Designation: C1153 – 97 (Reapproved 2003)ε1

Standard Practice for Location of Wet Insulation in Roofing Systems Using Infrared Imaging[1]

This standard is issued under the fixed designation C1153; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Warning notes were editorially moved into the standard text in April 2003.

1. Scope

1.1 This practice applies to techniques that employ infrared imaging at night to determine the location of wet insulation in roofing systems that have insulation above the deck in contact with the waterproofing. This practice includes ground-based and aerial inspections. (**Warning—**Caution should be taken in handling any cryogenic liquids and pressurized gases required for use in this practice.) (**Warning—**Extreme caution should be taken when accessing or walking on roof surfaces and when operating aircraft at low altitudes, especially at night.) (**Warning—**It is a good safety practice for at least two people to be present on the roof surface at all times when ground-based inspections are being conducted.)

1.2 This practice addresses criteria for infrared equipment such as minimum resolvable temperature difference, spectral range, instantaneous field of view, and field of view.

1.3 This practice addresses meteorological conditions under which infrared inspections should be performed.

1.4 This practice addresses the effect of roof construction, material differences, and roof conditions on infrared inspections.

1.5 This practice addresses operating procedures, operator qualifications, and operating practices.

1.6 This practice also addresses verification of infrared data using invasive test methods.

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

1.8 *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.* Specific precautionary statements are given in 1.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C168 Terminology Relating to Thermal Insulation

D1079 Terminology Relating to Roofing and Waterproofing

E1149 Definitions of Terms Relating to NDT by Infrared Thermography

E1213 Test Method for Minimum Resolvable Temperature Difference for Thermal Imaging Systems

2.2 *ANSI-ASHRAE Standard:*

ANSI-ASHRAE Standard 101—Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics[3]

2.3 *ISO Standard:*

ISO/DP 6781.3E—Thermal Insulation—Qualitative Detection of Thermal Irregularities in Building Envelopes—Infrared Method[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *blackbody*, *n*—the ideal, perfect emitter and absorber of thermal radiation. It emits radiant energy at each wavelength at the maximum rate possible as a consequence of its temperature, and absorbs all incident radiance. (See Terminology C168.)

3.1.2 *core, n*—a small sample encompassing at least 13 cm^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.

3.1.3 *detection*, *n*—the condition at which there is a consistent indication that a thermal difference is present on the surface of the roof. Detection of thermal anomalies can be accomplished when they are large enough and close enough to be within the spatial resolution capabilities of the imaging

[1] This practice is under the jurisdiction of ASTM Committee C16 on Thermal Insulation and is the direct responsibility of Subcommittee C16.30 on Thermal Measurement.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

system; that is, when their width is at least two times the product of the instantaneous field of view (IFOV) (see 3.1.10) of the system and the distance from the system to the surface of the roof divided by 1000.

3.1.4 *emittance, ε, n*—the ratio of the radiant flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions. (See Terminology C168.)

3.1.5 *expansion joint, n*—a structural separation or flexible connection between two building elements that allows free movement between the elements without damage to the roofing or waterproofing system. (See Terminology D1079.)

3.1.6 *field-of-view, (FOV), n*—the total angular dimensions, expressed in radians, within which objects can be imaged, displayed and recorded by a stationary imaging device.

3.1.7 *infrared imaging line scanner, n*—an apparatus that scans along a single line for variations in infrared radiance and is moved perpendicular to that line to produce a two-dimensional image of the region scanned.

3.1.8 *infrared imaging system, n*—an apparatus that converts the spatial variations in infrared radiance from a surface into a two-dimensional image, in which variations in radiance are displayed as a range of colors or tones.

3.1.9 *infrared thermography, n*—the process of generating images that represent variations in infrared radiance of surfaces of objects.

3.1.10 *instantaneous field of view, (IFOV), n*—the smallest angle, in milliradians, that can be instantaneously resolved by a particular infrared imaging system.

3.1.11 *line scanner, n*—an apparatus that scans along a single line of a scene to provide a one-dimensional thermal profile of the scene. (See Terminology E1149.)

3.1.12 *membrane, n*—a flexible or semiflexible roof covering or waterproofing whose primary function is the exclusion of water. (See Terminology D1079.)

3.1.13 *minimum resolvable temperature difference (MRTD), n*—a measure of the ability of operators of an infrared imaging system to discern temperature differences with that system. The MRTD is the minimum temperature difference between a four slot test pattern of defined shape and size and its blackbody background at which an average observer can discern the pattern with that infrared imaging system at a defined distance.

3.1.14 *moisture meter probe, n*—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 roofing system.

3.1.15 *radiance, n*—the rate of radiant emission per unit solid angle and per unit projected area of a source in a stated angular direction from the surface (usually the normal). (See Terminology C168.)

3.1.16 *recognition, n*—the ability to differentiate between different types of thermal patterns such as board-stock, picture-framed and amorphous. Recognition of thermal anomalies can be accomplished when their width is at least eight times the product of the IFOV of the infrared imaging system and the distance from the system to the surface of the roof divided by 1000.

3.1.17 *roof section, n*—a portion of a roof that is separated from adjacent portions by walls or expansion joints and in which there are no major changes in the components.

3.1.18 *roofing system, n*—an assembly of interacting components designed to weatherproof, and normally to insulate, a building's top surface. (See Terminology D1079.)

3.1.19 *survey window, n*—the time period during which roof moisture surveys can be successfully conducted according to the requirements of Section 10.

3.1.20 *thermal anomaly, n*—a thermal pattern of a surface that varies from a uniform color or tone when viewed with an infrared imaging system. Thermal anomalies may be caused by wet insulation.

3.1.21 *thermogram, n*—a recorded visual image that maps the apparent temperature pattern of an object or scene into a corresponding contrast or color pattern. (See Terminology E1149 with the word "recorded" added.)

4. Significance and Use

4.1 This practice should be used to outline the minimum necessary elements and conditions to obtain an accurate determination of the location of wet insulation in roofing systems using infrared imaging.

4.2 This practice is not meant to be an instructional document or to provide all the knowledge and background necessary to provide an accurate analysis. For further information, see ANSI-ASHRAE Standard 101 and ISO/DP 6781.3E.

4.3 This practice does not provide methods to determine the cause of moisture or its point of entry. It does not address the suitability of any particular system to function capably as waterproofing.

5. Infrared Survey Techniques

5.1 *Ground-Based*:

5.1.1 *Walk-Over*—Walking on a roof using an infrared imaging system. The system may be hand-carried or mounted on a cart. Thermograms are taken of areas of interest. Areas that appear to contain wet insulation are identified and marked for verification.

5.1.2 *Elevated Vantage Point*—Use of an infrared imaging system from an elevated vantage point may provide an improved view of the roof.

5.2 *Aerial*:

5.2.1 *Real-Time Imaging*—Use of an infrared imaging system from an aircraft. Thermograms are obtained for the entire roof.

5.2.2 *Line Scanner Imaging*—Use of a line scanner from an aircraft to record thermal imagery for the entire roof.

6. Instrument Requirements

6.1 *General*:

6.1.1 *Objective*—Instrument requirements have been established in order to permit location of insulation that has lost as little as 20 % of its insulating ability because it contains moisture.

6.1.2 *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.

6.1.3 *Minimum Resolvable Temperature Difference (MRTD)*—The MRTD at 20°C shall be 0.3°C.

6.1.3.1 The survey shall be conducted with the thermal imaging system only on sensitivity settings that meet this requirement.

6.1.4 *Test for Minimum Resolvable Temperature Difference*:

6.1.4.1 *Instrument Setting*—The thermal imaging system shall be tested at each sensitivity that the system will be used.

6.1.4.2 *Test Target Pattern*—The test target shall consist of two plates with known temperatures, located in front of the imaging system. The near plate shall have four equally spaced slots each having 7:1 height-to-width ratio (see Fig. 1).

6.1.4.3 *Test Geometry*—Refer to Fig. 1. The ratio of the width, (*w*), on the test pattern to the distance, (*d*), to the imaging system shall be established, using the maximum IFOV allowed for the type of survey being conducted, as follows:

$$w/d < 0.002 \text{ (IFOV)}$$

where:

w and *d* are in the same units and IFOV is in milliradians. Maximum allowable values of IFOV are defined in 6.2.2, 6.3.2, and 6.4.2.

6.1.4.4 *Test Procedure*—In accordance with Test Method E1213, the temperature difference between the two plates of the target is slowly increased without communicating with the observer. The observer announces when the test pattern comes into view on the display. The temperature at this point is recorded.

6.1.4.5 *Test Replicates*—Because of differences in visual acuity, more than one observer shall perform the procedure in 6.1.4.4. The average temperature difference is the MRTD for that test condition.

6.2 *Walk-Over Surveys*:

6.2.1 *Anomaly Size*—Instrument requirements have been established to permit recognition of areas of wet insulation as small as 0.15 m on a side.

6.2.2 *Recognition Distance, FOV and IFOV*—Recognition can be accomplished when the width of a thermal anomaly, in metres, is at least 0.008 times the product of the IFOV of the system and the distance, in metres, from the system to the anomaly. Since the walkover survey shall be accomplished at a maximum distance of 5 m, the IFOV of the apparatus shall be 3.8 milliradians, or less. The horizontal and vertical FOVs shall be at least 0.21 rad (12°) by 0.10 rad (6°), respectively.

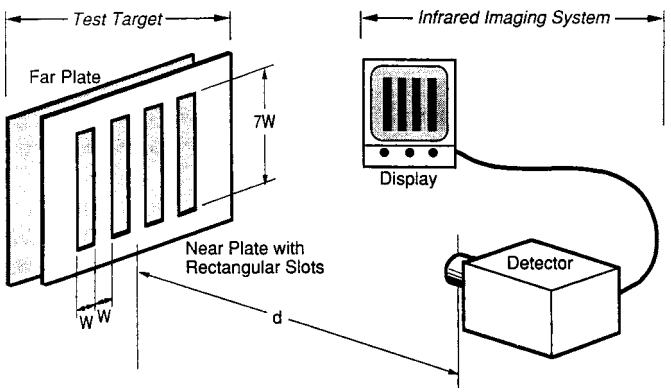

FIG. 1 Test Arrangement for Minimum Resolvable Temperature Difference (MRTD) of an Infrared Imaging System

6.3 *Elevated Vantage Point Surveys*:

6.3.1 *Anomaly Size*—Instrument requirements have been established to permit recognition of areas of wet insulation as small as 0.15 m on a side.

6.3.2 *Recognition Distance, FOV and IFOV*—Since recognition must be possible at distances greater than 5 m, the maximum allowable IFOV in milliradians is related to distance, (*d*), in metres from the infrared imaging system to the place on the roof being scanned as follows:

$$\text{IFOV} = 18.8/d$$

The minimum horizontal FOV shall be $1.0/d$ and the minimum vertical FOV shall be $0.5/d$, both expressed in rad.

6.4 *Aerial Surveys*:

6.4.1 *Anomaly Size*—Aerial surveys shall be conducted with infrared imaging line scanners or infrared imaging systems that have the ability to detect areas of wet insulation as small as 0.3 m on a side directly below the system.

6.4.2 *Detection Distance, FOV and IFOV*—Detection can be accomplished when the width of a thermal anomaly, in metres, is at least 0.002 times the product of the IFOV of the system and the distance, in metres, from the system to the anomaly. The maximum allowable IFOV is related to the vertical distance (*d*), in metres, above the roof, as follows:

$$\text{IFOV} = 150/d$$

The FOV along the line of flight and across the line of flight shall be at least 0.05 rad by 0.10 rad, respectively. The usable field of view shall be within 0.35 rad of a point directly below the infrared imaging system.

7. Level of Knowledge

7.1 The proper conduct of a roof moisture survey using an infrared imaging system requires knowledge of how and under what circumstances the system can be used and a general understanding of roof construction.

7.2 Proper interpretation of infrared data requires knowledge of infrared theory, moisture migration, heat transfer, environmental effects, and roof construction as they apply to roof moisture analysis.

8. Limitations (Applicability of Constructions)

8.1 Applicable constructions include membrane systems 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 When extruded polystyrene insulation is placed under ballast and above a protected membrane, it is quite difficult to locate moisture in the insulation below the membrane by use of infrared thermography.

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

8.4 When moisture sensitive materials are located under pavers, stone ballast or insulating gravel (for example, scoria),