors yellow, orange, and red shall have a corresponding, temperature-dependent change in hue as temperatures increase.

6.6.4.2.4 Light yellow shall be displayed to depict the lowest temperature within the yellow temperature band, and the hue shall gradually change to a darker yellow to depict hotter temperatures within the yellow temperature band.

6.6.4.2.5 Orange shall start immediately following the hottest temperature in the yellow temperature band. Light orange shall be displayed to depict the lowest temperature within the orange temperature band, and the hue shall gradually change to a darker orange to depict hotter temperatures within the orange temperature band.

6.6.4.2.6 Red shall start immediately following the hottest temperature in the orange temperature band. Light red shall be used to depict the lowest temperature within the red temperature band, and the hue shall gradually change to a darker red to depict hotter temperatures within the red temperature band. The darkest shade of red in the red color band shall correspond to the hottest temperature in the scene.

6.6.4.3 Power Source Status.

6.6.4.3.1 A visual indicator shall display the status of power source. The visual indicator shall be a black battery icon with four colored segments corresponding to the available power source as shown in Figure 6.6.4.

6.6.4.3.2 The black battery symbol shall display the state of the available capacity from full to nearly depleted as specified below:

(1) Four green segments displayed (76 to 100 percent available power source)

(2) Three green segments displayed (51 to 75 percent available power source)

(3) Two yellow segments displayed (26 to 50 percent available power source)

(4) One red segment displayed (0 to 25 percent available power source), which shall flash when at least 5 minutes of available power source remains

6.6.4.3.3 The power source status indicator shall be positioned anywhere in the alarm and operational indicators (center vertical) section of the viewing area.

6.6.4.4 Internal Electronics Overheat Indicator.

6.6.4.4.1 All thermal imagers shall be equipped with an internal electronics overheat indicator that provides a visual warning to the user that the thermal imager is about to shut down due to internal overheating.

6.6.4.4.2 The internal electronics overheat icon shall be positioned in the upper center vertical (alarm and operational indicators) section of the viewing area as shown in Figure 6.6.4.

6.6.4.4.3 The internal electronics overheat indicator shall be a flashing indicator consisting of a solid red thermometer-shaped image within a transparent equilateral triangle having a red border as shown in Figure 6.6.4.

6.6.4.5 Thermal Imager-On Indicator. A visual indicator to the user that the thermal imager is in

the powered-on operational mode shall be visible to the user any time the thermal imager is powered on.

6.6.4.6 Low Sensitivity Mode Indicator.

6.6.4.6.1 All thermal imagers equipped with a low sensitivity mode shall have a low sensitivity mode indicator.

6.6.4.6.2 The low sensitivity mode indicator shall be an icon consisting of a solid green equilateral triangle enclosed in a transparent square box with a green border as shown in Figure 6.6.4.

6.6.4.6.3 The low sensitivity mode indicator icon shall always be positioned in the uppermost left (additional information area) vertical section of the viewing area as shown in Figure 6.6.4.

6.6.4.6.4 Irrespective of number of sensitivity modes, the thermal imager shall display the low sensitivity mode indicator icon only when the thermal imager is not in its highest sensitivity mode.

6.6.4.7 TI BASIC PLUS Operational Format Indicator.

6.6.4.7.1 All thermal imagers equipped with a TI BASIC PLUS operational format shall have a TI BASIC PLUS operational format indicator. A visual indicator shall appear only when a thermal imager is in the TI BASIC PLUS mode.

6.6.4.7.2 The TI BASIC PLUS operational format indicator shall be an indicator consisting of a solid green “plus sign” (+) enclosed in a transparent square box with a green border as shown in Figure 6.6.4.

6.6.4.7.3 The TI BASIC PLUS operational format indicator shall be positioned in the lower left (additional information area) vertical section of the viewing area as shown in Figure 6.6.4.

6.6.4.7.4 The TI BASIC PLUS operational format indicator shall be displayed any time the thermal imager is not in the TI BASIC operational format irrespective of the number of operational formats.

6.6.4.8 TI BASIC PLUS Indicators.

6.6.4.8.1 Each visual indicator shall appear only when the associated feature is utilized.

6.6.4.8.2 Each TI BASIC PLUS option indicator shall consist of an indicator distinctly different from other icons.

6.6.4.8.3 Each TI BASIC PLUS option icon shall be displayed in the center of the left (additional information area) vertical section of the viewing area.

Chapter 7 Performance Requirements

7.1 Thermal Imager Performance Requirements.

7.1.1 Thermal imagers shall be tested for image recognition as specified in Section 8.1, Image Recognition Test, and shall have an image recognition test P_{IQ} value of at least 0.80.

7.1.2 Thermal imagers shall be tested for image nonuniformity as specified in Section 8.1, Image Recognition Test, and shall have an image nonuniformity P_{IQ} value of at least 0.80 for each of the temperatures specified in 8.1.5.8.

7.1.3 Thermal imagers equipped with heat indicating color in TI BASIC mode shall be tested for image color as specified in Section 8.10, Image Color and Effective Temperature Range Test, and

the temperatures T_Y, T_O, and T_R at which the heat indicating colors yellow, orange, and red, respectively, appear within 10 percent of the temperature ranges as identified in the manufacturer's literature pertaining to the thermal imager being tested.

7.1.4 Thermal imagers shall be tested for effective temperature range as specified in Section 8.10, Image Color and Effective Temperature Range Test, and shall have all P_{IQ} values be greater than or equal to 0.80.

7.1.5 Thermal imagers shall be tested for thermal sensitivity as specified in Section 8.12, Thermal Sensitivity Test, shall have a response slope greater than or equal to 0.02 per °C, and shall have a correlation coefficient greater than or equal to 0.80.

7.1.6 Thermal imagers shall be tested for listing to ANSI/ISA-12.12.01, *Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations*, and shall meet the requirements for at least Class I, Division 2, Groups C and D hazardous locations, and with a Temperature Class of T3 or T4 or T5 or T6. For the purpose of the impact test referenced in 15.4 of ANSI/ISA 12.12.01, NFPA 1801 shall be considered the applicable standard for products in unclassified locations.

7.1.7 Thermal imagers shall be tested for ingress protection (IP) rating as specified in IEC 60529, *Degrees of protection provided by enclosures (IP Code)*, and shall have a rating of IP6X.

7.1.8 Thermal imagers shall be tested for electromagnetic emission as specified in IEC 61000-6-3, *Electromagnetic Compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial, and light-industrial environments*, and shall meet the emissions requirements.

7.1.9 Thermal imagers shall be tested for electromagnetic immunity as specified in IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*, and shall meet the immunity requirements, and the thermal imager shall remain functional throughout the test.

7.1.10 Thermal imagers shall be tested for resistance to vibration as specified in Section 8.2, Vibration Test, and shall have a minimum image recognition test P_{IQ} value of 0.80.

7.1.11 Thermal imagers shall be tested for resistance to impact as specified in Section 8.3, Impact-Acceleration Resistance Test, and shall have a minimum image recognition test P_{IQ} value of 0.80 and shall have nothing fall off the thermal imager, and the thermal imager shall have no observable damage to any external component that would compromise the case integrity.

7.1.12 Thermal imagers shall be tested for corrosion resistance as specified in Section 8.4, Corrosion Test, and shall have metals that are inherently resistant to corrosion show no more than light surface-type corrosion or oxidation, shall have ferrous metals show no corrosion of the base metal, and shall have the use and function of controls and operating features of the thermal imager remain functional.

7.1.13 The thermal imager display viewing surface shall be tested for abrasion resistance as specified in Section 8.5, Viewing Surface Abrasion Test, and shall not have the viewing surface exhibit an average delta haze greater than 14 percent.

7.1.14 Thermal imagers shall be tested for resistance to heat as specified in Section 8.6, Heat Resistance Test, and shall have a minimum image recognition test P_{IQ} value of 0.80 and shall not have any part of the thermal imager melt, drip, or ignite.

7.1.15 Thermal imagers shall be tested for resistance to heat and flame as specified in Section 8.7, Heat and Flame Test, and shall not have any afterflame exceed 2.2 seconds, shall have nothing fall off the thermal imager, and shall not have the thermal imager fall from its mounted position.

7.1.16 Thermal imager product labels shall be tested for durability and legibility as specified in Section 8.8, Product Label Durability Test, and shall have the product labels remain attached to the thermal imager, and the product labels shall be legible.

7.1.17 Where thermal imagers incorporate external wiring, the wire's entry into any associated components shall be tested for connection strength as specified in Section 8.9, Cable Pullout Test, and shall have a minimum connection strength of 89 N (20 lbf), and the thermal imager shall remain functional.

7.1.18 Thermal imagers shall be tested for durability as specified in Section 8.13, Durability Test, and shall have the thermal imager remain functional, shall have a minimum image recognition test P_{IQ} value of 0.80, shall have no water inside the electronics compartment(s), and shall have no water inside the power source compartment(s).

7.1.19 Thermal imagers shall be tested for field of view as specified in Section 8.11, Field of View Measurement, and shall have a horizontal field of view of at least 36 degrees and shall have a vertical field of view of at least 20 degrees.

Chapter 8 Test Methods

8.1 Image Recognition Test.

8.1.1 Application. This test method shall apply to all thermal imagers.

8.1.2 Samples. Samples shall be complete thermal imagers.

8.1.3 Specimens.

8.1.3.1 Specimens for testing shall be complete thermal imagers.

8.1.3.2 A minimum of three specimens shall be tested.

8.1.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.1.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.1.4 Apparatus.

8.1.4.1 Testing shall be conducted in a room having an ambient temperature of 22°C, ±3°C (72°F, ±5°F).

8.1.4.2 The image recognition test apparatus shall consist of the following:

(1) A nonuniformity source target as specified in 8.1.4.3

(2) A thermal imager positioning device as specified in 8.1.4.4

(3) A spatial resolution source target as specified in 8.1.4.5

(4) Ten thermocouples as specified in 8.1.4.6

(5) Data acquisition software and hardware as specified in 8.1.4.7

(6) A thermal imager positioning device as specified in 8.1.4.8

(7) A visible spectrum camera, lens, and close-up filter as specified in 8.1.4.9

(8) A visible spectrum camera mount as specified in 8.1.4.10

(9) Image capturing software and hardware as specified in 8.1.4.11

(10) A computer and image analysis software as specified in 8.1.4.12

8.1.4.2.1 The thermal imager shall be set up at a distance of 1 m (40 in.) from the image recognition target.

8.1.4.2.2 The ambient lighting in the testing room shall be 1 lux or less.

8.1.4.2.3 The test operator shall have 20/20 vision.

8.1.4.3 The nonuniformity source target shall be a flat-surface, extended-area blackbody. The emitting surface shall have dimensions of at least 101 mm × 101 mm (4 in. × 4 in.) and shall have an emissivity of 0.95, ±0.03. The source target shall be calibrated every 6 months. The nonuniformity of the emitting surface shall not exceed 0.02 using the method in 8.1.5.14 as applied to temperature measurement of the surface of the black body. The emitting surface temperature accuracy shall be 0.02°C or better for setpoint temperatures of 0°C to 160°C and shall be 0.5°C or better for setpoint temperatures above 160°C. The stability of the emitting surface temperatures shall be 0.01°C or better for setpoint temperatures of 0°C to 160°C and shall be 0.15°C or better for setpoint temperatures above 160°C.

8.1.4.4 The thermal imager positioning device shall position the thermal imager in front of the nonuniformity source target such that the target fills the thermal imager's field of view (FOV). The thermal imager shall not be required to be in focus. The thermal imager shall be centered on the nonuniformity source target with the line of sight perpendicular to the plane of the source target. The thermal imager shall not wobble, vibrate, or otherwise move out of position during the course of the test. When placed or replaced in the positioning device, the thermal imager shall always be positioned at the same distance, angle, and attitude relative to the nonuniformity source target.

8.1.4.5 The spatial resolution source target shall consist of two thin, rigid, flat metal surfaces: the emitting surface and the stencil. The metal shall be copper for the emitting surface and aluminum for the stencil as detailed in Figure 8.1.4.5. Each surface shall have dimensions of 3 mm, ±0.5 mm, × 610 mm, ±2 mm, × 915 mm, ±2 mm (0.12 in., ±0.02 in., × 24 in., ±0.08 in., × 36 in. ±0.08 in.). One side of both surfaces shall be painted with flat black paint having a stated emissivity of 0.95, ±0.03.

****INSERT EXISTING FIGURE 8.1.4.5 FROM 2010 EDITION****

FIGURE 8.1.4.5 Image Recognition Source Target.

8.1.4.5.1 The emitting surface shall be capable of being evenly heated to a surface temperature of 28°C, ±0.5°C (82°F, ±1°F). The mechanism by which the emitting surface is heated shall not be visible to the thermal imager under test. The heating mechanism shall be permitted to add thickness to the side of the surface that does not face the thermal imager during the test.

8.1.4.5.2 The stencil shall be held at ambient temperature and shall have a pattern cut cleanly through it as shown in gray in Figure 8.1.4.5.

8.1.4.5.3 Both surfaces shall be mounted such that their painted sides face the thermal imager under test, with the stencil placed directly between the emitting surface and the thermal imager at a distance of 102 mm, ±6 mm (4 in., ±¼ in.), from the emitting surface.

8.1.4.6 Ten Type J thermocouples having a temperature measurement accuracy of 1.1°C and a response time of less than 1 second shall be secured to the surfaces of the source target facing the

thermal imager under test as shown in Figure 8.1.4.5.

8.1.4.6.1 Five thermocouples shall be secured to the emitting surface, and five thermocouples shall be secured to the stencil. The thermocouples and thermocouple leads secured to the emitting surface shall not be visible to the thermal imager under test.

8.1.4.6.2 The thermocouple leads secured to the stencil surface shall be painted with flat black paint having a stated emissivity of 0.95, ±0.03, and shall not cross any of the open areas of the pattern cut into the stencil.

8.1.4.7 The data acquisition system, consisting of software and hardware, shall be capable of acquiring thermocouple signals collected from the source target.

8.1.4.7.1 The data acquisition system shall average temperature measurements over 1 second.

8.1.4.7.2 The data acquisition system shall store the averaged temperature measurements in an electronic text file at a rate of at least one measurement per thermocouple per second.

8.1.4.8 The thermal imager positioning device shall position the thermal imager facing the spatial resolution source target at a distance of 1 m (40 in.) from the stencil. The thermal imager shall be centered on the spatial resolution source target with the line of sight perpendicular to the plane of the source target.

8.1.4.8.1 The thermal imager shall not wobble, vibrate, or otherwise move out of position during the course of the test.

8.1.4.8.2 When placed or replaced in the positioning device, the thermal imager shall always be positioned at the same distance, angle, and attitude relative to the spatial resolution source target.

8.1.4.9 The visible spectrum camera shall be a Nikon D3; the lens shall be a Nikkor 28 mm, f/2.8; the close-up filter shall be +10; and the shutter shall be activated by a remote trigger release. Other lenses and filters of equivalent quality shall be permitted to be used in cases where the thermal imager display size or configuration is incompatible with the use of the Nikkor 28 mm, f/2.8; and the +10 close-up filter.

8.1.4.9.1 The Nikon D3 shall be calibrated for color and luminance every 12 months.

8.1.4.9.2 The Nikon D3 settings shall be as listed below; Nikon D3 settings not listed shall remain set at the factory default selections:

(1) ISO Setting = 200
(2) Image Quality = NEF (RAW)
(3) White Balance = Direct Sunlight
(4) Focus Point = Center
(5) Exposure Mode = Shutter Priority
(6) Exposure Compensation = 0
(7) Bracketing = Off
(8) Image Area/Auto DX Crop = Off
(9) Image Area = FX Format
(10) NEF (RAW) recording/Type = Uncompressed
(11) NEF (RAW) recording/Bitdepth = 14 Bit (images stored as 16 Bit)
(12) NEF (RAW) recording/Picture Control = Neutral

(13) NEF (RAW) recording/Colorspace = sRGB

(14) NEF (RAW) recording/High ISO NR = Off

(15) Live View Mode = Tripod

(16) Release Mode = Live View with Framing Grids

(17) Metering Method = 3D Color Matrix II

(18) Shutter Speed = $^1/_6$ second

(19) Focus Mode Selector = Manual

8.1.4.10 The visible spectrum camera shall be mounted such that the thermal imager display fills 90 percent of the FOV in the vertical dimension and is in focus.

8.1.4.10.1 The visible spectrum camera shall not wobble, vibrate, or otherwise move out of position during the course of the test.

8.1.4.10.2 A black shroud shall be placed around the viewpath of the visible spectrum camera to block out all glare from the surrounding environment.

8.1.4.10.3 When placed or replaced in the visible spectrum camera mount, the visible spectrum camera shall always be positioned at the same distance, angle, and attitude relative to the thermal imager's display.

8.1.4.11 The image capturing software and hardware shall permit 16-bit uncompressed color images to be downloaded from the visible spectrum camera to a computer or memory at a rate of one image every 3 seconds, ±0.1 second.

8.1.4.12 The image analysis software shall open 16-bit uncompressed color image files, convert the image files to 16-bit uncompressed grayscale images, determine the pixel intensities of selected pixels, calculate the contrast transfer function of the selected pixels, and write the results to an electronic text file.

8.1.5 Nonuniformity Procedure.

8.1.5.1 The thermal imager lens and display and the visible spectrum camera lens shall be cleaned in accordance with the manufacturer's specifications. If they exist, condensation and frost shall be removed.

8.1.5.2 The thermal imager shall be equipped with a fully charged power source.

8.1.5.3 The thermal imager shall be activated 3 minutes, ±1 minute, prior to the beginning of the test. Specimens shall operate in the TI BASIC mode.

8.1.5.4 The nonuniformity source target shall be stabilized to within ±0.02°C (±0.036°F) of each set point temperature lower than or equal to 160°C (320°F) prior to conducting the test and shall be stabilized to within ±0.5°C (±0.9°F) of the setpoint measurement temperature at 260°C (500°F).

8.1.5.5 The thermal imager shall be positioned such that the nonuniformity source target fills the entire FOV and the thermal imager's line of sight is perpendicular to the nonuniformity source target surface.

8.1.5.6 The visible spectrum camera shall be mounted such that the thermal imager display fills 90 percent of the FOV in the vertical dimension and is in focus.

8.1.5.7 A black shroud shall be placed around the viewpath of the visible spectrum camera to block all glare incident upon the thermal imager display from the surrounding environment. The shroud shall be held securely in place and shall not be disturbed during the course of each test.

8.1.5.8 Each thermal imager shall be tested with the nonuniformity source target at setpoint temperatures of 1°C (34°F), 30°C (86°F), 100°C (212°F), 160°C (320°F), and 260°C (500°F). Where one or more setpoints fall within 10°C (18°F) of a shift condition defined by the manufacturer, the setpoint at that temperature shall be shifted down by 10°C (18°F).

8.1.5.9 A minimum of 10 uncompressed color images at a minimum bit depth of 16 bits shall be captured from the visible spectrum camera at a rate of one image every 3 seconds, ±0.1 second, at each nominal measurement temperature. The image having the lowest contrast shall be excluded.

8.1.5.10 After data collection is complete at each setpoint temperature, the thermal imager shall be removed from its position in front of the source target within 60 seconds.

8.1.5.11 The images captured from the visible spectrum camera shall be converted to uncompressed grayscale images having a minimum bit depth of 16 bits using Equation 8.1.5.11.

(8.1.5.11) $$\text{Grayscale} = 0.30 \times \text{red} + 0.59 \times \text{green} + 0.11 \times \text{blue}$$

8.1.5.12 A rectangular region of interest, encompassing at least 90 percent of the source target image area but excluding pixels located along the edge of the nonuniformity source target, shall be used to select pixels for analysis. Pixels within the region of interest that represent symbols, icons, and text shall be excluded from the analysis. The same region of interest shall be used on all the images captured throughout the nonuniformity procedure.

8.1.5.13 The high frequency noise created by oversampling the thermal imager's display shall be removed from the captured images. A moving average in two dimensions shall be applied to the region of interest, with the average having a period equal to the width and height of the thermal imager display pixels observed in the captured images.

8.1.5.14 Each image shall be analyzed by calculating the standard deviation (σ) of the selected pixel intensities using Equation 8.1.5.14a, and then dividing by the mean (μ) of the pixel intensities using Equation 8.1.5.14b, where N is the total number of pixels and x_i is each individual pixel intensity value. These equations shall define the nonuniformity for each individual image.

(8.1.5.14a) $$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

(8.1.5.14b) $$\mu = \frac{1}{N}\sum_{i=1}^{N}x_i$$

8.1.5.15 The individual image nonuniformities shall be ranked from the highest to the lowest values, and the images having nonuniformities in the highest 10 percent of values shall be excluded from further analysis. The nonuniformity values of the remaining images captured at each setpoint temperature shall be averaged. Where the standard deviation of the remaining nonuniformity values is larger than 10 percent of the mean of the nonuniformity values, the test operator shall repeat the test once.

8.1.5.16 The averaged nonuniformity values taken at 1°C, 30°C, 100°C, 160°C, and 260°C (34°F, 86°F, 212°F, 320°F, and 500°F) shall be NU(1), NU(30), NU(100), NU(160), and NU(260), respectively.

8.1.6 Spatial Resolution Procedure.

8.1.6.1 The thermal imager lens and display and the visible spectrum camera lens shall be cleaned in accordance with the manufacturer's specifications. If they exist, condensation and frost

shall be removed.

8.1.6.2 The thermal imager shall be activated 3 minutes, ± 1 minute, prior to the beginning of the test. Specimens shall operate in the TI BASIC mode.

8.1.6.3 The spatial resolution source target emitting surface temperature shall be stabilized at 28°C, ±0.5°C (82°F, ±1°F).

8.1.6.4 The thermal imager shall be positioned facing the spatial resolution source target at a distance of 1 m, ±5 mm (40 in., ±0.2 in.), from the stencil. The thermal imager shall be centered on the spatial resolution source target with the line of sight perpendicular to the plane of the source target.

8.1.6.4.1 For one randomly chosen specimen either the spatial resolution source target or the specimen shall be rotated 180 degrees, such that the lower indices appear on the right side of the spatial resolution source target. All other components of the equipment setup shall remain unchanged.

8.1.6.5 The visible spectrum camera shall be placed at the optimum viewing position with respect to the thermal imager display such that the thermal imager display fills 90 percent of the FOV in the vertical dimension and is in focus.

8.1.6.6 A black shroud shall be placed around the viewpath of the visible spectrum camera to block out all glare incident upon the thermal imager display from the surrounding environment. The shroud shall be held securely in place and shall not be disturbed during the course of each test.

8.1.6.7 A minimum of 10 uncompressed color images at a minimum bit depth of 16 bits shall be captured from the visible spectrum camera at a rate of one image every 3 seconds, ±0.1 second.

8.1.6.8 The images captured from the visible spectrum camera shall be converted to uncompressed grayscale images having a minimum bit depth of 16 bits using Equation 8.1.5.11.

8.1.6.9 The high frequency noise created by oversampling the thermal imager's display shall be removed from the captured images. A moving average in two dimensions shall be applied to the region of interest, with the average having a period equal to the width and height of the thermal imager display pixels observed in the captured images.

8.1.6.10 The captured images shall be rotated such that the centerline of the converging lines of interest is vertical . The contrast transfer function (*CTF*) and the mean pixel intensity (μ) of the two sets of converging lines of the stencil pattern in the captured images shall be calculated at each of the numbered indices, beginning at 1 and ending at 9. Regions of interest that encloses each of the two sets of converging lines of the stencil pattern shall be used to select pixels for analysis.

8.1.6.10.1 The pixels selected to calculate CTF_i and μ_i shall be located along a baseline that is perpendicular to the centerline of the converging lines of the stencil pattern, as shown in Figure 8.1.6.10.1 (a) and (b). Along these lines, all pixels between the maxima of the leftmost and rightmost lines of the stencil pattern shall be used.

****INSERT NEW FIGURE 8.1.6.10.1 (a) from TIA Log No. 1018****

****INSERT EXISTING FIGURE 8.1.6.11.1 AND LABEL 8.1.6.10.1 (b) HERE****

FIGURE 8.1.6.10.1 (a) and (b) Pixel Selection for Contrast Transfer Function Calculations.

8.1.6.10.2 Masks shall be used to remove pixels within the region of interest that represent symbols, icons, and text. Each mask shall completely enclose, but not extend more than 5 pixels beyond, the outer edge of each symbol, icon, or test string to be removed from the image analysis.

8.1.6.11 CTF_i shall be calculated at least at each indexed baseline as specified in Equation 8.1.6.11, where I_{max} and I_{min} are the averaged maximum and minimum pixel intensity values, respectively, for each of the hot and cold regions along the baseline. CTF_1 shall be defined as the maximum CTF_1 value calculated between indices 1 and 2, inclusive.

(8.1.6.11)
$$CTF_i = \frac{I_{max} - I_{min}}{65536}$$

8.1.6.12 All pixel intensity values taken at each index on each image shall be averaged. The averaged pixel intensity value shall be the brightness (*B*).

8.1.6.13 For each of the two sets of converging lines, the CTF_i values shall be divided by their respective CTF_1value.

8.1.6.14 For each of the two sets of converging lines, the NU(30) value obtained in 8.1.5.16 shall be subtracted from all the CTF_i values.

8.1.6.15 For each of the two sets of converging lines, the CTF_i values shall be paired with the frequencies listed below, integrated, and the result multiplied by π/4:

(1) CTF_1 0.029 cyc/mrad
(2) CTF_2 0.058 cyc/mrad
(3) CTF_3 0.083 cyc/mrad
(4) CTF_4 0.118 cyc/mrad
(5) CTF_5 0.143 cyc/mrad
(6) CTF_6 0.167 cyc/mrad
(7) CTF_7 0.200 cyc/mrad
(8) CTF_8 0.250 cyc/mrad
(9) CTF_9 0.286 cyc/mrad

8.1.6.16 The two resulting values obtained in 8.1.6.15 shall be averaged, rendering the spatial resolution (*SR*).

8.1.6.17 The image quality probability (P_{IQ}) shall be calculated for the spatial resolution procedure as specified in Equation 8.1.6.17, where *C* is the average value of the CTF_1's calculated in 8.1.6.11, *B* is the average brightness calculated in 8.1.6.12, *SR* is the spatial resolution calculated in 8.1.6.16, and *NU* is the NU(30) value calculated in 8.1.5.14.

(8.1.6.17)
$$P_{IQ} = \frac{e^X}{1 + e^X}$$

where:

$$X = 0.2563 + 0.8737 \times C + 0.4595 \times B + 15.85 \times SR - 2.567 \times NU - 8.359 \times C^2 - 4.631 \times B^2 - 242.2 \times SR^2 + 2.893 \times NU^2 + 3.779 \times C \times B + 48.71 \times C \times SR + 11.60 \times C \times NU + 34.91$$

$\times B \times SR - 8.016 \times B \times NU - 5.008 \times SR \times NU$

8.1.6.18 The image quality probability (P_{IQ}) shall be calculated for the nonuniformity procedure at setpoint temperatures of 1°C, 30°C, 100°C, 160°C, and 260°C (34°F, 86°F, 212°F, 320°F, and 500°F) as specified in Equation 8.1.6.17, where C is the CTF_1 value calculated in 8.1.6.11, B is the average mean pixel intensity μ calculated in 8.1.5.14 (b) for NU(1), NU(30), NU(100), NU(160), NU(260), SR is the spatial resolution calculated in 8.1.6.16, and NU is the nonuniformity value calculated in 8.1.5.14, NU(1), NU(30), NU(100), NU(160), and NU(260), respectively.

8.1.7 Report. The P_{IQ} values shall be calculated, recorded, and reported.

8.1.8 Interpretation. Any one specimen failing the test shall constitute failing performance.

8.2 Vibration Test.

8.2.1 Application. This test method shall apply to all thermal imagers.

8.2.2 Samples. Samples shall be complete thermal imagers.

8.2.2.1 Samples shall be conditioned as specified in 8.1.3.

8.2.3 Specimens.

8.2.3.1 Specimens for testing shall be complete thermal imagers.

8.2.3.2 A minimum of three specimens shall be tested.

8.2.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.2.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.2.4 Apparatus.

8.2.4.1 Product shall be tested on a typical package tester within the compartments specified in 8.2.4.2 through 8.2.4.4.

8.2.4.2 Compartments shall be set up as specified in Figure 8.2.4.2(a) and Figure 8.2.4.2(b).

****INSERT EXISTING FIGURE 8.2.4.2 (a) FROM 2010 EDITION****

FIGURE 8.2.4.2(a) Vibration Table Compartments — Top View (Not to Scale).

****INSERT EXISTING FIGURE 8.2.4.2 (b) FROM 2010 EDITION****

FIGURE 8.2.4.2(b) Vibration Table Compartments — Side View (Not to Scale).

8.2.4.2.1 The sides and the base of the compartments shall be constructed of nominal 6 mm (¼ in.) stainless steel, and the top of the compartments shall remain open.

8.2.4.2.2 There shall be no burrs, sharp edges, surface discontinuities, or fasteners on the internal surfaces of the holding boxes.

8.2.4.3 The large compartments shall encase the complete thermal imager that is larger than 5161.0 mm^2 (8 $in.^2$).

8.2.4.4 The small compartments shall encase the complete thermal imager that is smaller than 5161.0 mm^2 (8 $in.^2$).

8.2.5 Procedure.

8.2.5.1 Test specimens shall be placed unrestrained in the compartments specified in 8.2.4.2, and where present, all product adjustments shall be fully extended.

8.2.5.2 Test specimens shall not be tied down.

8.2.5.3 The basic movement of the bed of the test table shall be a 25 mm orbital path, such as can be obtained on a standard package tester operating in synchronous mode at 250 rpm, ±5 rpm.

8.2.5.4 The test duration shall be 3 hours.

8.2.5.5 Test specimens shall be evaluated for image recognition as specified in Section 8.1, Image Recognition Test, and the image recognition values recorded in the vertical and horizontal directions.

8.2.6 Report. Each of the image recognition values in the horizontal and vertical directions shall be recorded and reported.

8.2.7 Interpretation. One or more specimens failing this test shall constitute failing performance.

8.3 Impact Acceleration Resistance Test.

8.3.1 Application. This test method shall apply to all thermal imagers.

8.3.2 Samples. Samples shall be complete thermal imagers.

8.3.2.1 Samples shall be conditioned as specified in 8.1.3.

8.3.3 Specimens.

8.3.3.1 Specimens for testing shall be complete thermal imagers.

8.3.3.2 A minimum of three specimens shall be tested.

8.3.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.3.3.4 Specimens shall be removed following the specified conditioning, and testing shall begin within 60 seconds of removal from conditioning.

8.3.4 Procedure.

8.3.4.1 Three specimens of product shall be subjected to a series of impact acceleration tests.

8.3.4.1.1 One test specimen for ambient temperature conditioning shall be exposed to a temperature of 23°C, ±1°C (73°F, ±2°F), for at least 4 hours.

8.3.4.1.2 One test specimen for cold temperature conditioning shall be exposed to a temperature of -20°C, ±1°C (-4°F, ±2°F), for at least 4 hours.

8.3.4.1.3 One test specimen for elevated temperature conditioning shall be exposed to a temperature of 60°C, ±1°C (140°F, ±2°F), for at least 4 hours.

8.3.4.2 Each product tested shall be complete with power source.

8.3.4.3 After conditioning, product shall be turned to the “on” position. Testing shall begin within 30 seconds of removal from conditioning.

8.3.4.4 Following each conditioning, the product shall be dropped a total of eight times from a distance of 2 m (6½ ft) onto a concrete surface so that impact is on each face and on one corner and one edge of the product.

8.3.4.5 The entire series of drops shall be completed within 10 minutes of removal from conditioning.

8.3.4.6 Specimens shall be evaluated for image recognition as specified in Section 8.1, Image Recognition Test, and the image recognition values recorded in the vertical and horizontal directions.

8.3.4.7 Specimens shall be evaluated to determine that the thermal imager enclosure has not incurred damage that affects normal operation or enclosure integrity.

8.3.5 Report. Each of the image recognition values in the horizontal and vertical directions shall be recorded and reported.

8.3.6 Interpretation. One or more specimens failing this test shall constitute failing performance.

8.4 Corrosion Test.

8.4.1 Application. This test method shall apply to all thermal imagers.

8.4.2 Samples. Samples shall be complete thermal imagers.

8.4.3 Specimens.

8.4.3.1 Specimens for testing shall be complete thermal imagers.

8.4.3.2 A minimum of three specimens shall be tested.

8.4.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.4.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.4.4 Procedure.

8.4.4.1 Specimens shall be tested in accordance with ASTM B 117, *Standard Method of Salt Spray (Fog) Testing.* Salt spray shall be 5 percent saline solution, and the test exposure shall be for 48 hours, +30/-0 minutes. The chamber shall be stabilized at a temperature of 35°C, ±3°C (95°F, ±5°F)

8.4.4.2 Specimens shall be placed in the chamber in the typical operating position as used by first responders, as specified by the manufacturer.

8.4.4.3 At the conclusion of the salt spray period, specimens shall be stored in an environment of 22°C, ±3°C (72°F, ±5°F) at 50 percent, ±5 percent, relative humidity for a minimum of 48 hours.

8.4.4.4 Following the conditioning period, specimens shall be tested within 60 seconds of removal from conditioning.

8.4.5 Report. The thermal imager shall be inspected for function of controls and operating feature. Corrosion shall be recorded and reported.

8.4.6 Interpretation. One or more specimens failing this test shall constitute failing performance.

8.5 Viewing Surface Abrasion Test.

8.5.1 Application. This test shall apply to all thermal imagers.

8.5.2 Samples. Samples shall be complete viewing surfaces or representative plaques from thermal imagers.

8.5.3 Specimens.

8.5.3.1 Specimens for testing shall be complete thermal imager viewing surfaces or representative plaques.

8.5.3.2 Seven specimens shall be chosen from a minimum of three viewing surfaces.

8.5.3.2.1 Four specimens shall be taken from the left viewing area, and three specimens shall be taken from the right viewing area.

8.5.3.2.2 One of the four specimens taken from the left viewing area shall be the set-up specimen.

8.5.3.3 The left test specimen shall include all of the following criteria:

(1) The specimen shall be a square measuring 50 mm × 50 mm (2 in. × 2 in.).

(2) Two edges of the square section shall be parallel within ±2 degrees of the axis of the cylinder or cone in the center of the sample.

(3) At least 38 mm (1½ in.) of the 50 mm × 50 mm (2 in. × 2 in.) square shall be taken from the left side of the center line of the viewing surface.

8.5.3.4 The right test specimens shall include all of the following criteria:

(1) The specimen shall be a square measuring 50 mm × 50 mm (2 in. × 2 in.).

(2) Two edges of the square section shall be parallel within ±2 degrees of the axis of the cylinder or cone in the center of the sample.

(3) At least 38 mm (1½ in.) of the 50 mm × 50 mm (2 in. × 2 in.) square shall be taken from the right side of the centerline of the lens.

8.5.3.5 Each of the specimens shall be cleaned in the following manner:

(1) The specimen shall be rinsed with clean tap water.

(2) The specimen shall be washed with a solution of nonionic/low-phosphate detergent and water using a clean, soft gauze pad.

(3) The specimen shall be rinsed with de-ionized water.

(4) The specimen shall be blown dry with clean compressed air or nitrogen.

8.5.3.6 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.5.3.7 Specimens shall be tested within 5 minutes after removal from conditioning.

8.5.4 Apparatus. The test apparatus shall be constructed in accordance with Figure 8.5.4(a) and Figure 8.5.4(b).

****INSERT EXISTING FIGURE 8.5.4 (a) FROM 2010 EDITION****

FIGURE 8.5.4(a) Lens Abrasion Tester.

****INSERT EXISTING FIGURE 8.5.4 (b) FROM 2010 EDITION****

FIGURE 8.5.4(b) Lens Abrasion Tester (details).

8.5.5 Procedure.

8.5.5.1 The haze of the specimen shall be measured using a haze meter in accordance with ASTM D 1003, *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics*, and recorded with the following additions:

(1) The haze shall be measured in the middle 2 mm of the specimen.

(2) The specimen shall be repositioned to achieve the maximum haze value within the area defined in 8.5.5.1(1).

(3) The haze meter shall have a specified aperture of 22 mm.

(4) The haze meter shall have a visual display showing 0.1 percent resolution.

(5) The haze meter shall be calibrated before and after each day's use following procedures specified in ASTM D 1003, *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics*.

8.5.5.2 The set-up specimen shall be placed cover side up in the test apparatus specimen holder. The specimen holder shall be configured with a flat surface under the lens or with an inner radius support.

8.5.5.3 The pad holder shall consist of a cylinder 9.5 mm (0.4 in.) high and 25 mm (1 in.) in diameter with a radius of curvature equal to the radius of curvature of the outside of the lens in the viewing area ±0.25 diopter. This cylinder shall be rigidly affixed to the stroking arm by a #10-32 UNF threaded rod.

8.5.5.4 The pad shall be a Blue Streak M306M wool felt polishing pad 23 mm (0.9 in.) in diameter.

8.5.5.5 The abrasive disc shall be made from 3M Part Number 7415, Wood Finishing Pad. A disc 23 mm (0.9 in.) in diameter shall be cut from the abrasive sheet. The marked side of the disc shall be placed against the pad. Care shall be exercised to maintain this orientation for each abrasive disc throughout the testing.

8.5.5.6 The pad holder, pad, and abrasive disc shall be installed on the stroking arm. The stroking arm shall be leveled to ±3 degrees by adjusting the threaded pin. The pin shall be secured to prevent rotation of the pad holder. The axis of curvature of the pad holder shall be coincident with the axis of curvature of the lens.

8.5.5.7 The stroking arm shall be counterbalanced with the pad holder, pad, and abrasive disc in place.

8.5.5.8 The set-up specimen shall be replaced with one of the six specimens to be tested.

8.5.5.9 A 1000 g, ±5 g (2.7 lb, ±0.16 oz.), test weight shall be installed on the pin above the test sample.

8.5.5.10 The test shall be run for 200 cycles, ±1 cycle. One cycle shall consist of a complete revolution of the eccentric wheel.

8.5.5.11 The length of stroke shall be 14 mm (½ in.), producing a pattern 38 mm (1½ in.) long. The frequency of the stroke shall be 60 cycles per minute, ±1 cycle per minute. The center of the stroke shall be within ±2 mm (±0.08 in.) of the center of the specimen.

8.5.5.12 The specimen shall be removed and cleaned following the test procedure. The abrasive disc shall be discarded.

8.5.5.13 The haze of the sample shall be measured following the test procedure.

8.5.5.14 The delta haze shall be calculated by subtracting the initial haze from the final haze.

8.5.5.15 The testing steps specified in 8.5.5.8 through 8.5.5.14 shall be repeated five times with a new sample and abrasive disc.

8.5.6 Report. The six delta haze values shall be averaged, recorded, and reported.

8.5.7 Interpretation. The average delta haze shall be evaluated to determine pass or fail.

8.6 Heat Resistance Test.

8.6.1 Application. This test method shall apply to all thermal imagers.

8.6.2 Samples. Samples shall be complete thermal imagers.

8.6.3 Specimens.

8.6.3.1 Specimens for testing shall be complete thermal imagers.

8.6.3.2 A minimum of three specimens shall be tested.

8.6.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.6.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.6.4 Apparatus. The test oven shall be as specified in ISO 17493, *Clothing and equipment for protection against heat – Test method for convective heat resistance using a hot air circulating oven.*

8.6.5 Procedure.

8.6.5.1 Testing shall be performed in accordance with ISO 17493, *Clothing and equipment for protection against heat – Test method for convective heat resistance using a hot air circulating oven,* using the following parameters:

(1) A test fixture capable of accommodating the device being tested shall be used.

(2) The test temperature shall be 260°C, +6/-0°C (500°F, +10/-0°F).

(3) Specimens shall be mounted in the "as worn" position on a test fixture and shall not touch any oven surface.

(4) The test fixture shall not degrade the oven recovery time.

(5) The test fixture shall be designed to allow the specimens to be attached in the same configuration as the specimens' mounting assembly attaches to the specimens.

8.6.5.2 The test fixture with the specimen attached shall be placed in the test oven perpendicular with the object lens facing perpendicular to the airflow of the oven.

8.6.5.3 The specimen shall be set to the "on" mode.

8.6.5.4 There shall be no obstructions between the specimen and the airflow. The test fixture shall position the specimen equidistant from all interior oven surfaces.

8.6.5.5 The test oven door shall not remain open more than 15 seconds. The air circulation shall be shut off while the door is open and turned on when the door is closed.

8.6.5.6 The total test oven recovery time shall not exceed 30 seconds. The thermocouple reading shall remain at 260°C, +6/-0°C (500°F, +10/-0°F) for the duration of the test.

8.6.5.7 The test specimen, mounted as specified, shall be exposed in the test oven for 5 minutes, +15/-0 seconds. The test exposure time shall begin when the test thermocouple recovers to 260°C, +6/-0°C (500°F, +10/-0°F).

8.6.5.8 After the specified exposure, the specimen shall be set to the "off" mode and removed and allowed to cool for at least 60 minutes.

8.6.5.9 Specimens shall be evaluated for image recognition as specified in Section 8.1, Image Recognition Test. The image recognition values shall be recorded in the vertical and horizontal directions.

8.6.6 Report.

8.6.6.1 The image recognition values in the horizontal and vertical directions shall be calculated, recorded, and reported.

8.6.6.2 Observations of melting, dripping, or ignition shall be recorded and reported for each specimen.

8.6.7 Interpretation.

8.6.7.1 One or more specimens failing this test shall constitute failing performance.

8.6.7.2 One or more specimens showing evidence of melting, dripping or igniting shall constitute failing performance for this test.

8.7 Heat and Flame Test.

8.7.1 Application. This test method shall apply to all thermal imagers.

8.7.2 Samples. Samples shall be complete thermal imagers.

8.7.3 Specimens.

8.7.3.1 Samples shall be complete viewing surfaces or minimum 50 mm × 50 mm (2 in. × 2 in.) identically coated and prepared coupons.

8.7.3.2 A minimum of three specimens shall be tested.

8.7.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.7.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.7.4 Apparatus.

8.7.4.1 A thermal imager test fixture to hold the specimen in the test apparatus shall be permitted to be provided by the manufacturer and shall not impede the intended operation. The manufacturer-supplied test fixture shall not add any additional protection for the thermal imager that could alter this test.

8.7.4.2 Where a thermal imager test fixture is not supplied by the thermal imager manufacturer, the thermal imager test fixture shall be as specified in Figure 8.7.4.2(a) and Figure 8.7.4.2(b). The thermal imager test fixture shall be used in a manner that is representative of the end product's intended use.

****INSERT EXISTING FIGURE 8.7.4.2 (a) FROM 2010 EDITION****

FIGURE 8.7.4.2(a) Mounted Thermal Imager for Heat and Flame Test.

****INSERT EXISTING FIGURE 8.7.4.2 (b) FROM 2010 EDITION****

FIGURE 8.7.4.2(b) Thermal Imager Mounting Armature.

8.7.4.3 The specimens shall be mounted on the test fixture to simulate the intended-use position as specified in the manufacturer's instructions, ensuring that the orientation of the center axis of the thermal imager lens is perpendicular to the burner array, horizontally centered, and located 610 mm (24 in.) above the base of the lift-cart subassembly.

8.7.4.4 The heat and flame test apparatus shall be as specified in Figure 8.7.4.4. The heat and flame test apparatus shall not be supplied by the thermal imager manufacturer.

****INSERT EXISTING FIGURE 8.7.4.4 FROM 2010 EDITION****

FIGURE 8.7.4.4 Heat and Flame Test Apparatus.

8.7.4.5 The test oven shall be a horizontal forced circulating air oven with an internal velocity of 61 m/min (200 ft/min). The test oven shall have minimum dimensions of 915 mm depth × 915 mm width × 1220 mm (36 in. × 36 in. × 48 in.) height.

8.7.5 Procedure.

8.7.5.1 The test oven shall be calibrated using a 30 gauge exposed bead Type J iron/constantan wire reference thermocouple that has been calibrated to set the 0°C (32°F) reference point with an

ice bath containing ice and deionized or distilled water.

8.7.5.2 Boiling water shall be used to set the 100°C (212°F) reference value.

8.7.5.3 The reference temperatures shall be corrected to standard temperatures using a barometric pressure correction.

8.7.5.4 For calibration prior to the heat and flame test, the calibration mannequin shown in Figure 8.7.4.4 shall be exposed to direct flame contact for 10 seconds using the heat and flame test apparatus.

8.7.5.5 All peak temperature readings shall be within a temperature range of 815°C to 1150°C (1500°F to 2102°F).

8.7.5.6 The average mean of all peak temperature readings shall not be higher than 950°C (1742°F).

8.7.5.7 The test oven recovery time, after the door is closed, shall not exceed 1.0 minute.

8.7.5.8 Specimens mounted on the test fixture shall first be placed in the test oven, which has been preheated to 95°C, ±2°C (203°F, ±5°F), for 15 minutes,+15/-0 seconds. The test exposure time of 15 minutes shall begin after the door is closed and the oven temperature recovers to 95°C (203°F).

8.7.5.9 At the completion of the 15-minute exposure at 95°C, ±2°C (203°F, ±5°F), the oven door shall be opened, and the specimen mounted on the test fixture shall be moved out of the oven and into the center of the burner array.

8.7.5.10 The product shall then be exposed to direct flame contact for 10 seconds, +¼/-0 sec. This exposure shall begin within 20 seconds of the product being removed from the test oven.

8.7.6 Report.

8.7.6.1 Any afterflame of the test specimen exceeding 2.2 seconds shall be recorded and reported.

8.7.6.2 Anything falling from the test specimen shall be recorded and reported.

8.7.6.3 Any test specimen falling from the mounted position shall be recorded and reported.

8.7.7 Interpretation.

8.7.7.1 One or more specimens failing this test shall constitute failing performance.

8.7.7.2 Any test specimen exceeding 2.2 seconds of afterflame shall constitute failing performance.

8.7.7.3 Any test specimen having parts or other items falling off shall constitute failing performance.

8.7.7.4 Any test specimen falling from its mounted position shall constitute failing performance.

8.8 Product Label Durability Test.

8.8.1 Application. This test method shall apply to all product labels.

8.8.2 Samples. Samples shall be complete thermal imagers.

8.8.3 Specimens.

8.8.3.1 Specimens for testing shall be complete thermal imagers with product labels attached.

8.8.3.2 A minimum of three specimens shall be tested.

8.8.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a

relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.8.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.8.4 Procedure.

8.8.4.1 Specimens with all product labels attached shall be subjected to the tests specified in Section 8.4, Corrosion Resistance; Section 8.6, Heat Resistance Test; and Section 8.13, Durability Test.

8.8.4.2 After each test, the specimen product labels shall be examined at a distance of 305 mm (12 in.) by the unaided eye with 20/20 vision or vision corrected to 20/20.

8.8.4.3 The product labels shall be permitted to be wiped clean with an untreated cloth prior to being examined.

8.8.5 Report. The legibility of each product label shall be recorded and reported.

8.8.6 Interpretation. Any specimen failing the test shall constitute failing performance.

8.9 Cable Pullout Test.

8.9.1 Application. This test method shall apply to thermal imagers and any associated assemblies with interconnecting wiring.

8.9.2 Samples. Samples shall be complete thermal imagers.

8.9.3 Specimens.

8.9.3.1 Specimens for testing shall be complete thermal imagers with any associated assemblies with interconnecting wiring.

8.9.3.2 A minimum of three specimens shall be tested.

8.9.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.9.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.9.4 Apparatus. A mass of known weight with the means for attachment to wiring shall be provided.

8.9.5 Procedure. A force of 89 N, +9/-0 N shall be applied gradually, in an axial direction to the wiring of the specimen tested.

8.9.6 Report.

8.9.6.1 Observations of the separation or nonseparation of interconnecting wiring shall be recorded and reported.

8.9.6.2 Observations of the proper specimen functionality shall be recorded and reported.

8.9.7 Interpretation.

8.9.7.1 Separation of interconnecting wiring of any specimen shall constitute failing performance.

8.9.7.2 Any improper functionality of any specimen, in accordance with the requirements of Chapter 6, Design Requirements, shall constitute failing performance.

8.10 Image Color and Effective Temperature Range Test.

8.10.1 Application. This test method shall apply to all thermal imagers.

8.10.2 Samples. Samples shall be complete thermal imagers.

8.10.3 Specimens.

8.10.3.1 Specimens for testing shall be complete thermal imagers.

8.10.3.2 A minimum of three specimens shall be tested.

8.10.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.10.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.10.4 Apparatus.

8.10.4.1 Testing shall be conducted in a room having an ambient temperature (T_{amb}) of 22°C, ±3°C (72°F, ±5°F).

8.10.4.2 The test apparatus shall consist of the following:

(1) A source target as specified in 8.10.4.3

(2) A thermal imager positioning device as specified in 8.10.4.4

(3) A visible spectrum camera, lens, and close-up filter as specified in 8.10.4.5

(4) A visible spectrum camera mount as specified in 8.10.4.6

(5) Image capturing software and hardware as specified in 8.10.4.7

(6) A computer

(7) Image analysis software as specified in 8.10.4.8

8.10.4.3 The source target shall consist of surfaces arranged as shown in Figure 8.10.4.3. All surfaces shall have an emissivity of 0.95, ±0.03. The use of a collimated source target shall be permitted.

****INSERT EXISTING FIGURE 8.10.4.3 FROM 2010 EDITION****

FIGURE 8.10.4.3 Test Image for Effective Temperature Range Test.

**[Note: Temperature on Figure 8.10.4.3 will be changed from 30° C to 50°
Side dotted lines will be moved so that they go down the middle of the outermost white bars on either side of the Figure]**

8.10.4.3.1 The surface labeled T_{hot} shall range in temperature from 50°C (122°F) to 550°C (1022°F) and shall fill at least 50 percent of the area of the FOV. The radiation source producing the T_{hot} surface shall be a blackbody and shall have an emissivity of 0.95, ±0.03. The blackbody shall be calibrated at least every 6 months. The blackbody temperature accuracy shall be ±0.5°C (±1°F). The stability of the blackbody temperatures shall not exceed 0.15°C. The nonuniformity of the blackbody shall not exceed 0.02 using the method in 8.1.5.14 as supplied to temperature measurements of the emitting surface of the blackbody.

8.10.4.3.2 The bars in the right region of the source target and the conjugate spaces between the bars shall be 13 mm, ±0.1 mm (½ in., ±0.003 in.), wide. The bars shall maintain a constant temperature (T_{bar}) of 30°C, ±0.5°C (86°F, ±1°F).

8.10.4.3.3 All surfaces in the FOV, excluding the T_{hot} and T_{bar} surfaces, shall be held constant at T_{amb}, 22°C, ±3°C (71°F, ±2°F).

8.10.4.4 The thermal imager positioning device shall position the thermal imager in front of the

source target such that the bars are in focus and are viewed at a frequency of 0.04 cyc/mrad. The thermal imager shall be centered on the surface labeled T_{hot} with the line of sight perpendicular to the plane of the source target. The thermal imager shall not wobble, vibrate, or otherwise move out of position during the course of the test. When placed or replaced in the positioning device, the thermal imager shall always be positioned at the same distance, angle, and attitude relative to the source target.

8.10.4.5 The visible spectrum camera shall be a Nikon D3; the lens shall be a Nikkor 28 mm, f/2.8; the close-up filter shall be +10; and the shutter shall be activated by a remote trigger release. Other lenses and filters of equivalent quality shall be permitted to be used in cases where the thermal imager display size or configuration is incompatible with the use of the Nikkor 28 mm, f/2.8, and the +10 close-up filter. The Nikon D3 shall be calibrated for color and luminance every 12 months. All Nikon D3 settings, other than those specified below, shall remain set at the factory default selections. The specific modifications to the Nikon D3 settings 1 through 19 shall be as follows:

(1) ISO Setting = 200
(2) Image Quality = NEF (RAW)
(3) White Balance = Direct Sunlight
(4) Focus Point = Center
(5) Exposure Mode = Shutter Priority
(6) Exposure Compensation = 0
(7) Bracketing = Off
(8) Image Area/Auto DX Crop = Off
(9) Image Area = FX Format
(10) NEF (RAW) recording/Type = Uncompressed
(11) NEF (RAW) recording/Bitdepth = 14 Bit (images are stored as 16 Bit)
(12) NEF (RAW) recording/Picture Control = Neutral
(13) NEF (RAW) recording/Colorspace = sRGB
(14) NEF (RAW) recording/High ISO NR = Off
(15) Live View Mode = Tripod
(16) Release Mode = Live View with Framing Grids
(17) Metering Method = 3D Color Matrix II
(18) Shutter Speed = 1/6 second
(19) Focus Mode Selector = Manual

8.10.4.6 The visible spectrum camera shall be mounted such that the thermal imager display fills 90 percent of the FOV in the vertical dimension and is in focus. The visible spectrum camera shall not wobble, vibrate, or otherwise move out of position during the course of the test. A black shroud shall be placed around the viewpath of the visible spectrum camera to block all glare from the surrounding environment. When placed or replaced in the visible spectrum camera mount, the visible spectrum camera shall always be positioned at the same distance, angle, and attitude relative to the thermal imager's display.

8.10.4.7 The image capturing software and hardware shall permit 16-bit uncompressed color

images to be downloaded from the visible spectrum camera to a computer or memory at a rate of one image every 3 seconds, ±0.1 second.

8.10.4.8 The image analysis software shall open 16-bit uncompressed color image files, convert the image files to 16-bit uncompressed grayscale images using a lossless conversion, select a group of pixels within an image, determine the mean pixel intensity and standard deviation of pixel intensities within the selected group, and write the results to a text file.

8.10.4.9 The high-frequency noise created by oversampling the thermal imager's display shall be removed from the captured images. A moving average in two dimensions shall be applied to the region of interest, with the average having a period equal to the width and height of the thermal imager display pixels observed in the captured images.

8.10.5 General Procedure.

8.10.5.1 The thermal imager lens and display and the visible spectrum camera lens shall be cleaned in accordance with the manufacturer's specifications.

8.10.5.2 The thermal imager shall be equipped with a fully charged power source.

8.10.5.3 The thermal imager shall be activated 3 minutes, ±1 minute, prior to the beginning of the test.

8.10.5.4 One randomly chosen specimen shall be rotated 90 degrees, 180 degrees, or 270 degrees such that the bars in the source target appear above, on the left side of, or below the surface labeled T_{hot}. All other components of the equipment setup shall remain unchanged.

8.10.5.5 All surface temperatures in the FOV shall be set at the assigned temperatures and shall be allowed to come to steady-state prior to starting the test.

8.10.5.6 The visible spectrum camera shall be placed at the optimum viewing position with respect to the thermal imager display such that the thermal imager display fills 90 percent of the FOV in the vertical dimension and is in focus.

8.10.5.7 A black shroud shall be placed around the viewpath of the visible spectrum camera to block out all glare incident upon the thermal imager display from the surrounding environment. The shroud shall be held securely in place and shall not be disturbed during the course of each test.

8.10.5.8 The image capturing software and hardware shall permit 16-bit uncompressed color images to be downloaded from the visible spectrum camera to a computer or memory at a rate of one image every 2^{o} C $\pm$ 0.1 C (3.6^{o} F $\pm$ 0.2^{o} F) second, as T_{hot} increases from ambient to 550°C (1022°F) at a rate not greater than 15°C (27°F) per minute.

8.10.5.9 After data collection is complete, the thermal imager shall be removed from its position in front of the source target within 60 seconds.

8.10.5.10 Pixels that represent symbols, icons, and text shall be excluded from the analysis.

8.10.5.11 The high-frequency noise created by oversampling the thermal imager's display shall be removed from the captured images. A moving average in two dimensions shall be applied to the region of interest, with the average having a period equal to the width and height of the thermal imager display pixels observed in the captured images.

8.10.6 Image Color Procedure.

8.10.6.1 For each image, processed in order as T_{hot} increases, the red, green, and blue (RGB)

pixel values within the hot region of interest shall be calculated to obtain a mean value for each color channel.

8.10.6.2 The mean normalized RGB values shall be converted to hue, luminosity, and color saturation.

8.10.6.3 The hue shall be determined by the following procedure, where Min_c is the value of the minimum color channel:

(1) If R > G and R > B:

(8.10.6.3a) $$Hue = 60\left(\frac{G-B}{R-Min_c}\right)$$

(2) If G > R and G > B:

(8.10.6.3b) $$Hue = 60\left(2+\frac{B-R}{G-Min_c}\right)$$

(3) If B > R and B > G:

(8.10.6.3c) $$Hue = 60\left(4+\frac{R-G}{B-Min_c}\right)$$

(4) If *Hue* < 0:

(8.10.6.3d) $$Hue = Hue + 360$$

8.10.6.4 The luminosity shall be determined by Equation 8.10.6.5, where Max_c is the value of the maximum color channel:

(8.10.6.4) $$\text{Luminosity} = \frac{Max_c + Min_c}{2}$$

8.10.6.5 The color saturation shall be determined by the following procedure:

(1) If Luminosity = 0, Color saturation = 0

(2) If 0 < Luminosity $\leq$ 0.5:

(8.10.6.5a) $$\text{Color saturation} = \frac{Max_c - Min_c}{Max_c + Min_c}$$

(3) If 0.5 $\leq$ Luminosity $\leq$ 1:

(8.10.6.5b) $$\text{Color Saturation} = \frac{Max_c - Min_c}{2 - Max_c - Min_c}$$

8.10.6.6 The color yellow shall be defined as having a hue between 45 and 69 degrees, a luminosity between 0.5 and 0.9, and a color saturation greater than 0.2.

8.10.6.7 The color orange shall be defined as having a hue between 24 and 32 degrees, a luminosity between 0.5 and 0.9, and a color saturation greater than 0.1.

8.10.6.8 The color red shall be defined as having a hue between 344 and 15 degrees, a luminosity between 0.5 and 0.9, and a color saturation greater than 0.4.

8.10.6.9 The color dark red shall be defined as having a hue between 344 and 15 degrees, a luminosity between 0.5 and 0.9, and a color saturation between 0.1 than 0.4.

8.10.6.10 The temperatures at which the colors yellow, orange, and red first appear in the color region of interest shall be identified as T_Y, T_O, and T_R, respectively.

8.10.7 Effective Temperature Range Procedure.

8.10.7.1 The images captured from the visible spectrum camera during the first 2 minutes of the test shall be excluded from further analysis. The remaining images shall be converted to uncompressed grayscale images having a minimum bit depth of 16 bits using Equation 8.1.5.11.

8.10.7.2 The bar contrast, *C*, shall be calculated for the bar region of interest for each image as specified in Equation 8.10.7.2.

(8.10.7.2) $$C = \frac{I_{\max} - I_{min}}{65536}$$

8.10.7.3 The mean pixel intensity (μ) shall be calculated for each image, as specified in Equation 8.1.5.14b. An equal number of light pixels and dark pixels shall be selected within the bar region of interest to determine the brightness, *B*, of the image.

8.10.7.4 The image quality probability ($P_{IQ,i}$) for each image shall be calculated as specified in Equation 8.1.16.17. In Equation 8.1.6.17, *C* shall be the bar contrast calculated for each image in 8.10.7.2; *B* shall be the average brightness calculated for each image in 8.10.7.3; *SR* shall be the spatial resolution calculated in 8.1.6.16; and *NU* shall be the NU(30) calculated in 8.1.5.15.

8.10.8 Report. T_Y, T_O, T_R, P_{IQ} shall be reported and recorded.

8.10.9 Interpretation. Any one specimen failing the test shall constitute failing performance.

8.11 Field of View (FOV) Measurement.

8.11.1 Application. This test method shall apply to all thermal imagers.

8.11.2 Samples. Samples shall be complete thermal imagers.

8.11.3 Specimens.

8.11.3.1 Specimens for testing shall be complete thermal imagers.

8.11.3.2 A minimum of three specimens shall be tested.

8.11.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.11.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.11.4 Apparatus.

8.11.4.1 Testing shall be conducted in a room having an ambient temperature of 22°C, ±3°C (72°F, ±5°F).

8.11.4.2 The FOV test apparatus shall consist of a calibrated rotary stage having a 0.5 degree angular accuracy and a thermal target. The use of a collimated thermal target shall be permitted.

8.11.5 Procedure 1, Horizontal FOV Measurement.

8.11.5.1 The thermal imager shall be mounted securely to the rotary stage. The thermal imager shall be oriented such that the horizontal axis of the display is parallel to the plane of rotation of the

stage.

8.11.5.2 The thermal imager shall be powered on and operating in the basic mode.

8.11.5.3 The position of the thermal imager shall be adjusted as necessary such that the thermal target is at least 3 m (10 ft) away and in focus.

8.11.5.4 The rotary stage shall be turned to a position in which a distinct point on the thermal target is positioned at the center of the extreme left edge of the thermal imager FOV. The angular position, AH1, of the rotary stage shall be recorded.

8.11.5.5 The rotary stage shall be turned to a position in which the same distinct point on the thermal target is positioned at the center of the extreme right edge of the thermal imager FOV. The angular position, AH2, of the rotary stage shall be recorded.

8.11.5.6 The horizontal FOV is the absolute value of the difference between AH2 and AH1.

8.11.5.7 The thermal imager shall be powered off and removed from the rotary stage.

8.11.6 Procedure 2, Vertical FOV Measurement.

8.11.6.1 The thermal imager shall be mounted securely to the rotary stage. The thermal imager shall be oriented such that the vertical axis of the display is parallel to the plane of rotation of the stage.

8.11.6.2 The thermal imager shall be powered on and operating in the basic mode.

8.11.6.3 The position of the thermal imager shall be adjusted as necessary such that the thermal target is at least 3 m (10 ft) away and is in focus.

8.11.6.4 The rotary stage shall be turned to a position in which a distinct point on the thermal target is positioned at the center of the extreme bottom edge of the thermal imager FOV. The angular position, AV1, of the rotary stage shall be recorded.

8.11.6.5 The rotary stage shall be turned to a position in which the same distinct point on the thermal target is positioned at the center of the extreme top edge of the thermal imager FOV. The angular position, AV2, of the rotary stage shall be recorded.

8.11.6.6 The horizontal FOV is the absolute value of the difference between AV2 and AV1.

8.11.6.7 The thermal imager shall be powered off and removed from the rotary stage.

8.12 Thermal Sensitivity Test.

8.12.1 Application. This test method shall apply to all thermal imagers.

8.12.2 Samples. Samples shall be complete thermal imagers.

8.12.3 Specimens.

8.12.3.1 Specimens for testing shall be complete thermal imagers.

8.12.3.2 A minimum of three specimens shall be tested.

8.12.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.12.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.12.4 Apparatus.

8.12.4.1 Testing shall be conducted in a room having an ambient temperature (T_{amb}) of 22°C, ±3°C (72°F, ±5°F).

8.12.4.2 The thermal sensitivity test apparatus shall consist of the following:

(1) Two source targets as specified in 8.12.4.3 through 8.12.4.6

(2) Thermal imager positioning device as specified in 8.12.4.7 through 8.12.4.10

(3) Visible spectrum camera, lens, and close-up filter as specified in 8.12.4.11

(4) Visible spectrum camera mount as specified in 8.12.4.12

(5) Image capturing software and hardware as specified in 8.12.4.13

(6) Computer and image analysis software as specified in 8.12.4.14

8.12.4.3 The source targets shall both be flat-surface extended-area blackbodies arranged as shown in Figure 8.12.4.3, where the emitting surfaces are indicated as T_1 and T_2. The source targets shall be calibrated every 6 months.

****INSERT EXISTING FIGURE 8.12.4.3 FROM 2010 EDITION****

FIGURE 8.12.4.3 Thermal Sensitivity Test Apparatus Configuration.

8.12.4.4 The emitting surfaces shall have dimensions of at least 102 mm × 102 mm (4 in. × 4 in.) and shall have an emissivity of 0.95, ±0.03.

8.12.4.5 The nonuniformity of the emitting surfaces shall not exceed 0.02, as defined using the method specified in 8.1.5.13. The temperature accuracy of the emitting surfaces shall be 0.02°C or better. The stability of the emitting surface temperatures shall be 0.01°C or better.

8.12.4.6 The emitting surface of the source targets shall be equal in size, ±10 percent, as viewed on the thermal imager's display.

8.12.4.7 The thermal imager positioning device shall position the thermal imager in front of the source targets such that the source targets fill at least 40 percent of the thermal imager's FOV. The thermal imager shall not be required to be in focus.

8.12.4.8 The thermal imager shall be centered on the space between the source targets with the line of sight perpendicular to the plane of the source targets.

8.12.4.9 The thermal imager shall not wobble, vibrate, or otherwise move out of position during the course of the test.

8.12.4.10 When placed or replaced in the positioning device, the thermal imager shall always be positioned at the same distance, angle, and attitude relative to the source targets.

8.12.4.11 The visible spectrum camera shall be a Nikon D3, the lens shall be a Nikkor 28 mm, f/2.8, the close-up filter shall be +10; and the shutter shall be activated by a remote trigger release. Other lenses and filters of equivalent quality shall be permitted to be used in cases where the thermal imager display size or configuration is incompatible with the use of the Nikkor 28 mm, f/2.8; and the +10 close-up filter. The Nikon D3 shall be calibrated for color and luminance every 12 months. All Nikon D3 settings, other than those specified below, shall remain set at the factory default selections. The specific modifications to the Nikon D3 settings 1 through 19 shall be as follows:

(1) ISO Setting = 200

(2) Image Quality = NEF (RAW)

(3) White Balance = Direct Sunlight

(4) Focus Point = Center

(5) Exposure Mode = Shutter Priority

(6) Exposure Compensation = 0

(7) Bracketing = Off

(8) Image Area/Auto DX Crop = Off

(9) Image Area = FX Format

(10) NEF (RAW) recording/Type = Uncompressed

(11) NEF (RAW) recording/Bitdepth = 14 Bit (images are stored as 16 Bit)

(12) NEF (RAW) recording/Picture Control = Neutral

(13) NEF (RAW) recording/Colorspace = sRGB

(14) NEF (RAW) recording/High ISO NR = Off

(15) Live View Mode = Tripod

(16) Release Mode = Live View with Framing Grids

(17) Metering Method = 3D Color Matrix II

(18) Shutter Speed = 1/6 second

(19) Focus Mode Selector = Manual

8.12.4.11.1 The visible spectrum camera shall not wobble, vibrate, or otherwise move out of position during the course of the test.

8.12.4.12 A black shroud shall be placed around the viewpath of the visible spectrum camera to block all glare from the surrounding environment.

8.12.4.13 When placed or replaced in the visible spectrum camera mount, the visible spectrum camera shall always be positioned at the same distance, angle, and attitude relative to the thermal imager's display.

8.12.4.14 The image capturing software and hardware shall permit 16-bit uncompressed color images to be downloaded from the visible spectrum camera to a computer at a rate of one image every 3 seconds, ±0.1 second.

8.12.4.15 The image analysis software shall be capable of opening 16-bit uncompressed color image files, converting them to 16-bit uncompressed grayscale images using a lossless conversion, selecting a group of pixels within an image, determining the mean pixel intensity and standard deviation of pixel intensities within the selected group, and writing the results to a text file.

8.12.5 Procedure.

8.12.5.1 The thermal imager lens and display and the visible spectrum camera lens shall be cleaned in accordance with the manufacturer's specifications.

8.12.5.2 The thermal imager shall be equipped with a freshly charged battery.

8.12.5.3 The thermal imager shall be activated 3 minutes, ±1 minute, prior to the beginning of the test.

8.12.5.4 Both source targets shall be stabilized to within ±0.02°C of their initial setpoint temperatures. The temperature setting of the T_1 source target shall remain constant throughout the test.

8.12.5.5 The thermal imager shall be positioned such that the source targets fill at least 40 percent of the FOV and the axis of the thermal imager's outermost lens is perpendicular with the source

target surface.

8.12.5.6 The visible spectrum camera shall be placed at the optimum viewing position with respect to the thermal imager display, such that the thermal imager display fills 90 percent of the FOV in the vertical dimension and is in focus.

8.12.5.7 A black shroud shall be placed around the viewpath of the visible spectrum camera to block all glare incident upon the thermal imager display from the surrounding environment. The shroud shall be held securely in place and shall not be disturbed during the course of each test.

8.12.5.8 Each thermal imager shall be tested with the source target T_1 at a setpoint temperature of 30°C (86°F).

8.12.5.8.1 The T_2 source target shall be set at $T_2 = T_{amb} - 5$°C, and the T_2 source target shall then be increased at a rate of 0.5°C per minute until $T_2 = T_{amb} + 5$°C. Uncompressed color images at a minimum bit depth of 16 bits shall be captured from the visible spectrum camera at a rate of one image every 3 seconds, ±0.1 second, while the T_2 temperature is increasing.

8.12.5.9 After data collection is complete, the thermal imager shall be removed from its position in front of the source targets within 60 seconds.

8.12.5.10 The images captured from the visible spectrum camera shall be converted to uncompressed grayscale images using a lossless conversion. The images shall have a minimum bit depth of 16 bits using Equation 8.1.5.11.

8.12.5.11 Two regions of interest shall be used to select pixels for analysis in each image. Pixels representing the T_2 source target shall make up one of the regions of interest, shall encompass at least 90 percent of the T_2 source target, and shall not include pixels located along the edge of the T_2 emitting surface. Pixels representing ambient conditions shall make up the other region of interest, which shall include the same number of pixels as the T_2 region of interest. The same regions of interest shall be used on all images captured throughout the test. Pixels that represent symbols, icons, and text shall be excluded from the analysis.

8.12.5.12 The high frequency noise created by oversampling the thermal imager display shall be removed from the captured images. A moving average in two dimensions shall be applied to the region of interest with the average having a period equal to the width and height of the thermal imager display pixels observed in the captured images.

8.12.5.13* The mean pixel intensity of each region of interest in each image shall be calculated using Equation 8.1.5.14 b. The mean pixel intensities shall then be divided by 65536. For each image, the resulting normalized pixel intensities for the T_{amb} region of interest shall be subtracted from the T_2 region of interest, and the difference shall be plotted with respect to the T_2 source target temperature. A linear trend line shall be fit to the plotted data using a least squares fit method. The slope of the trend line shall be the response slope. The goodness of fit of the data to the trend line shall be the correlation coefficient.

8.12.6 The response slope and the correlation coefficient shall be calculated, recorded, and reported.

8.12.7 Interpretation. Any one specimen failing the test shall constitute failing performance.

8.13 Durability Test.

8.13.1 Application. This test method shall apply to all thermal imagers.

8.13.2 Samples. Samples shall be complete thermal imagers.

8.13.3 Specimens.

8.13.3.1 Specimens for testing shall be complete thermal imagers. Where the thermal imager is equipped with a retention device, the retention device shall be permitted to be removed prior to testing.

8.13.3.2 A minimum of three specimens shall be tested.

8.13.3.3 Specimens shall be conditioned at a temperature of 22°C, ±3°C (72°F, ±5°F), and a relative humidity of 50 percent, ±25 percent, for at least 4 hours.

8.13.3.4 Specimens shall be tested within 5 minutes after removal from conditioning.

8.13.4 Apparatus.

8.13.4.1 An environmental conditioning test chamber shall be capable of accepting complete specimen thermal imagers.

8.13.4.2 The environmental conditioning test chamber shall be capable of maintaining and continuously monitoring the required conditions throughout the envelope of air surrounding the complete thermal imagers.

8.13.4.3 A water dunk container capable of covering and maintaining the uppermost point of the specimen thermal imagers with a depth of 1 m, ±0.1 m (40 in., ±4 in.), of de-ionized water shall be used.

8.13.4.4 The water temperature in the water dunk container shall be 22°C, ±3°C (72°F, ±5°F). The water temperature shall not change more than 3°C (5°F) for the duration of the test.

8.13.4.5 A tumble test apparatus shall be as specified in Figure 8.13.4.5.

****INSERT EXISTING FIGURE 8.13.4.5 FROM 2010 EDITION****

FIGURE 8.13.4.5 Tumble Test Apparatus.

8.13.5 Procedure 1.

8.13.5.1 The pre-test image recognition values in the vertical and horizontal directions shall be recorded as specified in Section 8.1, Image Recognition Test.

8.13.5.2 The test specimen shall be placed in the environmental conditioning test chamber that has been stabilized at 49°C, +3°/-0°C (120°F, +5°/-0°F).

8.13.5.3 After 6 hours, the temperature shall be raised within 1 hour to 60°C, +3°/-0°C (140°F, +5°/-0°F) and maintained for 4 hours.

8.13.5.4 The temperature shall then be decreased within 1 hour to 49°C, +3°/-0°C (120°F, +5°/-0°F).

8.13.5.5 This cycle shall be repeated twice.

8.13.5.6 After the second cycle, the temperature shall be raised to 60°C, +3°/-0°C (140°F, +5°/-0°F) for 4 hours.

8.13.5.7 The test specimen shall be removed following the conditioning specified in 8.13.5.2, and within 30 seconds the specimens shall be immersed in the water dunk container containing the de-ionized water for 30 minutes, +5/-0 minutes.

8.13.5.7.1 The test specimens shall be removed from the water dunk container, wiped dry, and placed in the environmental conditioning test chamber that has been stabilized at -20°C, +3°/-0°C

(-4°F, +5°/-0°F) and maintained for a minimum of 4 hours.

8.13.5.7.2 Following the 4-hour conditioning of the test specimen at -20°C (-4°F), the test specimen shall be removed from the environmental conditioning test chamber and within 30 seconds shall be re-immersed in the water dunk container for 30 minutes, +5/-0 minutes.

8.13.5.8 The test specimens shall be removed from the water dunk container, wiped dry, and placed in the tumble test apparatus. Only one specimen shall be tested in the tumble test apparatus at a time. All specimens shall be unrestrained.

8.13.5.8.1 The tumble test apparatus shall be run at a speed of 15 rpm, ±1 rpm.

8.13.5.8.2 The test shall be run for 30 minutes, +5/-0 minutes.

8.13.5.8.3 Upon completion of the test duration, the specimens shall be immersed in the water dunk container for 30 minutes, +5/-0 minutes.

8.13.5.8.4 The test specimens shall be blown dry with clean compressed air or nitrogen until the lens and viewing windows are free from all moisture. Evaluation of the three specimens shall begin within 5 minutes of completion of drying.

8.13.5.8.5 The specimens shall be evaluated for post-test image as specified in Section 8.1, Image Recognition Test, and the post-test image recognition values in the vertical and horizontal directions shall be recorded.

8.13.5.8.6 One test specimen shall be selected at random, and its electronics compartment shall be opened and checked for water leakage.

8.13.6 Procedure 2.

8.13.6.1 One test specimen shall be selected at random from the remaining specimens submitted for testing to this section.

8.13.6.2 The random specimen shall be re-immersed in the water dunk container for 5 minutes. The power source compartment(s) shall be open, and the power source shall not be installed.

8.13.6.3 After the 5 minutes, +1/-0 minutes, the random specimen shall be removed from the water dunk container and shall be wiped dry.

8.13.6.4 The power source shall be reinstalled, and the random specimen shall be evaluated for post-test image as specified in Section 8.1, Image Recognition Test. The post-test image recognition values in the vertical and horizontal directions shall be recorded.

8.13.6.5 The electronic compartment(s) of the random specimen shall be opened and inspected for water leakage.

8.13.7 Procedure 3.

8.13.7.1 The remaining test specimen shall be submitted for testing in accordance with Procedure 3.

8.13.7.2 The second random test specimen shall be activated and then immersed in the water dunk container for 5 minutes. After 5 minutes, +1/-0 minutes, the specimen shall be removed from the test water container and shall be wiped dry.

8.13.7.3 The second random test specimen shall be evaluated for post-test image as specified in Section 8.1, Image Recognition Test, and the post-test image recognition values in the vertical and horizontal directions shall be recorded.

8.13.7.4 The second random test specimen shall be deactivated and the power supply compartment(s) and external power supplies shall be opened and inspected for water leakage.

8.13.8 Reports for Procedures 1, 2, and 3.

8.13.8.1 In Procedures 1, 2, and 3, the proper functioning of image recognition values in the vertical and horizontal directions shall be determined as specified in Section 8.1, Image Recognition Test, and shall be calculated, recorded, and reported.

8.13.8.2 In Procedures 1, 2, and 3, any water leakage into any electronic compartment(s) shall be recorded and reported.

8.13.8.3 In Procedure 3, any water leakage into any power supply compartment(s) or external power supply shall be recorded and reported.

8.13.9 Interpretation. Any one specimen failing any test shall constitute failing performance.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1.5 Purchasers and manufacturers of thermal imagers should understand that NFPA 1801 addresses minimum requirements for thermal imagers with the TI BASIC operational format. The TI BASIC PLUS operational format permits accessories and enhancements for a thermal imager so long as they meet the applicable requirements and can be easily disabled or removed, reverting the camera back to the certified TI BASIC mode. Thermal imaging technology is advancing quickly. Potentially useful thermal imaging accessories and enhancements should be considered so long as they do not negatively affect the thermal imager's performance.

Thermal imager enhancements and accessories include wireless video transmitters, image and video capture, alternative uses of color in the thermal image, user-set color-temperature transition points, and icons on the screen for other functions. Purchasers interested in enhanced thermal imager capabilities (TI BASIC PLUS) should consider the benefits and limitations of the additional capabilities before making a purchase. Fire departments vary greatly in size, response types, and capabilities. For example, fire departments on the west coast are more likely to encounter large wildland fires than New York City, Boston, or Chicago, which are more likely to experience multiple-alarm tenement or row house building fires. Flood-prone regions are less likely to have underground garages, sub-basements, or subway systems. These examples provide different challenges for the utilization of thermal imagers and any accessories.

Some thermal imaging enhancements and accessories utilize radio signal technology. Radio signals react differently in variable and different environments and present different challenges to radio signals. Transmission of radio signals is affected by topography, weather conditions, building layout and design, and construction materials, and other obstructions in a given area.

In the testing lab environment, wireless thermal imaging accessories such as video transmitters, image-capturing devices, and alarm devices cannot be "tested" in the total environment in which they could be used. Prospective end users can conduct field testing of such devices in the total environment in which they could be used. Antennas or repeaters can be incorporated into radio frequency (RF) systems used in large industrial and commercial facilities. Realistic and rigorous on-site testing of systems and components will help ensure satisfactory coverage and help the user develop reasonable expectations. Physical testing of thermal imagers utilizing any form of RF technology should be conducted in an actual or realistic environment. Current RF laboratory testing methods cannot take into account the commonly found variety of construction and

obstructions. Fire service organizations should take into consideration the local factors in their immediate response areas.

Based on actual jurisdictional performance testing, fire service organizations can make informed decisions regarding the purchase, use, and development of operational procedures to be used in providing the maximum level of protection for fire and rescue personnel in their jurisdiction. Purchasers should develop operational procedures to ensure that their thermal imager's enhancements and accessories will function as expected.

In consideration of the factors previously noted, the purchaser should develop testing and performance criteria similar to the following:

(1) Prior to using or purchasing a product or system, the local fire service organization should select several different typical target hazard test scenarios likely to be encountered in the normal response area for field testing of the product or system.

(2) These target hazard test locations should provide rigorous testing scenarios and should include RF dead spots (if applicable), unusual building complexes, aboveground and belowground configurations, and typical local construction materials.

(3) A person(s) designated by the fire service organization(s) should participate in site selection and field testing.

(4) Testing should be conducted by simulation of actual emergency operations and conditions.

  (a) The fire service official should designate an area (i.e., a base station) where accessory receiving components of the thermal imager system would be located if the incident were real.

  (b) Fire service responders should use the devices just as they would during an actual emergency and travel to all areas of the simulated emergency scene test area.

  (c) The test scenarios for RF testing should be made as difficult and as challenging as possible so problem areas where an RF signal might have difficulty penetrating a building or structure can be isolated and addressed.

  (d) Testing results should be recorded along with environmental factors such as the type of occupancy (residential, commercial, industrial, etc.), construction features, weather conditions, and location.

(5) Enhancement devices (leaky coaxial feeders, repeaters, enhanced radio receivers) can be used as necessary, with placement and effectiveness recorded.

(6) Fire service responders who would routinely have multiple receiving components on the scene of an actual emergency should place multiple receiving devices in service during field-testing scenarios in accordance with their standard operating procedures.

(7) *NFPA 5000, Building Construction and Safety Code*, outlines the eight basic types of construction that should be considered as part of the field-test criteria.

(8) Users should evaluate the effectiveness of the device as it relates to the developed operational procedures.

By conducting these recommended field tests, fire service organizations can witness the performance of the product in the environment in which it is intended to be used, determine with reasonable accuracy whether the product meets their expectations, and then make an appropriate decision.

A.1.3.4 See A.1.1.5.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3 The following terms are commonly used in the thermal imaging field but do not have official definitions:

(1) **2X Zoom.** A method to change a distant view to a closer view by enlarging the image by a factor of 2, thereby reducing the field of view.

(2) **Digital Zoom.** The enlargement of a viewable image achieved by digitally enlarging a portion of the optical image.

(3) **Ge.** Germanium.

(4) **Hand Held.** Referring to a thermal imager design that is intended to be held in the hand and normally operated in such fashion.

(5) **Hands Free.** An operational mode whereby, once activated, the device no longer requires manipulation by hand for regular use.

(6) **Infrared (IR).** Electromagnetic radiation having a wavelength in the range from c.75×10^{-6} cm to c.$100{,}000 \times 10^{-6}$ cm (0.000075 to 0.1 cm).

(7) **Optical Zoom.** The enlargement of a viewable image achieved through the physical movement of optical elements to change the focal length.

(8) **Phase Alternating Line (PAL).** A composite video standard that displays 25 interlaced frames per second (50 half frames per second) at 625 lines of resolution.

(9) **Radio Frequency Interference (RFI).** The unwanted reception of radio signals.

A.3.3.20 Product Label. The product label is not the certification organization's label, symbol, or

identifying mark; however, the certification organization's label, symbol, or identifying mark is attached to or part of the product label.

A.6.1.2 All power sources consisting of battery cells and battery packs should be evaluated by a national recognized testing laboratory (NRTL) in accordance with the regulations outlined in UL 1642, *Standard for Lithium Batteries*, or UL 2054, *Standard for Household and Commercial Batteries*, or both.

A.6.3.1 An FMEA provides an approach to identifying and ranking thermal imager failure modes that could lead to product hazard. The FMEA is organized based on safety functions provided by the thermal imager. These functions can be implemented in a single component or across multiple components.

The FMEA should address, at a minimum, all failure modes of components that would result in the following failure effects for TI BASIC functions:

(1) Failure to indicate inadequate power source

(2) Failure to provide shutdown notification due to an overheat condition

(3) Failure to meet image quality requirements

(4) Failure to turn on

(5) Failure to be restarted to the TI BASIC operational format

The FMEA should be conducted in accordance with the industry standard JEDEC Publication JEP131A, *Potential Failure Mode and Effect Analysis (FMEA).*

The effect of the failure mode is determined by the system's response to the failure. The FMEA identifies subassemblies and their functions, the failure mode for those subassemblies, the failure effect on other subassemblies as well as the whole system, and the corrective action to be taken.

Step 1: Select function. The FMEA process begins by selecting a thermal imager function to be analyzed. Record the requirement number and the requirement description on the FMEA form *(see Figure A.6.3.1).*

****INSERT EXISTING FIGURE A.6.3.1 FROM 2010 EDITION****

FIGURE A.6.3.1 FMEA Form.

Step 2: Identify equipment components. Step 2 identifies all the equipment components that implement the function requirement. List the components in column 1 of the FMEA form.

Step 3: Specify failure mode for identified components. For each component listed in column 1 of the FMEA form, list potential failure modes in column 2. A failure mode is any component failure that results in failure of the component to deliver part or all of its intended functionality.

Step 4: Identify failure effects. For each component failure mode included in column 2, step 4 identifies one or more failure effects that the identified failure mode would have on delivery of the thermal imager function being analyzed. Include the failure effect in the third column. A failure effect is a deviation in function output value (e.g., "cross-hairs" in wrong location) or timing (e.g., "instant on" takes 2 minutes instead of 10 seconds).

Step 5: Determine severity (S) of failure modes and effects. Table A.6.3.1(a) provides the criteria for determining the severity of failure modes and effects.

Table A.6.3.1(a) Determining Severity (S) of Failure Modes and Effects

Severity (S)	Description	Value
Critical	A product hazard that judgment and experience indicate is likely to result in a condition immediately dangerous to life or health (IDLH) for individuals using or depending on the compliant product. If an IDLH condition occurs, the user will sustain or will be likely to sustain an injury of a severity that could result in loss of life or in significant bodily injury or loss of bodily function, either immediately or at some point in the future.	10
Major A	A product hazard other than Critical that is likely to result in failure to the degree that the compliant product either does not provide any protection or reduces protection and that is not detectable to the user. The term "reduces protection" means the failure of specific protective design(s) or feature(s) that results in degradation of protection in advance of reasonable life expectancy to the point that continued use of the product is likely to cause physical harm to the user, or where continued degradation could lead to IDLH conditions.	10
Major B	A product hazard other than Critical or Major A that is likely to result in reduced protection and that is detectable to the user. The term "reduces protection" means the failure of specific protective design(s) or feature(s) that results in degradation of protection in advance of reasonable life expectancy to the point that continued use of the product is likely to cause physical harm to the user, or where continued degradation could lead to IDLH conditions.	5
Minor	A product hazard other than Critical, Major A, or Major B that is not likely to materially reduce the usability of the compliant product for its intended purpose or a product hazard that is a departure from the established applicable standard and has little bearing on the effective use or operation of the compliant product for its intended purpose.	1

For each component failure mode and effect included in column 3 of the FMEA form, the value for the severity level is recorded in column 4. Base the value of the severity level, on the criteria provided in Table A.6.3.1(a).

Step 6: Determine the causes of failure and their probability (P). Table A.6.3.1(b) lists the probability of the failure for each potential failure mode and effect combination in column 5. For each root cause, list in column 6 the probability that the failure would occur using the categories in Table A.6.3.1(b).

Table A.6.3.1(b) Probability (P) Criteria

Category	Description	Probability
Frequent	The failure will occur often in the equipment life cycle.	10
Occasional	The failure will occur at least once in the equipment life cycle.	5
Improbable	So unlikely that it can be assumed that the failure will not occur in the equipment life cycle.	1

Step 7: Determine design controls and detectability (D). For each likely cause of failure, Table A.6.3.1(c) lists whether the design controls will help ensure that the failure can be detected. The design control is identified in column 7 of the FMEA form. When causes are identified, discuss and document the design controls that will prevent, remove, or detect and recover from the effects of the failure mode. For each design control, assign a detectability value based on the criteria in Table A.6.3.1(c) and list it in column 8 of the FMEA form.

Step 8: Compute risk priority number (RPN). Step 8 computes a risk priority number (RPN), listed in column 9 of the FMEA form, based on the values of risk, probability, and detectability, as follows:

$RPN = S \times P \times D$

The lower the value of the RPN, the lower the risk that a given failure will occur. The RPN value is the measure used as input to the risk analysis.

Table A.6.3.1(c) Detectability (D) Criteria

Category	Description	Value
Undetectable	There is no way to detect the occurrence of the failure mode and effect. Effective design controls are not in place.	10
Not Sure	The design controls in place might not always detect the failure mode and effect.	5
Detectable	The design controls in place will always detect the failure mode and effect.	1

A.6.3.4 The FMEA process includes a step for computing a measure identified as the risk priority number, or RPN (column 9), in Figure A.6.3.1. Higher RPN values imply higher risks. RPN values can be used to determine the ALARP region. Using the ALARP region provides a consistent criterion for stopping the FMEA for a required thermal imager function.

As shown in Figure A.6.3.4, the ALARP region has an upper and a lower limit. The upper limit is the horizontal line that separates the ALARP region from the intolerable region, where risk is refused. The lower limit is the horizontal line that separates ALARP from the broadly acceptable region, where the risk is insignificant. When the design controls implemented have reduced the risk to fall in the ALARP region, the FMEA may be stopped.

Specifying an ALARP value of 25 reduces the risk of remaining failures to the following:

(1) Minor severity failures that are occasional and that might or might not be detected

(2) Major B severity failures that are improbable and that might or might not be detected

(3) Major B severity failures that are occasional and that will be detected

The value of 25 thus seems reasonable for a more quantitative definition of an ALARP upper limit for thermal imagers.

Specifying an ALARP value of 10 reduces the risk of remaining failures to the following:

(1) Minor severity failures that are improbable and that will not be detected

(2) Minor severity failures that are frequent and that might or might not be detected

(3) Critical or Major A severity failures that are improbable and that will be detected

The value of 10 thus seems reasonable for a more quantitative definition of an ALARP lower limit for thermal imagers.

****INSERT EXISTING FIGURE A.6.3.4 FROM 2010 EDITION****

FIGURE A.6.3.4 Upper and Lower Limits of ALARP Region Based on RPN.

Table A.6.3.4 maps the target ALARP upper and lower limits to exposure.

Table A.6.3.4 Target ALARP Upper and Lower Exposure Limits

Exposure Category	ALARP Region
Hostile, fire	$10 \leq \text{RPN} \leq 25$
Hostile, non-fire	$10 \leq \text{RPN} \leq 25$

A.6.4.2 The TI BASIC functions feature is designed to allow the user who may be unfamiliar with a particular model of thermal imager to pick it up and use it. In the TI BASIC mode, the thermal imager is limited to those features that are standard on all thermal imagers. Operators with NFPA-compliant TI BASIC operational format training should be able to operate any other NFPA-compliant TI BASIC thermal imager.

A.6.5.2 Manufacturers can offer additional features, but the user should obtain instruction from a manufacturer's recognized trainer before placing the thermal imagers into service. TI BASIC PLUS features are limited to those who have received such advanced operational training.

The AHJ should have the option to go directly into the TI BASIC PLUS mode once they have determined their personnel have sufficient knowledge to operate in the TI BASIC PLUS mode.

A.6.5.5 Access to the TI BASIC PLUS functions should have an alternative method of limiting user access to personnel who the AHJ has determined have sufficient knowledge of thermal imagers to operate in the TI BASIC PLUS operational format.

A.8.12.5.13 A trend line determined by the least squares fit method is consistent with the following set of equations:

A.8.12.5.13a $$y = mx + b$$

where y is a point on the trend line, m is the slope of the line and is defined in Equation A.8.12.5.13b, x is a point on the x-axis, and b is the value at which the trend line crosses the zero point of the x-axis and is defined in Equation A.8.12.5.13c.

A.8.12.5.13b $$m = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sum (x - \bar{x})^2}$$

A.8.12.5.13c $$b = \bar{y} - m\bar{x}$$

where y and mx are the mean x and y values, respectively.

The correlation coefficient (R^2) of the data with respect to the trend line is determined by Equation A.8.12.5.13d:

A.8.12.5.13d $$R^2 = \left(\frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 (y - \bar{y})^2}} \right)^2$$

Annex B Informational References

B.1 Referenced Publications.

The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

B.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 5000®, Building Construction and Safety Code®, 2009 edition.

B.1.2 Other Publications.

B.1.2.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/ISA-12.12.01, *Nonincendive Electrical Equipment for Use in Class I and II, Division 2 and Class III, Divisions 1 and 2 Hazardous (Classified) Locations*, 2007.

B.1.2.2 JEDEC Publications. Joint Electron Devices Engineering Council, 3103 North 10th Street, Suite 240–S, Arlington, VA 22201.

JEP131A, *Potential Failure Mode and Effects Analysis (FMEA),* 2005.

B.1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 1642, *Standard for Lithium Batteries*, 2009.

UL 2054, *Standard for Household and Commercial Batteries*, 2009.

B.2 Informational References.

(Reserved)

B.3 References for Extracts in Informational Sections.

(Reserved)