Standard for Infrared Inspection of Insulated Roofs

2008 Edition

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Foreword

This standard outlines the procedures and documentation requirements for conducting infrared inspections of insulated roofs. This standard covers an application which is both art and science. This document assumes that the reader is generally familiar with the science of infrared thermography. It is not intended to be an absolute step-by-step formula for conducting an infrared inspection.

The use of this standard is not intended to qualify an individual using it to conduct an infrared inspection, or to analyze the resulting infrared data without formal training prior to its use. This document is intended to support infrared thermographers who have been professionally trained and certified. It must be acknowledged and understood that the misinterpretation of data that can occur without proper training and experience cannot be avoided simply by using this standard. In no event shall Infraspection Institute be liable to anyone for special, collateral, incidental or consequential damages in conjunction with or arising from use of this standard.

Other Infraspection Institute Standards

Infraspection Institute began publishing guidelines for infrared thermography in 1988. Since their initial publication, Infraspection Institute guidelines have been adopted by hundreds of companies worldwide and incorporated into documents published by recognized standards organizations such as the American Society for Testing and Materials (ASTM). Beginning in 2007, Infraspection Institute guidelines were renamed as standards to reflect their industry-wide acceptance and the best practices they embody.

Several standards are available from Infraspection Institute. These standards cover equipment operation, temperature measurement, and specific applications. A complete list of current Infraspection Institute standards may be found online at www.infraspection.com.

Infraspection Institute standards represent the work of many practicing infrared thermographers and other experts. We thank them for their valuable contributions.

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1.0 Scope

1.1 This standard covers procedures for conducting an infrared inspection at night to determine the location of wet insulation in roofing systems that have insulation above the deck and in contact with the underside of the waterproofing membrane. Inspections may be ground-based or conducted from an aircraft.

1.2 This standard provides a common document for the end user to specify infrared inspections and for the infrared thermographer to perform them.

1.3 This standard lists the joint responsibilities of the end user and the infrared thermographer that, when carried out, will result in the safest and highest-quality inspection for both.

1.4 This standard outlines specific content for documenting the results of an infrared inspection.

1.5 This standard may involve use of equipment in hazardous or remote locations.

1.6 This standard addresses criteria for infrared imaging equipment, such as spatial resolution and thermal sensitivity.

1.7 This standard addresses meteorological conditions under which infrared inspections should be performed.

1.8 This standard addresses operating procedures and operator qualifications.

1.9 This standard addresses verification of infrared data using invasive test methods.

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

2.0 Referenced Documents

2.1 *Occupational Safety and Health Standards for General Industry 29 CFR, Part 1910.* US Department of Labor. Occupational Safety & Health Administration, Washington, DC.

2.2 *Occupational Safety and Health Standards for the Construction Industry 29 CFR, Part 1926.* US Department of Labor. Occupational Safety & Health Administration, Washington, DC.

2.3 *Level-I Certified Infrared Thermographer® Reference Manual.* Infraspection Institute, Burlington, NJ.

3.0 Terminology

For the purpose of this standard,

3.1 **Core sample -** A small sample encompassing at least 13 cm^2 (2 in^2) of the roof surface area taken by cutting through the roof membrane and insulation and removing the insulation to determine its composition, condition, and moisture content.

3.2 **Exception -** an abnormally warm or cool portion of a roof that may be a potential problem for the end user.

3.3 **Expansion joint -** a structural separation or flexible connection between two building elements that allows free movement between the elements without damage to the roof or waterproofing system.

3.4 **Infrared inspection -** the use of infrared imaging equipment to provide specific thermal information and related documentation about a structure, system, object or process.

3.5 **Infrared thermal imager (infrared camera) -** a camera-like device that detects, displays and records the apparent thermal patterns across a given surface.

3.6 **Infrared thermographer -** a person who is trained and qualified to use an imaging radiometer.

3.7 **Inspection window -** the time period during which infrared inspections of insulated roofs can be successfully conducted.

3.8 **Insulated roof -** a roof whose insulation is between the deck and the membrane and is in direct contact with the underside of the membrane.

3.9 **Membrane -** a flexible or semiflexible roof covering or waterproofing material whose primary function is the exclusion of water.

3.10 **Moisture meter probe -** an invasive (electrical resistance or galvanometric type) test that entails the insertion of a meter probe(s) through the roof membrane to indicate the presence of moisture within the insulated roof.

3.11 **Qualified assistant -** a person provided and authorized by the end user to perform the tasks required to assist the infrared thermographer. He/she is knowledgeable of the operation and history of the roof(s) to be inspected and is trained in all the safety practices and rules of the end user.

3.12 **Qualitative infrared thermography -** the practice of gathering information about a structure, system, object or process by observing images of different patterns of infrared radiation, and recording and presenting that information.

3.13 **Roof section -** a portion of a roof that is separated from adjacent portions by walls or expansion joints.

3.14 **Roofing system -** see Insulated roof.

3.15 **Standard -** a set of specifications that define the purposes, scope and content of a procedure.

3.16 **Thermogram -** a recorded visual image that maps the apparent temperature pattern of an object or scene into a corresponding contrast or color pattern.

3.17 **Thermographer -** see Infrared thermographer.

4.0 Significance and Use

4.1 The purpose of an infrared inspection of an insulated roof is to locate and document patterns of infrared radiation (exceptions) on the roof surface that are caused by wet insulation beneath the membrane.

4.1.1 Invasive testing is necessary to verify the presence of water in the insulation.

4.2 Providing opinions about the causes of exceptions, the integrity of the roofing system, or recommendations for corrective actions requires skills beyond those of infrared thermography.

4.2.1 Infrared thermography will be presented as a visual inspection technique to gather and present information about the roofing system at a specific time.

4.2.2 Performing invasive testing is beyond the scope of infrared thermography.

4.2.3 Data from infrared inspections of insulated roofs may be used for assessing the condition of a roofing system or for quality assurance inspections of new installations, repairs, or retrofits.

4.3 This standard does not provide methods to determine the cause of latent moisture within an insulated roof or its point of entry. It does not address the suitability of any particular material or system to function satisfactorily as waterproofing or insulation.

5.0 Responsibilities of the Infrared Thermographer

5.1 Infrared inspections will be performed when environmental and physical conditions such as solar gain, wind, surface and atmospheric moisture and heat transfer are favorable to gathering accurate data.

5.2 The infrared thermographer will have knowledge of the materials and construction of insulated roofs sufficient to understand the observed patterns of radiation.

5.3 The infrared thermographer will be accompanied by a person who is responsible for the thermographer's safety when accessing roofs.

5.4 Unless so qualified, the infrared thermographer will not perform any tasks that are normally performed by a construction tradesperson.

5.5 The infrared thermographer will comply with the security and safety rules of the end user and applicable safety standards.

5.6 The infrared thermographer will use thermal imaging and/or measurement equipment with capabilities sufficient to meet the inspection requirements.

6.0 Responsibilities of the End User

6.1 Prior to the inspection, the end user will inform the infrared thermographer of any past and current problems with the roof(s) to be inspected and the reasons for conducting the inspection.

6.2 Prior to the inspection, the end user will heat or cool the building to be inspected to a uniform air temperature throughout when requested by the infrared thermographer.

6.3 When requested, the end user will provide a qualified assistant familiar with the construction and history of the roof(s). This person will be responsible for gaining access to, and maintaining the security of, the end user's facilities and premises.

6.4 The end user will ensure that the subject roof surfaces are dry and free of debris or construction materials for a period of at least 24 hours prior to the infrared inspection.

6.5 When requested and available, the end user will furnish building drawings and/or blueprints to the infrared thermographer.

6.6 The end user will take full responsibility for consequences resulting from actions taken, or not taken, as a result of information provided by an infrared inspection.

7.0 Instrument Requirements

7.1 General

7.1.1 Infrared thermal imaging systems shall detect emitted radiation and convert detected radiation to a real-time visual signal on a monitor screen. Imagery shall be monochrome or multi-color.

7.1.2 Spectral Range: the infrared imaging system shall operate within a spectral range from 2 to 14 µm. A spot radiometer or nonimaging line scanner is not sufficient.

7.1.3 The infrared thermal imaging system shall have a Minimum Resolvable Temperature Difference (MRTD) of 0.2°C or less at 20°C.

7.2 Ground-based Inspections

7.2.1 For walk-over inspections or inspections performed from an elevated vantage point, the infrared imaging system shall have sufficient resolution to permit recognition of exceptions as small as 0.15 m (6 inches) on a side from the chosen vantage point.

7.3 Aerial Inspections

7.3.1 For aerial inspections, the infrared imaging system shall have sufficient resolution to permit recognition of exceptions as small as 0.3 m (12 inches) on a side from the chosen altitude.

8.0 Limitations (Applicability of Constructions)

8.1 Applicable constructions include insulated roofs containing any of the commercially available rigid insulation boards. This includes boards made of organic fibers, perlite, cork, fibrous glass, cellular glass, polystyrene, polyurethane, isocyanurate, and phenolic. Composite boards and tapered systems made from these materials can also be inspected as can roofs insulated with foamed-in-place polyurethane.

8.2 Wet applied insulations such as lightweight concrete and wet applied decks such as gypsum can be difficult to inspect since they may retain significant quantities of construction water.

8.3 When moisture sensitive materials are located under pavers, stone ballast, or layers of dry insulation, thermal anomalies on the surface of the roof are diminished.

8.4 For roofs with highly reflective surfaces (aluminized coatings or foils) in the spectral range of the infrared thermal imager, infrared inspections are not practical until the surface is naturally or temporarily dulled.

8.5 The wetting rates of roof insulations vary according to the type of insulation and environmental exposure. New roofs with insulations that wet slowly, such as cellular plastics or cellular glass, usually should not be inspected until they are at least three months old.

8.6 Infrared inspections are not intended to identify the source of the moisture.

9.0 Significant Environmental Parameters

9.1 Water retained in roofing systems decreases the thermal resistance and increases the heat storage capacity of such systems. This can lead to thermal anomalies on the surface that can be located using an infrared thermal imager. These thermal anomalies depend upon the type of roofing system, the amount of moisture in the insulation, and the weather conditions. For a given roof, there are four weather related parameters that can cause significant changes in surface temperatures over wetted roof areas compared to dry areas. These are: inside to outside temperature difference, the rate of change of temperature in the hours prior to viewing, the amount of solar loading, and the wind speed.

9.2 Acceptable weather conditions for nighttime infrared imaging inspections will be light winds with some combination of a large inside to outside temperature difference, a rapid decrease in ambient temperature in the late afternoon and a sunny day prior to the inspection. Typically, an infrared inspection during cold weather relies on a large inside to outside temperature difference. An infrared inspection during warm weather relies on solar loading.

9.2.1 Inside to Outside Temperature Difference: exceptions become more distinct as the inside to outside temperature difference increases.

9.2.2 Rate of Change of Temperature: the surface temperature over a wet roof area responds more slowly to a change in the air temperature than the surface temperature over a dry roof area. Thus, when the whole roof is cooling, wet areas will cool more slowly. The greater the rate of outside temperature change, the greater the difference in surface temperature between wet and dry areas.

9.2.3 Solar Loading: during the course of a sunny day, areas of the roof containing wet insulation will store more solar energy than dry areas causing these areas to cool more slowly during the evening. This effect increases as solar loading increases. Thus, the effect is greater in the summer than in the winter and greater on a clear day than on a cloudy day. Shaded areas receive less solar loading than unshaded areas.

9.2.4 Wind: air flow over a roof surface increases the convective heat transfer to the surrounding air significantly. This causes all surface temperatures to approach the ambient air temperature reducing the intensity of exceptions or making them undetectable.

10.0 Required Conditions

10.1 No appreciable precipitation shall have fallen on the roof during the 24 hours prior to the infrared inspection.

10.2 At the time of the infrared inspection, the surface of the roof shall be free of ponded water, snow, ice, debris, and piles of aggregate except that these conditions may exist in a few areas provided that those areas are delineated as being uninspected in the report.

10.3 At the time of the infrared inspection, winds in the area shall be less than 25 km/h (15 mph).

10.4 After a day of heavy overcast, infrared inspections shall not be conducted unless the outside temperature is at least 10°C (18°F) colder than the temperature of the space under the roof deck at the time of the inspection and for most of the prior 24 hours. In other weather, the indoor to outdoor temperature difference is not an issue except as indicated in 10.7 and 12.2.

10.5 Most infrared inspections can be conducted from one hour after sunset until sunrise. However, the inspection window will be dependent upon roof construction, amount of moisture in the roof, and local weather conditions both before and during the infrared inspection. It may be necessary to delay the start of inspections after warm cloudy days since cloud cover reduces both solar loading and nighttime radiational cooling. To check that a sufficient delay has been allowed after such days, the first portion of the infrared inspection shall be repeated before leaving the roof.

10.6 The formation of dew or frost on the roof will reduce the intensity of exceptions. It may not be possible to conduct infrared inspections under these conditions.

10.7 Infrared inspections of roofing systems ballasted with stone or pavers should only be conducted when the outside temperature at the time of the inspection and for most of the prior 24 hours has been at least 18°C (32°F) colder than the temperature of the space under the roof deck.

11.0 Inspection Techniques & Procedures

11.1 Infrared inspections may be conducted from a ground-based vantage point or from an aircraft.

11.1.1 Ground-based inspections may be conducted as follows:

11.1.1.1 Walk-over: maneuvering a man-portable infrared thermal imager while walking on the surface of a roof. The system may be hand carried or mounted on a cart. Thermograms are taken of areas of interest. Exceptions are outlined on the surface of the roof using spray paint or other semi-permanent means. Invasive verification is used to confirm the presence of moisture within the outlined areas.

11.1.1.2 Elevated vantage point: Use of a man-portable infrared thermal imager from an elevated vantage point may provide an improved view of the roof.

11.1.2 Aerial inspections may be conducted using an infrared imaging system from an aircraft. Thermograms are obtained for the entire roof and subsequently analyzed.

11.2 Prior to performing an infrared inspection, the infrared thermographer will ascertain, whenever possible, the construction of the roof system including the types and thicknesses of the membranes and insulations for each roof section of different construction.

11.2.1 Ideally, this should be accomplished via core sampling of the subject roofs prior to the infrared inspection.

11.3 The infrared thermographer will inform the end user of any limitations of the roof system design, weather, inspection techniques and/or the infrared inspection equipment, and will provide or recommend inspection techniques as necessary to perform a complete and accurate inspection.

11.4 Ground-based inspections

11.4.1 Prior to the infrared inspection, the infrared thermographer will visually inspect the roof system during daylight to locate means of access, identify possible safety hazards, identify heat sources beneath the roof, and determine the most effective procedure for inspecting the roof.

11.4.2 The infrared thermographer will exercise reasonable care while on the roof and will avoid damaging the roof membrane and other components of the roof.

11.4.3 Whenever possible, the underside of the roof should be visually examined to note conditions that may affect inspection results such as, room temperature, equipment, air movement, and changes in construction.

11.4.4 An infrared imaging system shall be maneuvered over the roof in an organized manner to ensure complete inspection viewing at an angle greater than 0.35 rad (20°) from the surface of the roof.

11.4.5 Exceptions shall be delineated on the surface of the roof in a semipermanent manner such as with spray paint.

11.4.6 Infrared data shall be verified in accordance with Section 13.

11.4.7 The location of all invasive test sites shall be marked on the surface of the roof.

11.5 Aerial inspections

11.5.1 Compliance: before aerial infrared inspections are conducted, the requirements of regulatory bodies such as the Federal Aviation Administration (FAA) must be met with regard to installed equipment, flight safety, security, and noise.

11.5.2 Execution: the infrared inspection shall be conducted so as to meet the conditions in 7.3. The findings of infrared imaging systems shall be viewed on a monitor in the aircraft during the flight to ensure that the roof has been inspected properly. The findings are also recorded for detailed study after the flight. The information required in Section 14 shall be obtained.

11.5.3 Visual: subject roofs shall be inspected visually during daylight hours within two days of when the aerial infrared inspection is conducted in order to provide a visual record of roof surface conditions which may affect the infrared inspection. The visual inspection can be accomplished by taking air photographs or by walking the roof. The condition of the roof surface shall not have changed appreciably in the period between the infrared inspection and the visual inspection.

11.5.4 Verification: infrared data shall be verified according to Section 13.

11.5.5 The location of all invasive test sites shall be marked on the surface of the roof.

12.0 Data Interpretation

12.1 The interpretation of infrared data from a roof is a process of pattern recognition for the purpose of differentiating exceptions caused by wet insulation from those caused by the following:

12.1.1 Variations in the type, thickness, density, or continuity of roof insulation.

12.1.2 Variations in membrane thickness, moisture content, or continuity.

12.1.3 Variations in the type or thickness of aggregate surfacing or ballast.

12.1.4 Variations within the roof deck or supporting structure.

12.1.5 Inconsistencies in the roofing system due to damage, repairs, coatings, or overlays.

12.1.6 Variations in temperature beneath the roofing system.

12.1.7 Fasteners, flashings, flanges, or projections from the roofing system or discontinuities within it.

12.1.8 Variations in roof surface emittance.

12.1.9 Infrared radiation from nearby sources.

12.1.10 Moisture or debris on the surface of the roof.

12.2 Most exceptions associated with wet insulation observed at night will be warmer than adjacent areas of the roof that contain dry insulation. However, the reverse may be true for roofs over refrigerated areas.

12.3 Exceptions associated with wet insulation generally fall into one of the following categories: board-stock, picture-framed, or amorphous.

12.3.1 Board-stock patterns are comprised of solid rectangular patterns generally associated with board by board wetting of perlite, cork, wood fiber, and glass fiber insulation.

12.3.2 Picture-framed patterns are comprised of rectangular outlined patterns generally associated with slow-wetting insulation boards such as cellular plastic and cellular glass. However, insulation boards that do not abut adjacent boards may give similar patterns even though the insulation is not wet.

12.3.3 Amorphous patterns are irregular in shape. They are generally associated with monolithic insulations such as lightweight concrete, gypsum, or foamed-in-place polyurethane. Such patterns can also be associated with layers of water above or below any insulation.

12.4 Accurate interpretation of infrared data requires verification.

13.0 Verification

13.1 Verification of infrared data must be carried out by the following invasive test methods: cores, or cores and moisture meter probes.

13.1.1 Cores shall be used to determine the composition and condition of the roofing system, and the quantity of moisture in the insulation.

13.1.2 Moisture meter probes may be used to indicate the presence of moisture in roofing systems provided that they are correlated with core moisture contents (see 13.4.2).

13.2 The penetrated roofing system at invasive verification sites must be repaired in a manner that will not impair its waterproof integrity.

13.3 Minimum verification shall meet these requirements:

13.3.1 One core in each roof section (see 3.1.13) to determine the composition of that section. This core can be of either wet or dry insulation so as to verify with the minimum number of cores.

13.3.2 One core or correlated moisture meter probe reading in an area of dry insulation for each roof section. However, at least one core in an area of dry insulation is required for each roofing system of different composition.

13.3.3 One core in each type of thermal pattern associated with wet insulation (see 12.3) for each roofing system of different composition.

13.4 Noninvasive testing equipment such as nuclear and capacitance meters may be used to compliment, but not replace invasive verification.

14.0 Documentation

14.1 The thermographer will provide documentation **for all infrared inspections**. The following information will be included in a written report to the end user:

14.1.1 The name and valid certification level(s) and number(s) of the infrared thermographer.

14.1.2 The name and address of the end user.

14.1.3 The name(s) of the assistant(s) accompanying the infrared thermographer during the inspection.

14.1.4 The manufacturer, model and serial number of the infrared equipment used.

14.1.5 A description of the location and construction of the roof(s) that were inspected and notations of any portions that could not be inspected.

14.1.6 The date(s) of the inspection and when the report was prepared.

14.1.7 The time the exception was documented.

14.1.8 The weather conditions surrounding the exception including the inside and outside air temperatures, wind speed and direction and the sky conditions.

14.1.9 Hard copies of a thermal image (thermogram) and corresponding visible-light image of the exception. When approved by the end user, the infrared thermographer may provide sketches or drawings in place of, or in addition to, thermograms and photographs.

14.1.10 The field-of-view of the infrared camera lens.

14.1.11 Notation of any windows, filters or external optics used.

14.1.12 Any other information or special conditions that may affect the results, repeatability or interpretation of the exception.

14.1.13 A written narrative that summarizes:

14.1.13.1 The roof construction and materials including the insulation type and thickness, if known.

14.1.13.2 The results of any destructive or other nondestructive tests performed.

14.1.13.3 The inspection procedures and findings.

14.1.14 Painted outlines on the roof surface of areas suspected to contain wet insulation beneath the membrane.

14.1.15 An accurate drawing of the roof with appropriate scale, direction orientation and showing the roof areas that have been outlined with paint on the roof surface.