

NFPA[®]

1801

**Standard on
Thermal Imagers for
the Fire Service**

2018



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NFPA® 1801

Standard on

Thermal Imagers for the Fire Service

2018 Edition

This edition of NFPA 1801, *Standard on Thermal Imagers for the Fire Service*, was prepared by the Technical Committee on Electronic Safety Equipment and released by the Correlating Committee on Fire and Emergency Services Protective Clothing and Equipment. It was issued by the Standards Council on August 1, 2017, with an effective date of August 21, 2017, and supersedes all previous editions.

This edition of NFPA 1801 was approved as an American National Standard on August 21, 2017.

Origin and Development of NFPA 1801

In December 2004, Dr. Francine Amon, Nelson Bryner, and Anthony Hamins of the National Institute of Standards and Technology (NIST) hosted the workshop, “Thermal Imaging Research Needs for First Responders.” The workshop provided a forum to discuss thermal imaging camera strategies, technologies, procedures, best practices, research, and development. Participants included representatives from the U.S. Fire Administration, International Association of Fire Chiefs, NIOSH NPPTL, Naval Research Lab, and thermal imaging camera and core manufacturers, as well as first responder users and trainers. The need for standards was clearly identified as a priority. In May 2005, as a direct result of that workshop, a group of manufacturers and fire service end users met to further identify the need for standardization. The Fire Service Thermal Imaging Camera Operational Standard (FSTICOS) Working Group was formed with Larry Konsin of the American Council for Thermal Imaging and MSA selected to be the group’s chairman.

The FSTICOS Working Group was well populated with representatives from all the manufacturers of fire service thermal imagers and imager core manufacturers along with fire fighter/end users and trainers. The Working Group focused principally on the needs of the fire service for thermal imagers and set about drafting a needs, functionality, usability, and ruggedness statement to begin defining the levels of performance that were deemed necessary. Through surveys conducted at fire service trade shows nationwide, fire fighters validated the findings of the group. As the FSTICOS Working Group was meeting bimonthly, Dr. Amon and her staff at NIST, with the assistance of the U.S. Army Night Vision Lab, began developing the criteria for image quality for fire service thermal imagers. The two groups met and collaborated on a proposed document for thermal imaging cameras. In September 2006, the FSTICOS Working Group requested that the NFPA Technical Committee on Electronic Safety Equipment (TC on ESE) work with them on the project. The TC on ESE agreed to create a Task Group on Fire Service Thermal Imagers, and many of the participants of the FSTICOS Working Group requested to be appointed as members of the TC’s task group. TC on ESE Chairman Bruce Varner appointed TC member Robert Athanas as the task group chairman and the following persons as task group members: Dr. F. Amon, N. Bryner, G. Francisco, C. Gestler, J. Hays, J. Henebury, P. House, R. Klug, L. Konsin, D. Little, S. Lumry, T. McDonald, M. McKenna, S. Nixdorff, T. Tedesco, D. Wiles, and T. Wolf.

During the development process, it became clear that the fire services operational environments were very different from most other emergency services organizations, which led the TC to change the focus of NFPA 1801 to thermal imagers for the fire service. The proposed standard was entered into the Fall 2009 standards cycle and underwent several development changes as the TC worked with the very technical design criteria and test methods developed for this standard. As with all PPE product standards in the Project on Fire and Emergency Services Protective Clothing and Equipment, NFPA 1801 included requirements for independent third-party certification of thermal imagers to ensure compliance with the labeling, design, performance, testing, and certification requirements for the certification organizations and the thermal imager manufacturers to claim “certified as compliant” to NFPA 1801.

The Report on Proposals (ROP) for NFPA 1801 was released for public review and comment on December 29, 2008. Following the public review period, which closed on March 6, 2009, the Report on Comments (ROC) was processed in the spring of 2009. The Technical Correlating Committee (TCC) on Fire and Emergency Services Protective Clothing and Equipment processed the proposed NFPA 1801 at their meeting in late May 2009 and approved the document to go forward.

The 2010 edition of NFPA 1801 was recognized as one of the most technical documents assembled and released under the NFPA Fire and Emergency Services Protective Clothing and Equipment Project to date. The image quality tests that were developed specifically for the standard were complicated due to their highly technical nature, and the degree to which they were reproducible from testing laboratory to testing laboratory was in question.

The TC sought the assistance and resources of the Fire Protection Research Foundation to coordinate a series of round robin tests to determine the lab-to-lab repeatability of the image quality tests. The project was conducted by Dr. Francine Amon, Ph.D., who began this project while employed by the National Institute of Standards and Technology (NIST). The remainder of the testing was conducted by Chad Morey of Intertek Testing Services of Cortland, New York. Additional sponsorship of the project came from Draeger Safety, Honeywell First Responder Products, ISG Infrasy, MSA, and Scott Safety.

A number of changes that needed to be made were identified in the document. A Tentative Interim Amendment (TIA) and Errata were issued to address these changes. Ultimately, the TC decided that the best course of action was to immediately enter the revision cycle for Annual 2012 and review the document for any additional changes.

In April 2011, several thermal imager manufacturers began work to revise the testing issues. In June 2011, at the direction of TC on ELS Chairman Bruce Varner, a task group was formed chaired by TC member Robert Athanas of FDNY and SAFE-IR, Inc. In an effort to identify and resolve these issues in an expeditious manner, the task group was comprised of thermal imager manufacturer technical personnel (engineers from the thermal imager camera and core manufacturers) and testing lab technicians. Task group members included Daniel Akins and John Morris (ISG INFRASYS), Landon Borders and Kyle Hawes (Bullard), Craig Gestler (MSA), Jason Patterson (Scott Safety), Jon Turner and Bill Wilson (e2v Technologies), and Dr. Bernd Spellenberg and Travis Tedesco (Draeger Safety). The thermal imager core manufactures were represented by Humphrey Ha (L-3 Communications), and Bob Nishi and Julie Hoy Moreira (FLIR Systems). Certification and testing organizations were represented by Steve Sanders and Jim Rose (SEI) and Jason Allen and Chad Morey (Intertek). Fire service representation included Bob Athanas of FDNY/SAFE-IR and Steve Townsend of the Carrollton, Texas Fire Department.

The first task group meeting was held on June 29, 2011 in Newark, New Jersey, where testing issues were further clarified and a course of action was developed and agreed upon by all the participants. This meeting was followed by several lengthy conference calls and many hours of research and testing over the summer months to meet a September, 2011 NFPA 1801 ROC deadline.

The last task group meeting was held in Austin, Texas on September 19, 2011, prior to a full meeting of the TC on ELS to finalize the proposed work. The final comments included revised language and test procedures, which improved the content of the first edition of the standard as initially written. The TC was balloted according to the NFPA Regulations Governing Committee projects. The ballot subsequently passed, enabling the TCs' changes to be included in the 2013 edition of NFPA 1801. It should be noted that participation and cooperation of all task group members and the support afforded them by their employers during this project was unprecedented and should serve as a model for future projects.

The 2018 edition of NFPA 1801 now also applies to the design, performance, testing, and certification of thermal imagers originally certified to the previous edition of this standard that incorporate replacement parts, components, and/or software to be certified to this edition of the standard. New UL standard references were added, as were specifications for labeling upgraded thermal imagers. The TI BASIC operational format is now permitted to include audio, video, and data transmission.

NFPA 1801 also has a new design requirement for an audio/video recording indicator, and there have been several editorial and referenced document updates.

Following is a summary of the updated thermal imager requirements:

- Battery locking mechanism testing was added so that where the use of a tool-secured feature is relied upon to meet ANSI/ISA-12.12.01 and this feature is not automatically engaged, the camera will inform the user by way of a message that prevents normal use of the camera.
- All imagers will be required to pass a 2-hour run-time conducted with video and image capture functions active.
- The thermal imager must display a useful image within 30 seconds of power being applied (battery installed).
- The thermal imager must display an icon in the form of a red dot inside a green circle when recording audio/video.
- Camera resolution of 76,800 pixels (320 × 240) is a minimum requirement.
- A sensor/image refresh rate of at least 25 Hz is required.
- Only specified symbols can be displayed at power-up.
- A display resolution of 76,800 was added to match the sensor requirement.

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Standard on

Thermal Imagers for the Fire Service

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

A reference in brackets [] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex B. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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.

N 1.1.2.1* This standard shall also specify the minimum requirements for the design, performance, testing, and certification of thermal imagers certified to an earlier edition of this standard that incorporate parts, components, and/or software to meet this edition of the standard.

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.

N 1.3.2.1 This standard shall also apply to the design, performance, testing, and certification of thermal imagers originally certified to the previous edition of this standard that incorporate replacement parts, components, and/or software to be certified to this edition of the standard.

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*, 2018 edition.

2.3 Other Publications.

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

ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*, 2011.

ASTM D1003, *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics*, 2013.

2.3.2 ISA Publications. The International Society of Automation, 67 T.W. Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709.

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*, 2013.

2.3.3 ISO/IEC Publications. International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*, Ed. 2.2, 2013/Cor 1:2013.

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*, 2011.

IEC 62133, *Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*, 2012.

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 9001, *Quality management systems — Requirements*, 2008.

ISO 9001, *Quality management systems — Requirements*, 2015.

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*, 2011.

ISO/IEC 17065, *Conformity assessment — Requirements for bodies certifying products, processes, and services*, 2012.

2.3.4 NIST Publications. National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070.

NIST Technical Note 1630, *Evaluation of Image Quality of Thermal Imagers Used by the Fire Service*, February 2009.

2.3.5 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 1642, *Standard for Lithium Batteries*, 2005, revised 2013.

UL 2054, *Standard for Household and Commercial Batteries*, 2004, revised 2011.

2.3.6 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. An NFPA Standard, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase “standards development process” or “standards development activities,” the term “standards” includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

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 Model. The collective term used to identify a group of elements or items of the same basic design and components from a single manufacturer produced by the same manufacturing and quality assurance procedures that are covered by the same certification.

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

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

3.3.20 Product. See 3.3.6, Compliant Product.

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

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

3.3.23 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.

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

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

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

N 3.3.26 Service Life. The period that a compliant product can be useful before retirement.

3.3.27 Specimen. The item that undergoes testing; the conditioned equipment or equipment component that is tested. Specimens are taken from samples. (*See also 3.3.23, Sample.*)

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

3.3.29 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.

Δ 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/IEC 17065, *Conformity assessment — Requirements for bodies certifying products, processes, and services*. The accreditation shall be issued by an accreditation body operating in accordance with ISO 17011, *Conformity assessment — 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.

N 4.1.7 The certification organization shall not certify any thermal imager to the 2013 edition of this standard on or after the NFPA effective date for the 2018 edition, which is August 21, 2017.

N 4.1.8 The certification organization shall not permit any manufacturer to label any thermal imager as compliant with the 2013 edition of this standard on or after August 21, 2018,

except when replacement labels or replacement components that bear the certification organization's label are required.

N 4.1.9 The certification organization shall require manufacturers to remove all certification labels and product labels indicating compliance with the 2013 edition of this standard from all thermal imagers that are under the ownership and control of the manufacturer on August 21, 2018. The certification organization shall verify that this action is taken.

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.

Δ 4.2.3 The certification organization shall be accredited for personal protective equipment in accordance with ISO/IEC 17065, *Conformity assessment — Requirements for bodies certifying products, processes, and services*. The accreditation shall be issued by an accreditation body operating in accordance with ISO 17011, *Conformity assessment — 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.

N 4.2.8.1 The certification organization and the manufacturer shall evaluate replacement parts, components, software, and upgrade procedures to determine any changes affecting the form, fit, or function of thermal imagers certified to earlier editions of this standard to permit incorporation of replacement parts, components, or software, leading to certification of devices to this edition of the standard.

N 4.2.8.2 Where a manufacturer has more than one model of thermal imager, all certified to this standard, the certifying organization and the manufacturer shall evaluate replacement parts, components, software, and upgrade procedures to determine the continued certification when modifying a fielded thermal imager with replacement parts, components, or software in one previously certified model to become another previously certified model.

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, *Conformity assessment — 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, *Conformity assessment — 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.

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, including, but not limited to, methods of attachment to the operator, 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. The thermal imager shall meet all the performance requirements specified in Chapter 7 with those accessories and enhancements installed or attached, including, but not limited to, methods of attachment to the operator, 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. Manufacturers shall be permitted to refocus camera samples prior to conducting testing.

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

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 (AHJ).

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 AHJ.

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 ISO/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 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 4.2.12 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.

Δ 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 public input 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 ($\frac{1}{32}$ in.) in height, and the label, symbol, or identifying mark shall be at least 6 mm ($\frac{1}{4}$ 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, 2018 EDITION. DO NOT REMOVE THIS LABEL!”

N 5.1.6.1 Thermal imagers originally certified to the previous edition of this standard that have been upgraded to meet this edition shall have the following statement legibly printed. All letters shall be at least 2 mm ($\frac{1}{16}$ in.) in height. The label shall not be restricted to one line. The original NFPA required labeling shall not be removed or covered by the upgrade label.

“UPGRADED TO NFPA 1801, 2018 EDITION.”

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

N 5.1.7.1 The year and month of manufacture shall be separate from the serial number and shall be in MM/YYYY format.

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

N 5.1.8.1 The year and month of manufacture shall be separate from the serial number and shall be in MM/YYYY format.

N 5.1.9 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 product label (marking) requirements for at least Class I, Division 2, Groups C and D and Class II, Division 2, Groups F and G hazardous locations, and with a temperature class of T3 through T6 inclusive.

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 preoperational use shall be provided on at least the following areas:

- (1) Safety considerations
- (2) Preuse 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) Estimated operational time associated with each of the four segments on the power source status indicator

- (7) Low-power source signals and power supply replacement, where applicable
- (8) Charging and recharging procedures
- (9) Marking recommendations and restrictions
- (10) Warranty information
- (11) Recommended storage practices
- (12) Mounting on/in vehicles or fire apparatus
- (13) Explanation and identification of the features and functions of TI BASIC/TI BASIC PLUS
- (14) Symbols and functions with associated temperature references in available operating modes
- (15) If equipped with a temperature bar, adequate description of the use of the temperature bar
- (16) If equipped with a numeric temperature indicator, adequate description of the use of the numeric temperature indicator
- (17) 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 service life, replacement, and retirement considerations for thermal imagers and components shall be provided.

N 5.2.8 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 user information (manufacturer's instructional manual) requirements for at least Class I, Division 2, Groups C and D and Class II, Division 2, Groups F and G hazardous locations, and with a temperature class of T3 through T6 inclusive.

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 at $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$) and without the power source being changed or recharged.

N 6.1.2.1 The continuous operating time shall be measured with all permissible TI BASIC mode current-drawing functions listed under Section 6.4, as well as all manufacturer background systems activated.

N 6.1.3 All power sources consisting of battery cells and battery packs shall be certified by a nationally recognized testing laboratory (NRTL) to the regulations outlined in UL 1642, *Standard for Lithium Batteries*; UL 2054, *Standard for Household and Commercial Batteries*; or IEC 62133, *Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*.

6.1.4 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.

N 6.1.5 The thermal imager shall incorporate a sensor engine consisting of an infrared sensor with at least 76,800 imaging pixels.

N 6.1.6 Video output shall be displayed on a display device consisting of at least 76,800 display pixels, where each display pixel can render all colors required in the standard.

N 6.1.7 Minimum Video Refresh Rate. All thermal imagers shall have a minimum video refresh rate of 25 frames per second in both the detector and the display.

Δ 6.1.8 All operational selection devices, including but not limited to switches, card readers, and keys, shall be rated for not less than 50,000 cycles.

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

Δ 6.1.10 All operational selection devices shall be capable of being switched by a gloved hand. The gloves used for this function test shall be constructed of American cowhide and include a PTFE moisture barrier, shall be properly sized according to the manufacturer and in size large, and shall be certified as compliant with the structural fire-fighting glove requirements of NFPA 1971.

6.1.11 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.

N 6.1.11.1 Methods of attachment shall not obstruct the operator's view of the display or the camera's field of view when held in the viewing position as stated by the manufacturer.

N 6.1.12 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 design (construction) requirements for at least Class I, Division 2, Groups C and D and Class II, Division 2, Groups F and G hazardous locations, and with a temperature class of T3 through T6 inclusive.

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-on/off button shall be located in an easily accessible area of the thermal imager.

6.2.2 The power-on/off 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-on/off 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-on/off 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-on/off button activation and the automatic activation shall present a useful thermal image with all the icons required in the TI BASIC operational format on the display in 30 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.

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.

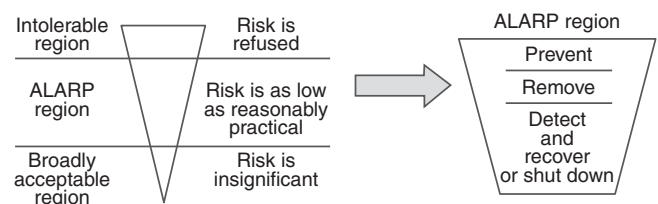


FIGURE 6.3.4 ALARP Region Activities.

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 **indicator**
- (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 **heat** color reference bar
- (2) Temperature bar
- (3) Numeric temperature measurement indicator
- (4) Audio, video, and data recording
- (5) Audio, video, and data transmission

6.5 TI BASIC PLUS Operational Format.

6.5.1 TI BASIC PLUS operational format shall have at least the TI BASIC operational format functions specified in 6.4.3, and any or all of the TI BASIC operational format 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 cycling the thermal imager’s power by pushing the green power-on/off button, or by pushing the green power-on/off button once 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.

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.

N 6.6.3.1.1 In the TI BASIC operational format the left vertical section shall include only the following:

- (1) Low sensitivity mode indicator
- (2) Audio, video, or data recording icon, if so equipped and in operation

N 6.6.3.1.2 In the TI BASIC PLUS operational format the left vertical section shall also include the following:

- (1) Low sensitivity mode indicator
- (2) TI BASIC PLUS activation
- (3) Activation and status of optional TI BASIC PLUS features and functions, if so equipped and in operation

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 **indicator**
- (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 section of the viewing area shall be reserved for temperature sensing indicators and heat color reference bar(s).

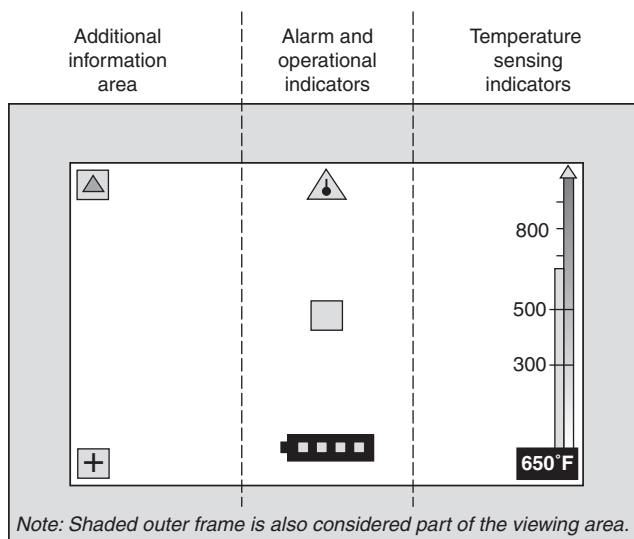


FIGURE 6.6.3 Thermal Imager Viewing Area and Icon Layout.

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 6.6.4.9.

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 section of the 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.

6.6.4.1.4.1 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 Figure 6.6.4. The temperature measurement bar shall be positioned in the right vertical section of the viewing area (temperature sensing indicators) as shown in Figure 6.6.4.

6.6.4.1.4.2 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 section of the viewing area. This icon shall be readable green numerals followed by an "F" for Fahrenheit or "C" for Celsius superimposed on a black background.

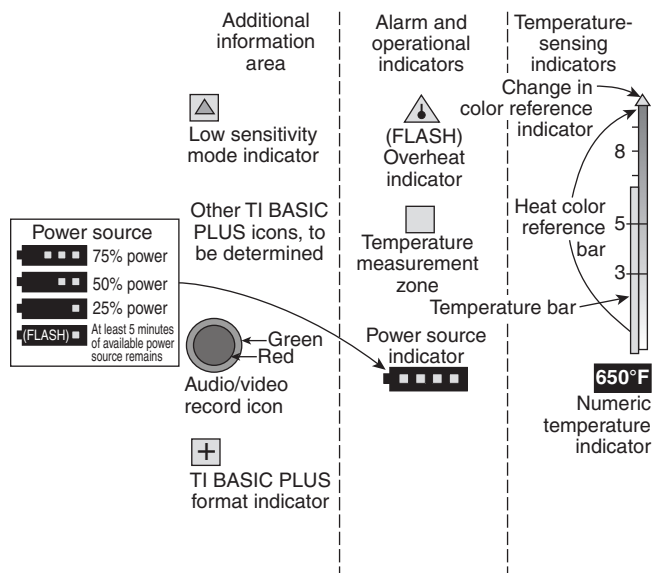


FIGURE 6.6.4 Icon Designs and Descriptions.

6.6.4.1.5 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 heat color reference scale as described in 6.6.4.1.9.

6.6.4.1.6 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.

6.6.4.1.6.1 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.

6.6.4.1.6.2 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.

6.6.4.1.7 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 long wave infrared (LWIR) energy emitted by an object targeted by the temperature measurement zone.

6.6.4.1.8 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.

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

- (1) **Greyscale** — at the bottom of the heat color reference bar before color indication begins and shall not be more than 50 percent of the overall height of the heat color reference bar.
- (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

6.6.4.1.9.1 When the thermal imager is operating in the TI BASIC mode and is equipped with automatic temperature indicating colorization, the colors as specified in 6.6.4.1.9 shall correspond to approximate temperature ranges determined by the manufacturer.

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

6.6.4.1.10 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.

6.6.4.1.11 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 percent to 100 percent available power source)
- (2) Three green segments displayed (51 percent to 75 percent available power source)
- (3) Two yellow segments displayed (26 percent to 50 percent available power source)
- (4) One red segment displayed (0 percent 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 might cease to operate properly 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.

6.6.4.4.5 Thermal Imager-On Indicator. If an additional visual indication to the user exists to indicate that the thermal imager is in the powered-on operational mode (other than a usable image on the display), the indicator 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 consist 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 Options 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 indicators.

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

N 6.6.4.9 Audio/Video Recording Indicator.

N 6.6.4.9.1 All thermal imagers equipped with audio or video, or both, recording capabilities shall have a visual indicator.

N 6.6.4.9.2 The audio/video recording icon shall consist of a solid red circle with a green border.

N 6.6.4.9.3 The audio/video recording icon shall be positioned in the left vertical section, above the location of the TI BASIC PLUS icon, below a horizontal midline as shown in Figure 6.6.4.

N 6.6.4.9.4 The indicator shall be displayed anytime the thermal imager is recording audio or video, or both, content irrespective of the selected TI BASIC or TI BASIC PLUS operational format.

Chapter 7 Performance Requirements**7.1 Thermal Imager Performance Requirements.**

7.1.1 Thermal imagers shall be tested for spatial resolution as specified in Section 8.1, Image Recognition Test, and shall have a minimum *SR* value of 0.06.

7.1.2 Thermal imagers shall be tested for effective temperature range as specified in Section 8.10, Effective Temperature Range Test, and shall have all ΔI values greater than or equal to 5000.

7.1.3 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.

7.1.4 Thermal imagers shall be listed 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 performance (test) requirements for at least Class I, Division 2, Groups C and D and Class II, Division 2, Groups F and G hazardous locations, and with a temperature class within the range of T3 through T6 inclusive. 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.

Assessment shall include all user removable parts in isolation and the action of removing them from the camera in the powered and unpowered state. Where the use of a tool-secured feature is relied upon to meet the ANSI/ISA-12.12.01 compliance, and this feature is not automatically engaged, the camera shall inform the user by way of a message that prevents normal use of the camera.

7.1.5 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.

7.1.6 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.

7.1.7 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.

7.1.8 Thermal imagers shall be tested for resistance to vibration as specified in Section 8.2, Vibration Test, and shall have a minimum *SR* value of 0.06.

7.1.9 Thermal imagers shall be tested for resistance to impact as specified in Section 8.3, Impact Acceleration Resistance Test, and shall have a minimum *SR* value of 0.06, shall have nothing fall off the thermal imager, and shall have no observable damage to any external component that would compromise the case integrity.

7.1.10 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.

7.1.11 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.

7.1.12 Thermal imagers shall be tested for resistance to heat as specified in Section 8.6, Heat Resistance Test, and shall be able to resolve frequencies to the index number 4 of the spatial resolution target and shall not have any part of the thermal imager melt, drip, or ignite.

7.1.13 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.

7.1.14 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.

7.1.15 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 Pull-out Test, and shall have a minimum connection strength of 89 N (20 lbf), and the thermal imager shall remain functional.

7.1.16 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 *SR* value of 0.06, shall have no water inside the electronics compartment(s), and shall have no water inside the power source compartment(s).

7.1.17 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. See NIST Technical Note 1630, *Evaluation of Image Quality of Thermal Imagers Used by the Fire Service*.

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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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.

8.1.3.5 Specimens shall be optimally focused to 1 m by the manufacturer for this test. If the thermal imager incorporates a visible-light camera or other sensor whose output is overlaid onto, or fused with, the thermal image, the sensor shall be disabled prior to conducting the test so that only the thermal image output is used to influence image recognition test results.

8.1.4 Apparatus.

8.1.4.1 Testing shall be conducted in a room having an ambient temperature of $22^{\circ}\text{C} \pm 1^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 2^{\circ}\text{F}$).

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

- (1) A thermal imager positioning device
- (2) A spatial resolution source target as specified in 8.1.4.3
- (3) Ten temperature measurement devices as specified in 8.1.4.4
- (4) Data acquisition software and hardware as specified in 8.1.4.5
- (5) A visible spectrum camera and lens as specified in 8.1.4.7
- (6) A visible spectrum camera mount as specified in 8.1.4.8
- (7) Image capturing software and hardware as specified in 8.1.4.9
- (8) A computer and image analysis software as specified in 8.1.4.10
- (9) The computer image conversion software shall be ViewNX, version 2

8.1.4.2.1 The thermal imager shall be set up at a distance of $1 \text{ m} \pm 5 \text{ mm}$ from the outer-most optical element to 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 visual acuity of at least 20/20 in each eye, uncorrected or corrected.

8.1.4.3 The spatial resolution source target shall consist of two thin, rigid, flat metal surfaces: the emitting surface, and the stencil with the target and $15 \text{ cm} \pm 5 \text{ mm} \times 15 \text{ cm} \pm 5 \text{ mm}$ square cutout. The metal shall be copper for the emitting surface and aluminum for the stencil as detailed in Figure 8.1.4.3. Each surface shall have dimensions of $3 \text{ mm} \pm 0.5 \text{ mm}$.

The front side of both surfaces shall be painted with flat black paint having a stated emissivity of 0.95 ± 0.03 .

8.1.4.3.1 The emitting surface shall be capable of being evenly heated to a surface temperature of $28^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ ($82^{\circ}\text{F} \pm 1^{\circ}\text{F}$). 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.

8.1.4.3.2 The stencil shall be maintained at ambient temperature and shall have a pattern cut cleanly through it as shown in black in Figure 8.1.4.3.

▲ 8.1.4.3.3 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 $102 \text{ mm} \pm 6 \text{ mm}$ ($4 \text{ in.} \pm \frac{1}{4} \text{ in.}$) from the emitting surface.

8.1.4.4 Ten temperature measurement devices having a temperature measurement accuracy of at least 0.1°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 8.1.4.3.

8.1.4.4.1 Five temperature measurement devices shall be secured to the emitting surface, and five temperature measurement devices shall be secured to the stencil. The temperature measurement devices and leads secured to the emitting surface shall not be visible to the thermal imager under test.

8.1.4.4.2 The temperature measurement device 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.

8.1.4.5 The data acquisition system consisting of software and hardware shall be capable of acquiring temperature measuring signals collected from the source target.

8.1.4.5.1 The data acquisition system shall average temperature measurements over a maximum of 10 seconds for each temperature measuring device.

8.1.4.5.2 The data acquisition system shall store the averaged temperature measurements in an electronic text file.

8.1.4.6 The thermal imager positioning device shall position the thermal imager facing the spatial resolution source target at a distance of $1 \text{ m} \pm 5 \text{ mm}$ ($39.4 \text{ in.} \pm 0.2 \text{ in.}$) from the outer-most optical element to the stencil.

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

8.1.4.7 The visible spectrum camera shall be a Nikon D3 or D3S (which will be referred to as D3 in 8.1.4.7.1 through 8.1.4.7.3). The lens shall be a Nikkor 60 mm, f/2.8 macro lens. Other lenses 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 60 mm, f/2.8.

8.1.4.7.1 The shutter shall be activated by a remote trigger release.

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

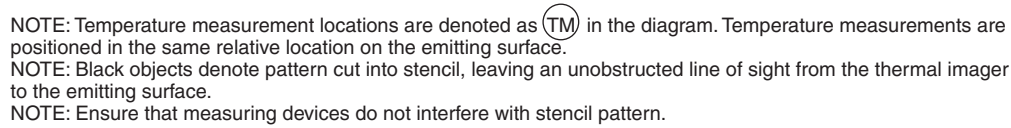


Diagram illustrating the experimental setup for thermal imaging. The setup consists of a vertical assembly of three layers: Heater/insulation (102 mm thick), Emitting surface, and Stencil (305 mm thick). A Thermal imager is positioned 1 m away from the emitting surface. A note states: "NOTE: Heater/insulation, emitting surface, and stencil are supported by a frame. The thermal imager is centered on the source target with the line of sight perpendicular to the plane of the source target."

FIGURE 8.1.4.3 Spatial Resolution Source Target.

8.1.4.7.3 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 shall be as follows:

- (1) Exterior (button and switch) settings
 - (a) Release mode “S”
 - (b) Focus mode “M” (manual)
 - (c) Right side of view finder — Metering mode: 3-D color matrix II
 - (d) Bottom right of the LCD — Focus mode: single-point AF (bottom of 3). Operator shall press the OK button to automatically center the focus point to the center of the Nikon camera display.
 - (e) Camera shall be turned on.
 - (f) If the lens has vibration reduction control, it shall be turned off (interior menu settings). (Click menu button to left of LCD to enter menu.)
- (2) Shooting menu
 - (a) Shooting menu bank — A
 - (b) Reset shooting menu — No
 - (c) Active folder — (N/A)
 - (d) File naming — (N/A) (or DSC default)
 - (e) Slot 2 — Overflow
 - (f) Image quality — NEF (RAW)
 - (g) Image area — Auto DX crop — Off
 - (h) JPEG compression — Size priority
 - (i) NEF RAW recording — Type — Off; NEF (RAW) bitdepth — 14 Bit
 - (j) White balance — Direct sunlight — Center color; A-B — 0; G-M — 0
 - (k) Set picture control — Neutral
 - (l) Manage picture control — (N/A)
 - (m) Color space — sRGB
 - (n) Active D-lighting — Off
 - (o) Vignette control — Normal
 - (p) Long exposure NR — Off
 - (q) High ISO NR — Off
 - (r) ISO sensitivity settings — ISO sensitivity — 200; ISO sensitivity auto control — Off
 - (s) Live view — Live view mode — tripod; release mode — Single frame
 - (t) Multiple exposure — Off
 - (u) Interval timer shooting — Off
- (3) Custom setting menu
 - (a) Autofocus
 1. AF-C priority selection — Release
 2. AF-S priority selection — Focus
 3. Dynamic AF area — 9 points
 4. Focus tracking with lock-on — Off
 5. AF activation — Shutter/AF-On
 6. Focus point illumination — Manual focus mode — On; Continuous mode — On; Focus point brightness — 0 Normal
 7. Focus point wraparound — No wrap
 8. AF point selection — AF51
 9. AF On button — AF-On
 10. Vertical AF On button — AF-On
 - (b) Metering/exposure
 1. ISO sensitivity step value — 1/3
 2. EV steps for exposure control — 1/3
 3. EV steps for exposure compensation — 1/3
 4. Easy exposure compensation — Off
5. Center weighted area — Average
6. Fine tune optimal exposure — No, don't continue
- (c) Timers/AE lock
 1. Shutter release button/AE-L — Off
 2. Auto meter-off delay — 6 sec
 3. Self-timer delay — 10 sec
 4. Monitor-off delay — 10 sec
- (d) Shooting/display
 1. Beep — Off
 2. Shooting speed — Continuous high-speed — 9fps
 3. Max continuous release — 130
 4. File number sequence — On
 5. Control panel/viewfinder — Rear control panel — ISO sensitivity; viewfinder display — Frame count
 6. Shooting info display — Auto
 7. LCD illumination — Off
 8. Exposure delay mode — Off
- (e) Bracketing/flash
 1. Flash sync speed — 1/250
 2. Flash shutter speed — 1/60
 3. Modeling flash — On
 4. Auto bracketing set — AE and flash
 5. Auto bracketing (Model M) — Flash/speed
 6. Bracketing order — MTR > under > over
- (f) “F” Controls
 1. Multi-selector center button — Shooting mode — Off; Playback mode — Thumbnail on/off
 2. Multi-selector — Do nothing
 3. Photo info/playback — Off
 4. Assign FUNC. button — FUNC. button press — Off; FUNC. button + dials — Choose image area (FX/DX/5:4)
 5. Assign preview button — Preview button press — Preview; Preview + command dials — None
 6. Assign AE-L/AF-L button — AE-L/AF-L button press — AE/AF lock; AE-L/AF-L + command dials — None
 7. Customize command dials — Reverse rotation — No; Change main/sub — Off; Aperture setting — Sub-command dial; Menus and playback — Off
 8. Release button to use dial — No
 9. No memory card? — Release locked
 10. Reverse indicators — +, ,,,, ,|, ,,,, - (Positive left, Negative right — For exposure compensation); This is the brightness sensor
- (4) The manual mode settings and calibration procedure shall be as follows:
 - (a) Turn Nikon on.
 - (b) Turn thermal imager on.
 - (c) Select “Manual” for the camera exposure mode.
 - (d) Thermal imager facing spatial resolution target as specified in 8.1.4.3.
 - (e) Use scroll wheel to adjust aperture setting on display to “22” for f/22.
 - (f) EV value set to the center (Hold down the +/- button next to the trigger release and adjust using the rear scroll wheel.).

- (g) Adjust the shutter speed with the rear scroll wheel such that the brightness sensor is in the middle ± 1 dot ($\frac{1}{3}$ of a tick) — this is one click with the scroll wheel.
- (h) The refresh rate of the display of the thermal imager shall be provided by the manufacturer.
- (i) The shutter speed shall be at least twice the refresh rate of the thermal imager and less than 3 seconds. If this cannot be met with f/22 aperture, adjust the aperture to the closest value to f/22 so that the conditions can be met.
- (j) Use ViewNX or ViewNX 2 to determine if there are areas within the regions of interest that either have lost highlights or lost shadows. Lost highlights represent areas of overexposure, and lost shadows represent areas of underexposure. In the event that areas within the region of interest are overexposed or underexposed, adjust the EV button toward the negative or positive, respectively, to make the image darker or lighter. Once the EV value is changed, change the shutter speed accordingly to align the brightness sensor to center again. The EV compensation value shall be as close to 0 as possible.

8.1.4.7.4* The camera focus shall be determined by looking in the lower left-hand side of the HUD within the viewfinder.

8.1.4.8 The visible spectrum camera shall be mounted such that the thermal imager display fills at least 90 percent of the FOV in the widest dimension.

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

8.1.4.8.2 A black shroud shall be placed around the visible spectrum camera and its view path to block out all light from the surrounding environment during all image capture.

8.1.4.9 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.

8.1.4.10 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 Spatial Resolution 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 any condensation or frost exists, it shall be removed.

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

8.1.5.3 The spatial resolution source target emitting surface temperature shall be stabilized at $28^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ ($82^{\circ}\text{F} \pm 1^{\circ}\text{F}$).

8.1.5.4 The thermal imager shall be oriented such that it is vertically centered and maximizes the visible area of the warm region of interest. A similarly sized space on the opposite side for a room temperature region of interest shall be included.

The thermal imager shall be normal to the spatial resolution target.

8.1.5.5 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 at least 90 percent of the FOV in the widest dimension and is in focus.

8.1.5.6 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. The image having the lowest contrast shall be excluded.

8.1.5.7 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 8.1.5.7.

[8.1.5.7]

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

8.1.5.8 A region of interest (ROI) shall be selected within the warm square on the right side of the spatial resolution target that encapsulates at least 70 percent of the available square area excluding any text, symbols, and boundary regions and shall not interfere with the spatial frequency patterns. This region of interest shall be labeled W. The image processing software shall apply these regions of interest to all images.

8.1.5.9 A region of interest shall be selected that is equal in size to the warm region of interest. This second region of interest shall be on the opposite side of the spatial resolution target from the warm region of interest. It shall contain ambient temperature pixels only and shall not interfere with the spatial resolution patterns and shall be labeled A. The image processing software shall apply these regions of interest to all images.

8.1.5.10* Two separate pixel smoothing filters shall be applied to the regions of interest. A moving average in two dimensions shall be applied to the regions 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. It shall be labeled the 1X filter. A second filter shall be applied in the same manner as the 1X filter but with a period four times greater and shall be labeled the 4X filter. Both filters shall be applied to the original image; the resulting images shall be labeled W_{1X} , W_{4X} , A_{1X} , and A_{4X} , and shall be stored independently for further calculation.

8.1.5.11 The image processing software shall scan each of the four regions of interest for the lightest pixel intensity (I_{\max}) and the darkest pixel intensity (I_{\min}). The software shall then find the contrast of each of the four regions of interest using Equation 8.1.5.11.

[8.1.5.11]

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

8.1.5.12 Noise warm (N_W) and noise ambient (N_A) shall be calculated as follows: N_W is the contrast of W_{4X} subtracted from the contrast of W_{1X} , and N_A is the contrast of A_{4X} subtracted from the contrast of A_{1X} .

8.1.5.13 N_w and N_A shall then be averaged and the resulting value is the noise of the image, N .

8.1.5.14 Noise shall be calculated for all images of the spatial resolution test.

8.1.5.15 The average pixel intensity, μ , of the W_{ix} region of interest shall be calculated using Equation 8.1.5.15 and labeled μW_0 .

[8.1.5.15]

$$\mu = \frac{1}{N} \sum_{i=1}^N x_i$$

8.1.5.16 The average pixel intensity, μ , of the A_{ix} region of interest shall be calculated using Equation 8.1.5.15 and labeled μA_0 .

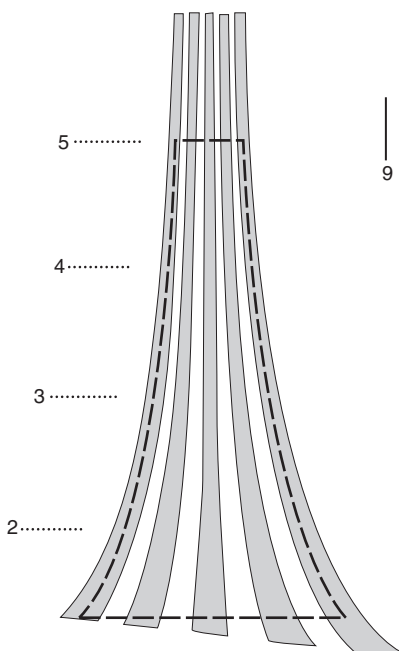
8.1.5.17 The contrast shall be calculated using Equation 8.1.5.11 where $I_{\max} = \mu W_0$ and $I_{\min} = \mu A_0$. N shall be subtracted from this value and the resulting value shall be labeled C_0 .

Δ 8.1.5.18 Each of the four sets of converging lines shall be rotated such that the center line is vertical before selecting a region of interest and performing calculations.

N 8.1.5.18.1 The region of interest shall be selected from index 1 to 5 on the low frequency bars, and from index 5 to 9 on the high frequency bars.

N 8.1.5.18.2 The region of interest shall be drawn along the lines as specified in Figure 8.1.5.18.2.

N 8.1.5.18.3 No symbology shall be included in the ROI. In the case where symbology interferes with the target, the ROI shall be drawn around the interference such that horizontal lines are perpendicular to the center line and equal portions of white and dark areas are included.



Δ FIGURE 8.1.5.18.2 Region of Interest Selection.

8.1.5.19 The data processing software shall analyze each row in the regions of interest of the converging lines. For each row, the maximum pixel intensity and the minimum pixel intensity shall be recorded. They shall be labeled I_{\max} and I_{\min} , respectively. For each row, the contrast C_i shall be found using Equation 8.1.5.11.

8.1.5.19.1 After all of the regions' rows have been analyzed, the C_i values from the sets of converging lines in quadrant 1 and quadrant 3 shall be concatenated from lowest frequency to highest frequency. Likewise, the C_i values from the sets of converging lines in quadrants 2 and 4 shall be concatenated from lowest frequency to highest frequency. All of the C_i values shall be paired with their respective frequencies.

8.1.5.19.2 The noise value, N , shall be subtracted from each of the C_i values and then normalized to C_0 as shown in the following equation:

[8.1.5.19.2]

$$CTF_i = (C_i - N) / C_0$$

8.1.5.19.3 The two resulting CTF_i curves shall be multiplied by $\pi/4$ in order to approximate the MTF of each ROI, resulting in curves $MTF_{i(up)}$ and $MTF_{i(down)}$. Each MTF_i curve shall be integrated resulting in SR_{up} and SR_{down} . Negative MTF_i values shall be set to zero before the integration.

8.1.5.19.4 The SR_{up} and SR_{down} values shall be averaged, resulting in the respective spatial resolution value for each image SR . The SR value shall be the average of each of the SR_i values.

8.1.6 Report. The SR value shall be reported after the spatial resolution test.

8.1.7 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.

N 8.2.2.2 The pretest image recognition values in the vertical and horizontal directions shall be recorded as specified in Section 8.1, Image Recognition Test.

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 $22^\circ\text{C} \pm 3^\circ\text{C}$ ($72^\circ\text{F} \pm 5^\circ\text{F}$), 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).

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 mm² (8 in.²).

8.2.4.4 The small compartments shall encase the complete thermal imager that is smaller than 5161 mm² (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.

370 mm ± 6 mm × 370 mm ± 6 mm (14¾ in. ± ¼ in.) × 14¾ in. ± ¼ in.)	370 mm ± 6 mm × 370 mm ± 6 mm (14¾ in. ± ¼ in.) × 14¾ in. ± ¼ in.)	735 mm ± 13 mm × 735 mm ± 13 mm (29 in. ± ½ in.) × 29 in. ± ½ in.)
370 mm ± 6 mm × 370 mm ± 6 mm (14¾ in. ± ¼ in.) × 14¾ in. ± ¼ in.)	370 mm ± 6 mm × 370 mm ± 6 mm (14¾ in. ± ¼ in.) × 14¾ in. ± ¼ in.)	
735 mm ± 13 mm × 735 mm ± 13 mm (29 in. ± ½ in.) × 29 in. ± ½ in.)		735 mm ± 13 mm × 735 mm ± 13 mm (29 in. ± ½ in.) × 29 in. ± ½ in.)

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

370 mm ± 6 mm × 610 mm ± 13 mm (14¾ in. ± ¼ in.) × 24 in. ± ½ in.)	370 mm ± 6 mm × 610 mm ± 13 mm (14¾ in. ± ¼ in.) × 24 in. ± ½ in.)	735 mm ± 13 mm × 610 mm ± 13 mm (29 in. ± ½ in.) × 24 in. ± ½ in.)
Vibration table surface		

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

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

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 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. The *SR* value 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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 B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*. 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 $35^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($95^{\circ}\text{F} \pm 5^{\circ}\text{F}$).

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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$) 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 Four specimens shall be taken. One of the four specimens shall be the setup specimen.

8.5.3.3 The test specimens shall include all of the following criteria:

- (1) The specimen shall be a square measuring 50 mm \times 50 mm (2 in. \times 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.

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

8.5.3.5 Specimens shall be conditioned at a temperature of $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), and a relative humidity of 50 percent ± 25 percent, for at least 4 hours.

8.5.3.6 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).

8.5.5 Procedure.

8.5.5.1 The haze of the specimen shall be measured using a haze meter in accordance with ASTM D1003, *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 mm² 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 D1003, *Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics*.

8.5.5.2 The setup specimen shall be placed cover side up in the test apparatus specimen holder.

8.5.5.2.1 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.

8.5.5.3.1 This cylinder shall be rigidly affixed to the stroking arm by a #10-32 UNF threaded rod.

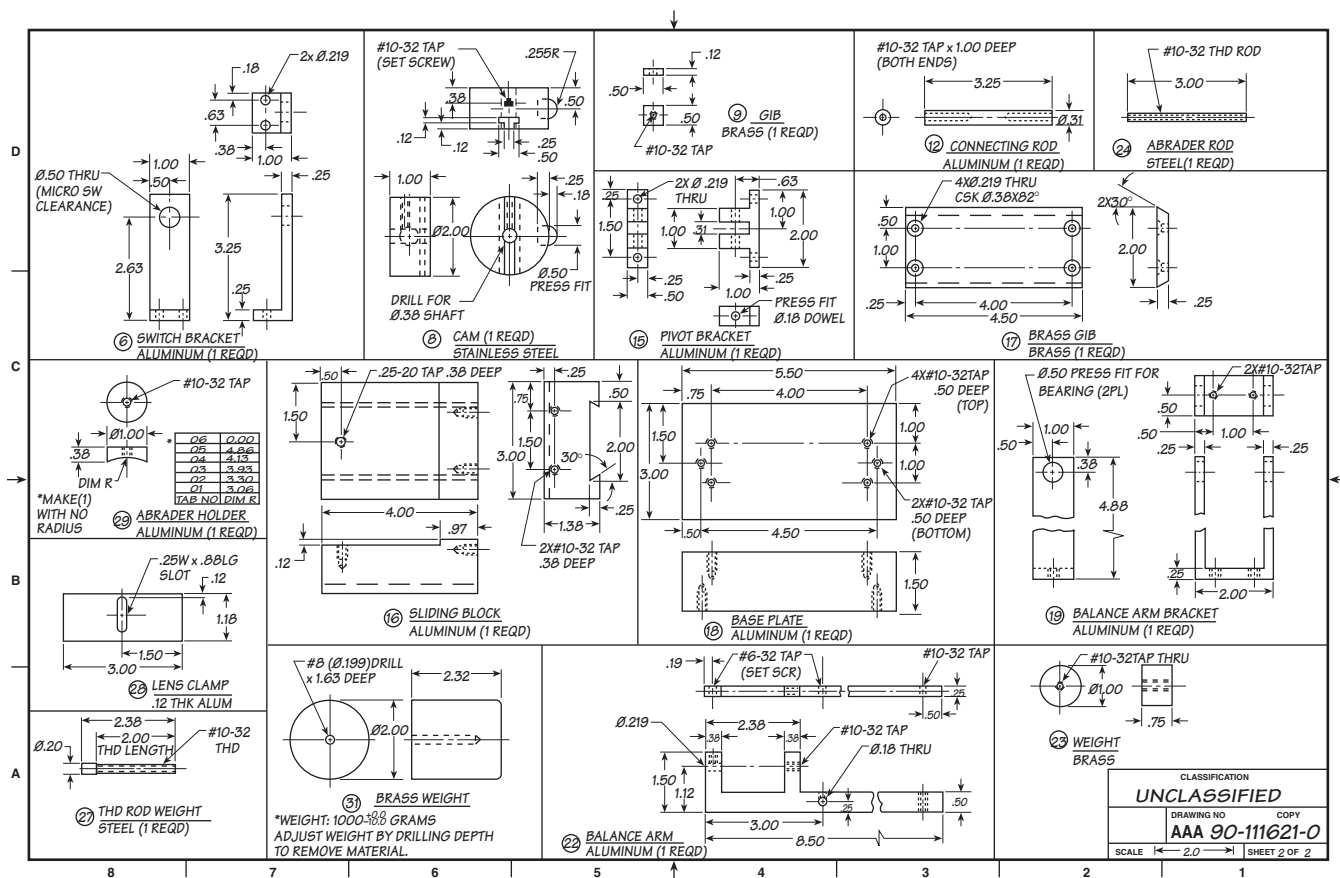
8.5.5.4 The pad shall be a Blue Streak M306M wool felt polishing pad 23 mm (0.9 in.) in diameter.

8.5.5.5 The abrasive disc shall be made from 3M Part Number 7415, Wood Finishing Pad.



Δ 8.5.5.11 The length of stroke shall be 14 mm (½ in.), producing a pattern 38 mm (1½ in.) long.

8.6.2 Samples. Samples shall be complete thermal imagers.



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

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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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.

▲ 8.6.3.5 Manufacturers shall optimally focus specimens to a distance of 1 m for this test.

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 , $+6/-0^{\circ}\text{C}$ (500°F , $+10/-0^{\circ}\text{F}$).

- (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 , $+6/-0^{\circ}\text{C}$ (500°F , $+10/-0^{\circ}\text{F}$) 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 , $+6/-0^{\circ}\text{C}$ (500°F , $+10/-0^{\circ}\text{F}$).

8.6.5.8 After the specified exposure, the specimen shall be removed from the oven and immediately aimed perpendicularly at the spatial resolution target at a distance of 1 m, $+0.01/-0$ m. The highest resolvable index number on the spatial resolution target shall be recorded.

8.6.6 Report.

8.6.6.1 The highest resolvable index number on the spatial resolution target shall be 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 Specimens for testing shall be complete thermal imagers.

8.7.3.2 A minimum of three specimens shall be tested.

8.7.3.3 Specimens shall be conditioned at a temperature of $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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.

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.) ± 25 mm 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.

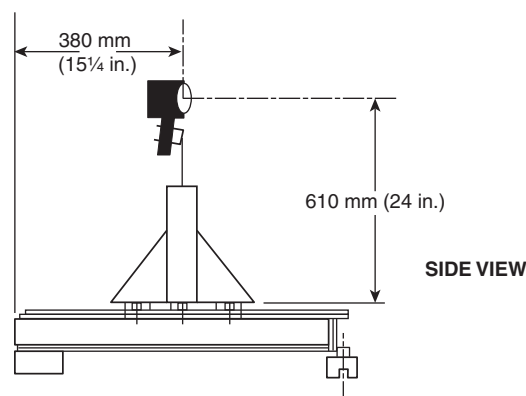


FIGURE 8.7.4.2(a) Mounted Thermal Imager for Heat and Flame Test.

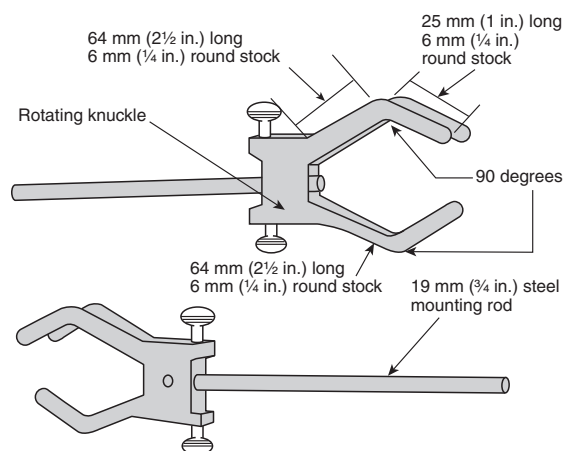


FIGURE 8.7.4.2(b) Thermal Imager Mounting Armature.

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) ± 15 m/min. The test oven shall have minimum dimensions of 915 mm depth \times 915 mm width \times 1220 mm (36 in. \times 36 in. \times 48 in.) height.

8.7.5 Procedure.

8.7.5.1 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.

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

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

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

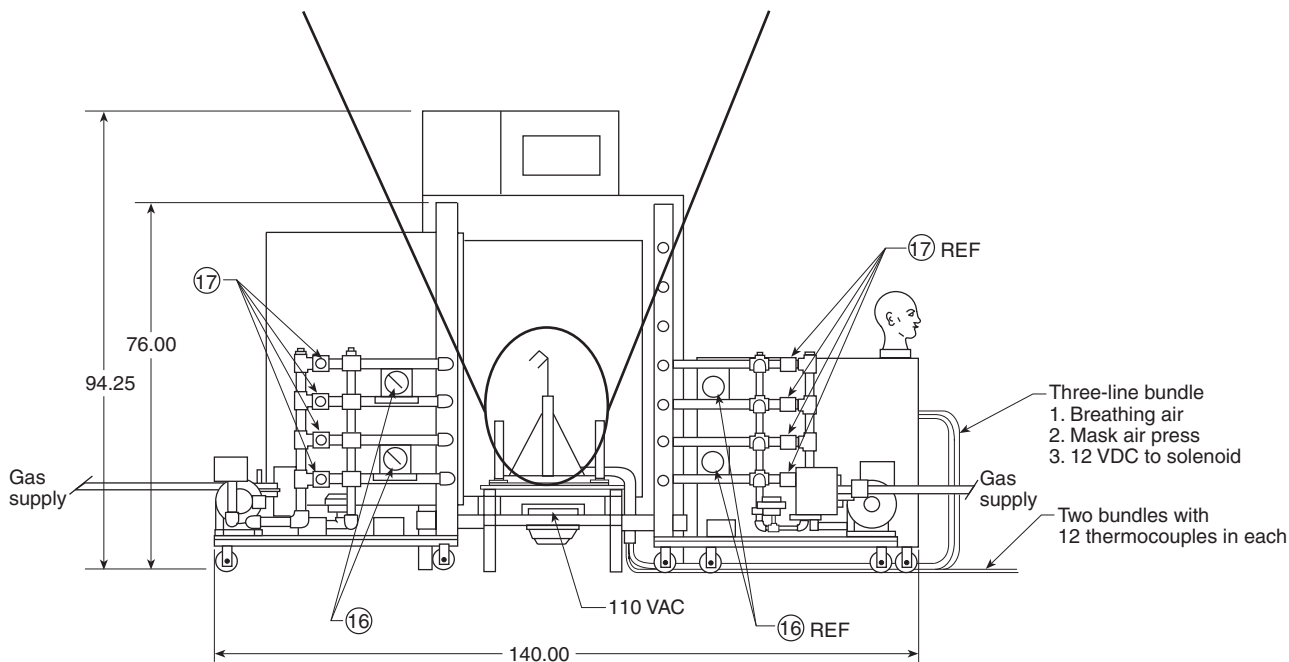


FIGURE 8.7.4.4 Heat and Flame Test Apparatus.

8.7.5.5 Specimens mounted on the test fixture shall first be placed in the test oven, which has been preheated to $95^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($203^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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).

8.7.5.6 At the completion of the 15-minute exposure at $95^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($203^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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.

8.7.5.7 The product shall then be exposed to direct flame contact for 10 seconds, $+1/4/-0$ seconds. 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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 Test; 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.) $+25/-0$ mm 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$).

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 and lens as specified in 8.10.4.5
- (4) A visible spectrum camera fixture 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) A mirror with the dimensions of height of 203 mm (8 in.) ± 6 mm (0.25 in.), width of 254 mm (10 in.) ± 6 mm (0.25 in.), and a thickness of 6 mm (0.25 in.) ± 3 mm (0.125 in.)

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.

8.10.4.3.1 The surface labeled T_{hot} shall range in temperature from 50°C to 550°C (1022°F) and shall fill at least $25\% \pm 5\%$ 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 shall be calibrated at least every 6 months. The nonuniformity of the blackbody shall not exceed 0.02. The blackbody temperature accuracy shall be $\pm 0.5^{\circ}\text{C}$ ($\pm 1^{\circ}\text{F}$). The stability of the emitting surface temperatures shall be 0.15°C . The mirror specified in 8.10.4.2(8) shall be used to reflect the hot surface into the camera's FOV, if necessary, to meet the $25\% \pm 5\%$ requirement.

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 ($\frac{1}{2}$ in. ± 0.003 in.) wide. The bars shall maintain a constant temperature (T_{bar}) of $8^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ above the surfaces in the FOV, excluding the T_{hot} surface.

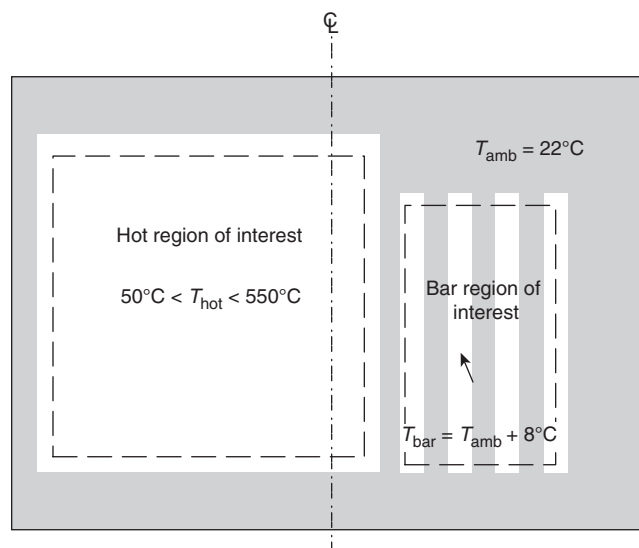


FIGURE 8.10.4.3 Test Image for Effective Temperature Range Test.

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} , $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$).

8.10.4.4 The thermal imager shall be positioned so that the image center points to the surface labeled T_{hot} and the bars are in focus and are viewed at a frequency of 0.04 cyc/mrad. The thermal imager shall not wobble, vibrate, or otherwise move out of position during the course of the test.

8.10.4.4.1 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 as specified in 8.1.4.7.

8.10.4.6 The visible spectrum camera shall be mounted as specified in 8.1.4.8 such that the thermal imager display fills 90 percent of the FOV in the vertical dimension and is in focus.

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

8.10.5.5 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.

8.10.5.6 A black shroud shall be placed around the visible spectrum camera and its view path to block out all light from the surrounding environment during all image capture.

8.10.5.7 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 $2^{\circ}\text{C} \pm 0.1^{\circ}\text{C}$ ($3.6^{\circ}\text{F} \pm 0.2^{\circ}\text{F}$), as

T_{hot} increases from 50°C to 550°C (122°F to 1022°F) at a rate not greater than $15^{\circ}\text{C}/\text{min}$ ($27^{\circ}\text{F}/\text{min}$).

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

8.10.6 Effective Temperature Range Procedure.

8.10.6.1 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.

8.10.6.2 The images shall be converted to uncompressed grayscale images having a minimum bit depth of 16 bits using Equation 8.1.5.7.

8.10.6.3 The bar pixel intensity differential, ΔI , as shown in the bar region of interest in Figure 8.10.4.3 shall be calculated for each row in each image as specified in the following equation. All of the ΔI values for each image shall be averaged and recorded as ΔI for that image.

[8.10.6.3]

$$\Delta I = I_{\text{max}} - I_{\text{min}}$$

8.10.7 Report. ΔI shall be reported and recorded.

8.10.8 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$).

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 and 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 TI 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.

Δ 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 **farthest left active image element** of the thermal imager FOV.

N 8.11.5.4.1 The angular position, AH1, of the rotary stage shall be recorded.

Δ 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 **farthest right active image element** of the thermal imager FOV.

N 8.11.5.5.1 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 TI 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.

Δ 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 **farthest bottom active image element** of the thermal imager FOV.

N 8.11.6.4.1 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 **farthest top active image element** of the thermal imager FOV. The angular position, AV2, of the rotary stage shall be recorded.

8.11.6.6 The **vertical** 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$), 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 $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ($72^{\circ}\text{F} \pm 5^{\circ}\text{F}$).

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 and lens as specified in 8.1.4.7
- (4) Visible spectrum camera fixture as specified in 8.1.4.8
- (5) Image capturing software and hardware as specified in 8.12.4.12
- (6) Computer and image analysis software as specified in 8.12.4.13

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.

8.12.4.4 The emitting surfaces shall have dimensions of at least 102 mm \times 102 mm and shall have an emissivity of 0.95 ± 0.03 .

8.12.4.5 The temperature accuracy of the emitting surfaces shall be $0.02^{\circ}\text{C}/-0.00^{\circ}\text{C}$ ($0.04^{\circ}\text{F}/-0.00^{\circ}\text{F}$) or better.

N 8.12.4.5.1 The stability of the emitting surface temperatures shall be $0.01^{\circ}\text{C}/-0.00^{\circ}\text{C}$ ($0.02^{\circ}\text{F}/-0.00^{\circ}\text{F}$) 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.

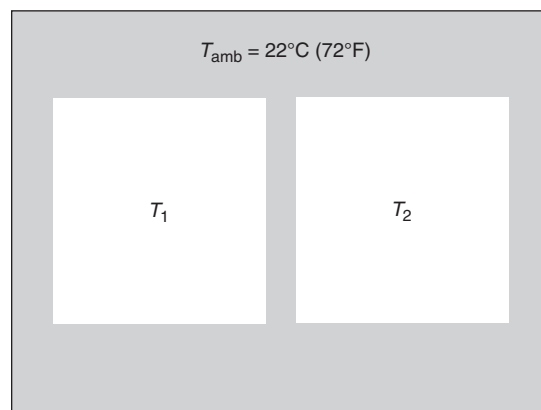


FIGURE 8.12.4.3 Thermal Sensitivity Test Apparatus Configuration.

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

8.12.4.11 A black shroud shall be placed around the visible spectrum camera and its view path to block out all light from the surrounding environment during all image capture.

8.12.4.12 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 \pm 0.1 second.

8.12.4.13 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 fully charged power source.

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

8.12.5.4 Both source targets shall be stabilized to within $\pm 0.02^\circ\text{C}$ of their initial set-point 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. The thermal imager shall not be required to be in focus.

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

8.12.5.7.1 The T_2 source target shall be set at $T_2 = T_{\text{amb}} - 5^\circ\text{C}$ and shall then be increased at a rate of $0.5^\circ\text{C}/\text{min}$ until $T_2 = T_{\text{amb}} + 5^\circ\text{C}$. 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 15 seconds \pm 0.1 second, while the T_2 temperature is increasing.

8.12.5.8 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 8.1.5.7.

8.12.5.9 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.

8.12.5.9.1 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.

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

8.12.5.10 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.

8.12.5.11* The mean pixel intensity of each region of interest in each image shall be calculated using Equation 8.1.5.15 and shall then be divided by 65,536. 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.

8.12.5.11.1 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 $22^\circ\text{C} \pm 3^\circ\text{C}$ ($72^\circ\text{F} \pm 5^\circ\text{F}$), and a relative humidity of 50 percent \pm 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 $1 \text{ m} \pm 0.1 \text{ m}$ (40 in. \pm 4 in.), of deionized water shall be used.

8.13.4.4 The water temperature in the water dunk container shall be $22^\circ\text{C} \pm 3^\circ\text{C}$ ($72^\circ\text{F} \pm 5^\circ\text{F}$). 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.

8.13.5 Procedure 1.

8.13.5.1 The pretest 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 60°C , $+3^\circ/-0^\circ\text{C}$ (140°F , $+5^\circ/-0^\circ\text{F}$) and maintained for 4 hours.

8.13.5.3 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 deionized water for 30 minutes, $+5/-0$ minutes.

8.13.5.3.1 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 , $+3^\circ/-0^\circ\text{C}$ (-4°F , $+5^\circ/-0^\circ\text{F}$) and maintained for a minimum of 4 hours.

8.13.5.3.2 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.

8.13.5.4 The test specimens shall be removed from the water dunk container, wiped dry, and placed in the tumble test apparatus.

8.13.5.4.1 Only one specimen shall be tested in the tumble test apparatus at a time.

8.13.5.4.2 All specimens shall be unrestrained.

8.13.5.4.3 The tumble test apparatus shall be run at a speed of $15 \text{ rpm} \pm 1 \text{ rpm}$.

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

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

8.13.5.4.6 The test specimens shall be blown dry with clean compressed air or nitrogen until the lens and viewing windows are free from all moisture.

8.13.5.4.6.1 Evaluation of the three specimens shall begin within 5 minutes of completion of drying.

8.13.5.4.7 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.

8.13.5.4.8 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 *SR* value 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 *SR* value shall be recorded.

8.13.7.4 The second random test specimen shall be deactivated and any 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 *SR* value 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.

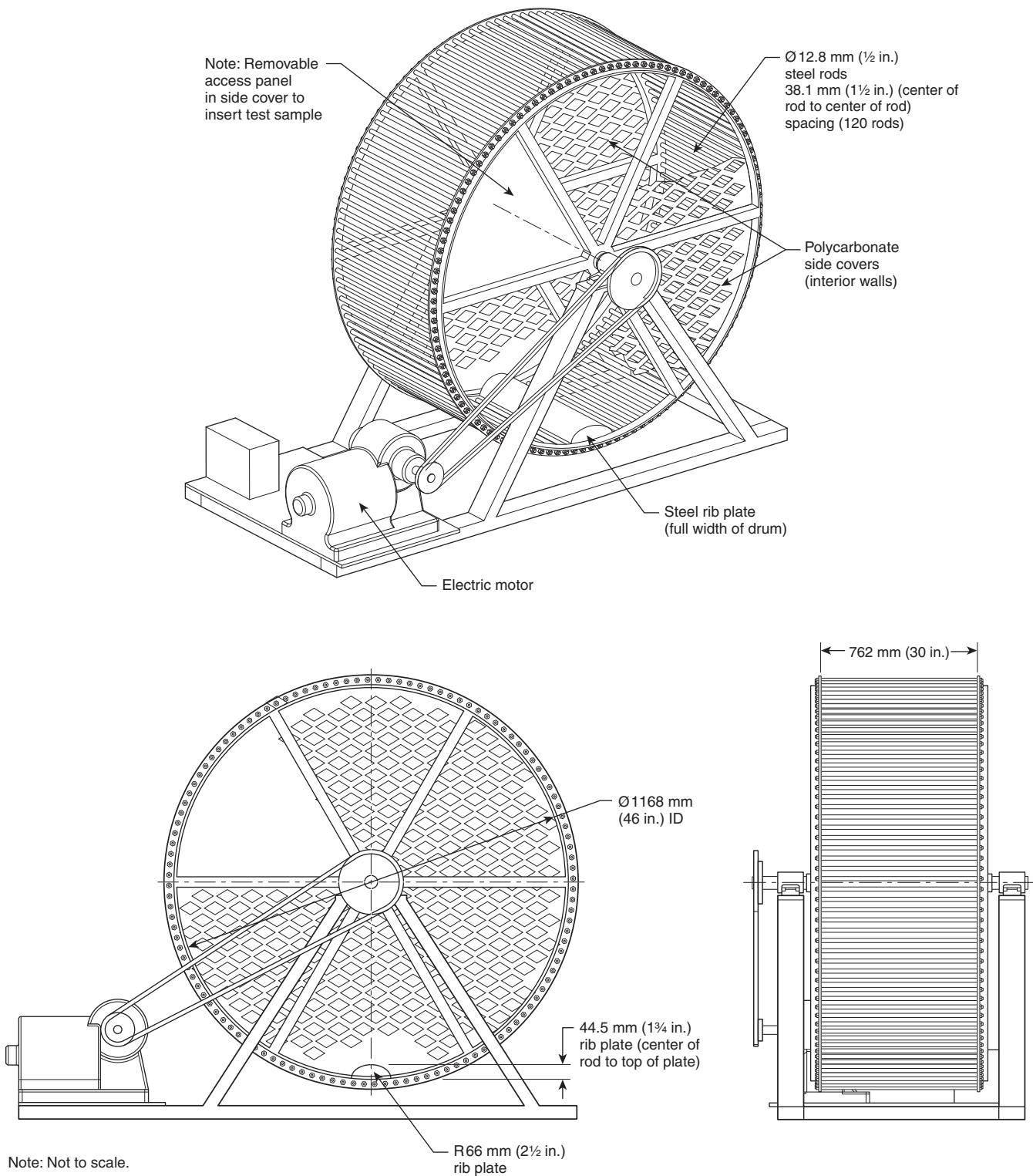


FIGURE 8.13.4.5 Tumble Test Apparatus.

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.1.1.2.1 Users of thermal imagers certified to earlier editions of this standard can incorporate updated parts, components, or software to allow certification to the latest edition of this standard. This paragraph has been added so that the latest revision of the standard can be used for devices containing new parts, components, or software to upgrade the certification to the current edition.

▲ 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 as 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 as 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* 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 $c.75 \times 10^{-6}$ 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.3.3.21 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.4.5.3 In September of 2015, a revised edition of ISO 9001, *Quality management systems — Requirements*, was issued. Both the 2008 and 2015 editions are referenced in this revision of the standard to allow manufacturers a sufficient amount of time to transition their quality management system’s registration to this new edition.

A.5.2.3 Information and materials regarding preoperational use (a user’s manual) provides the user with information about the operation of the TIC, Basic and Basic Plus features, its care, and maintenance. The organization of the user’s manual is not specified. The checklist in Table A.5.2.3 can help assure that the supplied documentation addresses all requirements. The column labeled “Page no./Paragraph” should identify the page and paragraph number where the requirement in the column labeled “Description” is addressed. This will ensure that all requirements have been met and manufacturers may provide the table to the certification organization with their user’s manual to assist with the verification of their compliance with the standard. Including this checklist, or some form of it, as part of the user’s manual will also assist users in becoming familiar with the camera.

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 over-heat 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 Effects 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).