RESNET Interim Guidelines for Thermographic Inspections of Buildings
April 4, 2012

Purpose
This standard provides guidance on the use of infrared thermography for the thermal examination of low rise, three stories or less, wood or steel frame, residential and light commercial buildings. The three-fold purpose of this standard is to:

- Provide a recommended path by which those wishing to obtain certification in infrared thermography will have a means to do so.
- Provide examination and analysis guidance in using infrared thermography for air intrusion and insulation inspections.
- Provide a substitute for Grade II and Grade III insulation examinations on a new building where viewing of the insulation installation was not accomplished before the drywall was applied.

This Standard also includes information for:

1. Using an infrared imaging system to determine radiation differences associated with surface temperature variations of a building enclosure,

2. Determining whether the areas being viewed meet the specifications in this Standard and in the RESNET 2006 Mortgage Industry National Home Energy Rating System Standards.

3. Documenting the type and extent of any observed thermal anomalies,

4. Locating the areas needing further physical examination related to thermal bridging, thermal bypasses and air infiltration,

5. Providing a thermal indication of insulation performance and continuity, and

6. Identifying areas affected by air and convection when an infrared imaging system is used in combination with blower door operation.

Relationship to Other Standards
This chapter complements the RESNET Mortgage Industry National Home Energy Rating System Standards. The referenced International Standards found below have been used as a normative guideline in establishing these RESNET Standards:

- ANSI/ASNT CP-105-2011 American National Standard ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel
- ASNT Recommended Practice Number SNT-TC-1A Personnel Certification and Qualification (2011)
- ASTM C 1060-90 (2003): Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings.
- ASTM E 1186-03: Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems.
- ISO 6781: Thermal Insulation---Qualitative Detection of Thermal Irregularities in Building Envelopes---Infrared Method.
- Canadian General Standards Board, Document 149-GP-2MP, Manual for Thermographic Analysis of Building Enclosures.
- British Standard: Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method.
- ISO6781:1983 modified.
- Canadian National Master Specifications (NMS), Section 02 27 13,
- Thermographic Assessment; Building Envelope

Relationship to State Law.
This Standard recognizes that federal or state laws take precedent over this Standard.

Scope
These standards are RESNET requirements for inspecting a building enclosure using an infrared imaging system to locate defective insulation installations, framing issues, air leakage, or thermal bypasses.

1 Building Science Thermographer
All individuals claiming to be a Building Science Thermographer must be trained in accordance with American Society for Nondestructive Testing (ASNT) SNT-TC-1A, and ASNT CP-105. These standards provide general guidance and are intended to be adapted by the end user to meet the specific requirements of the end user. It is the responsibility of the end user to ensure that all of the requirements have been fulfilled.

1. The candidate must have a minimum of HERS Rating Field Inspector certification and should be able to demonstrate sufficient building science knowledge and understanding of the effects of stored heat, stack and wind effect, solar heating, reflectivity and emissivity .

2. AND, the candidate must complete a course of study that fully complies with the ASNT Level II. The course of study must meet the minimum ASNT Guidelines of thirty-two (32) classroom hours and successful completion of an exam, focused specifically on infrared thermography for building science. Appendix F is provided for reference. The exam will be in three (3) parts – general (written), application specific (written), and practical (hands-on).

2 Thermographic Imaging Requirements

Infrared Imaging System Performance

The infrared imaging system must have the gain or contrast (level or span) set so as to be able to distinguish a framing member from the other parts of the enclosure cavities under the ambient thermal conditions with the IR imaging system at a distance, which permits the recognition of thermal anomalies. The imaging system should be able to ensure any recognizable defects or anomalies won't appear in either saturation (maximum brightness or white) or in suppression (minimum brightness or black) on the display or on the thermographic images. Some imaging systems that meet the specifications may have fixed focus and automatic level and span adjustment. It is the responsibility of the thermographer to adjust their viewing position relative to the envelope surfaces to ensure that data is of acceptable quality and the subject is properly documented. This requirement assumes all minimum required conditions necessary for the analysis and observations have all been met. A radiometric camera is recommended but not required. (Note: If temperatures are being measured, you must also have the ability to adjust emissivity and set background reflected temperature; this can be done in the camera OR by using software.)

Resolution

The Noise Equivalent Temperature Difference (NETD), which is a measurement of thermal resolution or sensitivity, must be less than or equal to 0.10°C at 30°C (0.18°F at 86°F).

Spectral Range

The infrared imaging system must have an operating spectral range that falls anywhere between 2 and 15 micrometers (µm).

Field of View (FOV)

This is defined as the picture size or total field of view at a working distance, which is normally expressed in angular degrees or radians per side if rectangular and angular degrees or radians if circular. The FOV should be capable of providing a thermal image of at least two wall-framing cavities wide while still being able to resolve an individual framing member at a working distance. In order to accomplish this prerequisite, a FOV of approximately 20 degrees is suggested.

Recorded Images

The thermal imaging system must have a means of recording thermal images seen on the imager's screen. The thermal images may either be in a video format or in individual still frame images.

Instantaneous Field of View and Detector

The detector and lens combination of the infrared imaging system must have sufficient resolution to resolve framing members and any small void areas or wall cavities. The camera's detector array is required to have no less than 120 x 120 pixels.

3 General Examination and Thermography Requirements
Observe the following general requirements for any infrared examination of a building:

1. Sample thermal images must be taken of representative parts of the building being examined and analyzed that demonstrate the majority of areas with anomalies or identifiable thermal features. In addition, parts of the building having no apparent anomalies must also have a sampling of thermal images, which demonstrate the correct functioning of building components.

2. As practical, remove furniture, pictures, and other obstructions as necessary to gain a clear field of view when necessary. This process is best accomplished by the building owner or occupant at least 12 hours before the beginning of the thermal examination. If items blocking a view of a building section have not or cannot be removed, this condition should be noted in the report.

3. Note any located anomalies or thermal features on a drawing or catalog them with a visible light picture for locating the defect for correction. Confirmation of the anomaly using the means stated in #7 below is recommended prior to inclusion in any report, as false positives are not uncommon.

4. Obtain your thermal images as close to perpendicular to the surfaces you're examining as possible.

5. Change your position and view the same area as necessary in areas where there is the possibility of reflected radiation. Document area and location of surfaces obscured by mirrors, metal, reflective tile or other low emissivity coverings that affect thermal interpretations.

6. The minimum criterion for satisfactory thermal conditions is the ability to distinguish the framing materials from the wall cavities. An inside to outside temperature difference of the wall surfaces of at least 10°C / 18°F for a period of 4 hours is recommended. (Ref: ISO 6781, 5.1, a. recommends 10°C for a period of 24 hours. Therefore the instruments controls must be set to resolve framing details clearly. If framing images can't be resolved, and site conditions can't be altered artificially, then reschedule the examination for a time when minimum temperature difference conditions are achieved. If the temperature is within range and no studs are visible, confirm if possible the presence of continuous foam insulation or atypical framing in the wall assembly before aborting the test. Document the conditions and complete sections of the house that scan "normally". False negatives are possible with details that

have reduced thermal bridges; for example, flat roof sections with all the insulation above the deck may not allow for the resolving of framing members.

7. One may provide further services/recommendations/secondary analysis to the client when allowed under contract or by additional contract for additional examinations of any anomalies by:
   - Physical examination of the building details at “best” and “worst” or other representative locations to calibrate the range of variation under these specific conditions,
   - Other means of examinations (e.g. surface temperature devices, air exhaust devices),
   - Experience, or
   - By comparing to thermal images of normal building surfaces or with reference thermographs of known defects.

8. Exterior visual and/or thermal examination of a building based on site conditions

   a. Verify that no direct solar radiation has heated the surfaces to be examined for a period of approximately 3 hours for frame construction and for approximately 8 hours for masonry veneer construction.

   b. Plan exterior investigations for an appropriate time after sunset, before sunrise, or on an overcast day when the influence of solar radiation can be determined to be minimal.

   c. Verify that wind speed is less than 8 mph at time of analysis and at end of analysis. Note any variations during test.

   d. Verify the exterior surfaces are dry.

   e. Check and record the ongoing test parameters, such as the temperature difference (ΔT) across the building enclosure, wind speed, and inside pressure with respect to outside pressure during the examination. Remain close to original readings; significant variations of these parameters may skew the outcome of the tests.

9. Interior investigations can also be influenced by wind, sun, sky condition and moist exterior surfaces. These influences typically lag the more direct exterior influence by 2-6 hours depending on conditions and structure type. Some of the conditions you may encounter are as follows.

   a. Interior partitions between rooms at different temperatures may appear abnormal and provide false positive images if not confirmed (a thermal bypass to a buffer space or to outside).

   b. Stored items, cabinets, bathroom fixtures and reflective finishes may limit wall scan to sample areas and provide thermal conditions not representative of the site conditions being examined. Where possible, scan obscured surfaces from the opposite side.

c. Buffer zones such as attics, crawlspaces, basements, attached garages may hold air at a temperature different from interior and exterior.

d. Chases and interior surface coverings open to the exterior or between buffer zones such as dropped soffits, plumbing walls, plumbing wall edges, floor joists open to porch roofs may show extensive IR contrast under wind or blower door operation, but appear without defect under as found conditions.

e. Ductwork, plumbing, electrical lines, and radiant heating components built into soffits, ceilings and floors may appear as anomalies but also obscure details of the construction assembly that holds them.

f. Additional interior cavities, such as furring spaces behind interior finish materials found in back-plaster, and some remodeling can obscure the conditions in the main building cavity. This construction detail can provide either false negatives or false positives if not confirmed.

g. Interior scans of hollow spaces such as interior cavities of Concrete Masonry Unit (CMU) walls below grade and between units can show convective loops where insulation is not continuous over the entire surface. This condition should be documented in the report.

h. Listed high performance windows sometimes fail and lose gas fill, which can show up as anomalies in the glass away from the frame.

4 Insulation Inspection

4.1 Procedures for Infrared Insulation Inspections

1. **Qualitative** analysis of installed insulation. Inspection used for determining *general areas* of the inspected surfaces having anomalies without quantification.

    a. The ΔT between the inside and outside wall surfaces and as defined by the surface being imaged must be a minimum of 10°C / 18°F or greater for a period of 4 hours before the inspection, or the thermographer verifies and documents that the imaging system being utilized for the inspection is capable of providing satisfactory results with less ΔT. If the conditions and/or equipment are not suitable for this type of inspection, the inspection must be rescheduled for a time when appropriate ΔT is present and/or satisfactory results can occur with less ΔT

    b. If the inspection is done in conjunction with a blower door used to depressurize the building to highlight any thermal bypasses, the inspection can be performed with a minimum ΔT of 6.7°C / 12°F, but an initial static thermal survey of the inspection areas must be done prior to depressurization testing in order to verify changes in any areas where a thermal bypass is occurring. Changes in anomalies must be explained in the report. See Section 802.5 for complete explanation of air leakage inspections.

It is best practice to perform pressurization and depressurization infrared inspection prior to performing air leakage testing and calculations, as these may interfere with or confuse infrared inspection results with excessive air-wash.

2. **Quantitative** analysis of installed insulation for the purpose of grading the insulation installation. *Quantitative* for this infrared investigation is defined as determining *the total square footage of anomalies of installed insulation of a structure as a percentage of the total surface area of installed insulation in the structure in square feet.*

    a. There must be a *minimum* ΔT across the building envelope wall surfaces of 10°C / 18°F or greater for a period of 4 hours before the inspection. *The use of a blower door or any air exhausting device is not allowed during or two hours before this specific insulation inspection procedure. For quantitative grading of insulation, the above stated minimum temperature difference at the time of the inspection must be achieved. Otherwise grading of the insulation cannot be achieved using this standard.*

b. Recognized anomalies may be used to grade the insulation by the guidelines in the 2006 Mortgage Industry National HERS Accreditation Standards (Appendix A “Sample Report”, pp. A-11 through A-16).

c. An insulation inspection demonstrating more than 5% anomalies must be followed either by physical inspections to determine whether there is missing insulation that must be documented or modeled as uninsulated wall cavities.

d. Under these specified testing parameters, the IR imaging system can also be used to locate thermal bridging areas.

e. If the RESNET Rating Provider for the HERS Rater allows for a more stringent inspection protocol for insulation inspections, then this Infrared Standard should be used as a referenced Standard for performing an infrared evaluation of onsite installed insulation. This Infrared Standard may therefore be used for the grading of insulation in any home in which a visual inspection of the insulation was not conducted.

4.2 Insulation Grading Standards in Reference to Chapter 8, “RESNET Standard for Thermographic Inspections”

Grade I
Grade I insulation installation cannot be verified using this infrared standard.

Grade II
Grade II is insulation determined to contain thermal anomalies of less than 2% for all inspected walls, floors and ceilings of the building.

Grade III
Grade III is insulation determined to contain thermal anomalies between 2% and 5% for all inspected walls, ceilings and floors of the building.

4.3 Quantitative Grading of Wall Insulation

For determining the percentage of insulation anomalies, the Building Science Thermographer must use the following method to comply with the quantitative insulation inspection. Method for converting infrared insulation inspection to grading: Measure the walls, ceilings, and framed floors to be inspected to the nearest square foot or scaled from the building blueprints. Measure each insulation anomaly to the nearest inch (see examples in Appendix C “Method for Converting Anomalies to Insulation Grading”. Then divide the total square footage of the insulation problem areas by the total square footage of the inspected surfaces.

1. **Example:** A building having 3100 square feet of inspected surfaces (insulated walls, floors, and ceilings) and 50 square feet of anomalies would have 1.61%

of problem areas and therefore be considered Grade II.

2. Appendix B “Inspection Form for Thermal Bridging and Thermal Bypass Investigations” contains examples of this method.

5 Air Leakage Inspection

The following procedures provide the Building Science Thermographer with techniques for analyzing the air barrier systems of a structure. These procedures are for locating air leakage and thermal bypass sites (qualitative) and not set up to determine quantitative airflow rates. A thermal bypass is the result of an incomplete or compromised air barrier.

IR is an important tool for quickly finding the highest impact air leakage locations in existing buildings. Documenting construction details where a change in the thermal image before blower door operation to what occurs during blower door operation is an important component of the basic skill set of a Building Science Thermographer.

1. The Air Leakage thermal inspection requires a temperature difference between the inside and the outside of the building to be a *minimum of 1.7°C / 3°F.* This temperature difference will allow for surveying of building surfaces to find air leakage sites and the temperature difference must be maintained during the entire inspection.

2. Buffer zone air temperature is more important for this test. Attic air can be at a higher temperature than interior air and very clearly show location and severity of any existing bypasses when the IR scan is done before and during blower door operation. Similarly, in weather with a 10°C/18°F or greater inside/outside wall surface temperature difference, attic air can be the same as interior air; then all the potential bypasses disappear from the scan when the blower door is operated. In some homes both effects can occur with separate attics or with slow scanning procedures as solar heated attic air is replaced by cooler outside air. Brick finger space air temperatures can reach over 100°F on the sunny side, which can aid in determining wall details and floor joist connections on that side, but obscure results on the shaded sides. Large openings inside joist and partition wall volumes to adjacent buildings/ units at the same temperature will not be visible – these may dominate blower door leakage numbers and provide odor and smoke transfer risk without a temperature signal.

3. Because air leakage sites may be difficult to locate under natural conditions, air must be artificially forced across the building enclosure by use of a fan such as a blower door or by using the mechanical and/or ventilation system(s) in the building. Building depressurization and inside inspection are preferred because of less interference of solar radiation and wind. The outside air is at a different temperature than the inside air and will therefore leave a thermal signature for the infrared imaging system to capture. The largest volumes that change the fastest, correlate with the biggest gaps. Confirm the physical details of the largest framing volumes at the edge that changes the most during the pressurization or depressurization of the building.

4. The thermal image for air leakage will appear as “fingers” or “streaking” showing as dark when cold air is observed and lighter colors when warm air is viewed. The thermal images will produce irregular shapes with uneven boundaries and large temperature variations. These air leakage sites are often at joints, junctions or penetrations in the enclosure. There is often a temperature gradient within a finger or streaking area. An isotherm **(or color alarm**) function on the camera or color display can isolate the highest contrast portion of each anomaly, which is typically closer to the source or thermal defect. Note, any interior insulation, surface coverings, or additional cavities (such as behind paneling) may mask the full path of air movement. A scan of all interior surfaces may reveal indications of significant air leakage in locations not typically associated with direct connection to the exterior.

5. Depressurization is employed for an interior inspection and pressurization is utilized for an exterior or attic inspection.

    a. When depressurizing the building, the resultant air leakage should be allowed to alter the building’s surface temperatures for a *minimum period of 10 minutes, depending on outside air temperature*. It is recommended that pressures on the building envelope of 20 Pascals be reduced to less than 10-15 Pascals after 30 minutes to minimize the washing effect of convective currents.

    b. As much as possible view all the key construction details at the same time. The interior finish will cool and show more contrast over time so details seen later appear in greater contrast. But pressurization or depressurization, when there are extreme temperatures outside, can also result in a change to the interior temperature of the building and consequent loss of identifiable thermal conditions over time needed for adequate and reliable imaging by equalizing the Delta T (ΔT).

    c. Thermal construction knowledge of the structure being analyzed is more important than the actual surface temperature change during the pressurization/depressurization tests. The airflow required to slightly cool (0.2℃) 30 lineal feet of 2x10 ceiling joist above a first story room that is open to a porch roof is hundreds of times greater than the amount of air required to get a 1/4” wide 3” long high contrast finger of air infiltration from an outlet or attic access weather strip corner. Cooling or heating an entire joist cavity between floors with air infiltration will take longer than finding an air leak around an electrical box.

    d. For the procedure, *normal pressure differences across the building envelope must be between 10 and 20 Pascals*. The higher pressure readings intensify surface temperature differences and further aid in the discovery of air leakage sites.

    e. Pressure readings must be taken separately on both the leeward and windward side of the building and whenever possible in the same areas on each floor of a multi-story building.

6. When depressurizing a structure, turn off or switch to pilot any combustion appliances in the conditioned space. Close fireplace dampers and cover ashes to prevent ashes from becoming airborne.

7. Although the primary air leakage sites viewed will be at the building enclosure, interior walls and floor/ceiling cavities must also be viewed since air leakage from the attic and basement are also a possibility.

8. Take care to discriminate between thermal bridging sites and thermal bypass or air leakage sites. Thermal bridging sites will not change size or shape during the pressure testing.

6 Inspection for Thermal Bypass and Thermal Bridging

1. Delta T (ΔT) requirements must be met for each specific anomaly being investigated, whether it be insulation (a minimum of 10° C/18° F or greater) or air leakage (a minimum of 1.7°C/3°F) situation. Thermal bridging (as defined in Section 802.4.1, 2d) is part of the insulation inspection and thermal bypass (defined in Section 802.5) is a component of the air leakage testing.
2. One of the problem situations for which the building is being examined through the use of infrared is to identify areas of the walls where excessive framing materials have been installed and therefore a larger framing fraction should be used in analysis of that portion of the wall, lowering the net R-value.
3. The second area of investigation in this area has to do with the introduction of unconditioned air either around installed insulation or within an interior wall cavity or interior space of the house. When a blower door is used (see section 805.1, Qualitative Analysis, #2) for the purpose of enhancing any apparent thermal bypasses, an initial thermal survey of all suspect areas must be performed first to establish a baseline view of any encountered anomalies. The blower door must then be turned on and allowed to run for ten minutes. The anomalies must then be viewed a second time with the infrared imaging system and any changes documented visually and by location.
4. If the RESNET Rating Provider for the HERS Rater allows for a more stringent inspection protocol for thermal bypass and thermal bridging inspections, then this Infrared Standard should be used as a referenced Standard for performing an infrared evaluation of onsite thermal bypasses (air intrusion) and thermal bridging (insulation) as found in Sections 802.4 and 802.5. This Infrared Standard, with the associated requirements for thermal imaging, may therefore be used for the evaluation of the presence of thermal bypasses and thermal bridging in any home in which a visual inspection for

these thermal bypasses and thermal bridging was not accomplished.

5. *A sample report can be found in Appendix B "*Inspection Form for Thermal Bridging and Thermal Bypass Investigations"*.*

7 THERMOGRAPH INTERPRETATION

The following guidelines are to help in the interpretation of thermal images.

1. As the thermographer, you should routinely select a familiar display palette for ease of identifying hot and cold areas. A gray scale or monochromatic color palette is generally recommended, but not required, for on site use because of the ease of interpretation of the images seen.
2. Typical building investigations of insulation, air leakage, framing and thermal bypasses do not require the identification of specific temperatures. These readings may be informative, however, when comparing actual surface wall or ceiling temperatures with the thermostat set point.
3. You must be aware of specific emissivity values of materials or components being viewed in order to identify reflected radiation. While observing the same areas, moving to a different location while viewing a surface may help identify reflected radiation.
4. Secondary methods of verifying anomalies may include experience, onsite measurements with specific devices, or by comparison to reference thermal images from houses with known anomalies or without anomalies.
5. The basic determining factor for correct interpretation is if the temperature distribution differs from that expected for the type of construction being viewed with the infrared imaging system. If the apparent anomaly can't be explained by the design of the building envelope, effects of heat sources, variations of emissivity, or by the physics of heat transfer, then the anomaly may require further investigation.

8 REPORTS

Reports must be generated for each specific type of investigation whether insulation, air leakage, framing, or thermal bypass. All of the following elements must be part of each report.

A sample report can be found in Appendix A"Sample Report".

1. A brief description of the way the building has been constructed.
2. Types of interior and exterior surface materials used in the building.
3. The geographical orientation of the building with a description of the exterior surroundings including other buildings, vegetation, landscaping, and surface water drainage.
4. Camera brand, model and serial number.
    a. Optional lenses with serial numbers (if applicable).
    b. Most recent calibration date or calibration verification date.
5. The name of thermographers and inspectors present.
6. Date and hour of tests.
7. Inside air temperature(s).
8. Ambient (outdoor) air temperature.
9. Temperatures of buffer zones and attics.
10. Indoor and outdoor relative humidity.
11. General information for the last 12 hours on the solar radiation conditions in the geographic area where the test is being performed.
12. Ambient conditions such as precipitation and wind direction and speed occurring within the last 24 hours, as applicable. Refer to specific requirements in each section of each inspection type for requirements in each specific area.
13. Records of the portions of the building, which were not within test conditions when the scan was performed and which portions were obstructed by adjacent structures, interior cabinets, intervening cavities or reflective surfaces.
14. Other relevant information, which may have influenced the test results.
15. Drawings, sketches and/or photographs detailing the locations in the building where thermograms were taken detailing possible irregularities in the components being tested.
16. Thermal images taken during the inspection with their relative locations and written or voice recorded explanations of the anomaly listed along with visual and reference images. Any spot, line or area temperature measurement marker embedded in a thermal image shall also include information regarding

its spot, line or area emissivity and background temperature setting.

17. An identification of the aspects or components of the building being examined.
18. Include the results of the analysis that explains the type and the extent of each construction defect observed during the inspection.
19. Any results from additional measurements and investigations. Identify additional equipment used and support with type, model number, serial number, and any calibration that has been performed on the devices.

9 SAFETY CONCERNS

It is not the intent of this standard to address safety concerns, if any, that may be associated with its use. It is the sole responsibility of the thermographer or user of this document to provide personal protective equipment, to follow any applicable manufacturer's guidelines for the operation of all diagnostic equipment, and to be familiar with health and safety practices or regulations for those involved with any of the previous procedures described in this document. The thermographer is held accountable for all company, local, state, and federal regulations regarding the various aspects of these inspections and their possible application to the work site.

10 DEFINITIONS AND ACRONYMS

Abnormal: Some defect exists in the construction and operation of the building enclosure.
Air barrier: Any solid material installed to control air leakage either into or out of the building envelope.
Air exfiltration: Air from the conditioned space leaking outside of the thermal boundary of a structure.
Air infiltration: Air from outside the thermal boundary of a structure, which enters the conditioned space.
Air leakage site: A specific location in a structure where the air barrier has irregularities in it allowing both air infiltration and exfiltration depending on the interior pressures of the building.
Air wash: The movement of air through insulation.
Anomaly (defect): An area of a building where the temperature distribution seen with an infrared imaging system differs by more than 4°F from the temperature distribution expected for the type of construction being viewed, denoting a possible problem area; an inconsistency.
ANSI: American National Standards Institute
ASNT: American Society for Nondestructive Testing
ASTM: ASTM International, originally known as the American Society for Testing and Materials (ASTM)
Blackbody: An object or surface which absorbs all radiant energy, within a specific spectral band, coming into contact with the surface and does not reflect or transmit any. Thus, the surface has an emissivity of 1.
Building envelope: The components of a building (walls, ceilings, windows, doors, floors, and foundations) that separate the conditioned space from the unconditioned spaces or conditioned space from outside.
Compression (insulation): This condition includes but is not limited to batt insulation compressed behind plumbing, heat and air, electrical, and other in cavity obstructions that results in the loss of R-value of the installed insulation. This condition can also occur within a wall cavity without obstructions. See also “Misalignment”.
Defect: See Anomaly
Emissivity: The ability of a surface to emit radiation, measured as the ratio of the energy radiated within a specific spectral band by a surface to that radiated within that same specific spectral band by a blackbody at the same temperature.
Field-of-view (FOV): The total area of height by width, normally expressed in either degrees or radians, in which an infrared imaging system is capable of displaying, imaging, and recording objects.
Framing spacing: The distance from center to center of wall studs, ceiling joists, floor joists and roof rafters.
Gaps (insulation): An insulation defect where installed insulation does not completely fill areas of the building enclosure, which allows for conductive and convective heat loss and a reduced R-value of the overall building enclosure.

Infrared imaging system: An instrument that converts radiation differences associated with surface temperature variations into a two dimensional image by assigning specific colors or tones to the differing temperatures.
Infrared thermography: The process of using an infrared imaging system to generate thermal images of the surfaces of objects, which can be viewed electronically or printed.
Infrared Training Provider – A firm or organization, who is currently qualified as a RESNET HERS Rater Provider or a RESNET Training Provider, that develops, manages, and operates an infrared training and quality assurance program."
Instantaneous Field of View (IFOV): The instantaneous spatial resolutions characteristics of infrared imagers (expressed in angular degrees or radians per side if rectangular and if round, in angular degrees or radians), or the smallest object able to be viewed by the imaging system at a given distance.
ISO: International Organization for Standardization.
Level I Thermographer: A person who is qualified by training, experience and testing to gather high-quality data and, where pass/fail guidance is provided, to interpret that data. The American Society for Nondestructive Testing (ASNT) defines a Level I as one who can

- Perform calibrations, tests, and evaluations for determining the acceptance or rejection of tested items in accordance with specific written instructions.
- Record test results but have no authority to sign reports for the purpose of signifying satisfactory completion of NDT operations.
- Receive instructions or supervision from a Level III or designee.

Misalignment (insulation): This defect occurs when installed insulation is not in contact with the air barrier and air intrusion between the insulation and the air barrier seriously compromises the effectiveness of the insulation in framed buildings.
Normal: The building shell is functioning as designed.
Qualitative: In relation to insulation inspections, determining general areas of anomalies without assigning temperature values to the patterns.
Quantitative: In relation to insulation inspections, determining the total square footage of anomalies of a structure as a percentage of the total surface area of the structure in square feet.
Spectral Wavelength: The electromagnetic wavelength interval or equivalent over which observations are made when using an infrared imaging system.
Thermal boundary: The line or boundary where the air barrier and insulation are installed in a building assembly. The air barrier and insulation should be adjacent to one another in a building assembly to prevent airflow from circumventing insulation.
Thermal bridging: Heat conduction through building components, typically framing, that are more conductive than the insulated envelope.
Thermal bypass: Air movement, air leakage or convection "cell", that circumvents the thermal barrier, is usually hidden and is the result of an incomplete or compromised air barrier.
Thermal image: A recorded electronic or printed image provided by an infrared imaging system of the thermal surface variations of an object or a surface.

Thermal resolution or Noise Equivalent Temperature Difference (NETD): The minimum temperature difference, typically specified in degrees Centigrade at 30 degrees Centigrade, an infrared imaging system is able to distinguish between two blackbody points on a thermal image.
Thermogram: An infrared picture obtained through the use of an infrared imaging system or other means of recording such images.
Thermography: The process of generating and interpreting thermal images.
Vapor barrier/retarder: A material used in the construction process to either slow or stop the movement of moisture, whether in liquid or vapor form, into or out of the building envelope or the wall structure.
Voids (insulation): Areas where no insulation has been installed.
Wind Wash(ing): Air intrusion between the insulation and the air barrier seriously compromises the effectiveness of the insulation in framed buildings. The long path exfiltration on the cold side of insulation allows moisture from the air to be deposited in the building assembly.

Appendix A (Informative)
Sample Report

(The following report can be customized to the needs of the thermographer and the type of investigation performed.)

Date
Name
Address
Address
Re: Name
Address
Address
Insurance Company:
Policy #:
Claim #:

Infrared Inspection

Name
COMPANY A is submitting the following Thermal Imaging Inspection Report for your approval. The report is for the above referenced facility. We hope the information included is self-explanatory. However, should you have questions, please do not hesitate to contact us.
Sincerely,
Thermographer/Certifications

HISTORY

COMPANY A was authorized by NAME to conduct a limited infrared investigation on DAY at TIME of the AREA OF THE INVESTIGATION of the HOME OR BUSINESS at ADDRESS in CITY, STATE, ZIP. The investigation was conducted due to concerns about INSULATION, AIR LEAKAGE, and THERMAL BYPASSES due to REASON.
The scope of work included the following components:

• A visual inspection of the damage and possible investigation of component failures contributing to the damage
• Thermal imaging of any areas of the structure necessary to complete the investigation.
• A report describing in detail the investigation, results, and conclusions.

SUMMARY OF THE INVESTIGATION

The FACILITY, HOUSE, DWELLING, ETC. was inspected with the use of an infrared imaging device that produces thermal images as video and/or digital pictures for documentation purposes. For this inspection, the following areas of the building were inspected: XXXX. Any building components suspected of being problematic are noted in this report.

Construction Design of Building

(Framing detail, wall construction detail, geographic orientation, description of surrounding buildings, vegetation, landscape, surface conditions, and microclimate.)

Inspection Personnel and Qualifications

The visual inspection, field notes, thermal imaging, video and/or digital photos for documentation were completed by (NAME).

Equipment

- Infrared Camera (make, model #, serial #, calibration date)
- Blower Door (make, model #)
- Digital Manometer (make, model #, calibration date)
- Other

Investigation Conditions

- Date and hour of test
- Ambient air temperature and relative humidity
- Conditioned space temperature and relative humidity
- Solar radiation conditions
- Precipitation
- Wind speed and direction
- Air pressure measurements and location
- Delta T
- Other relevant conditions

Standards and References

- RESNET 2006 National Mortgage Industry Home Energy Rating Systems Accreditation Standards, Chapter 8, “RESNET Standard for Thermographic Inspections”

INSPECTION RESULTS

The infrared camera reads radiation variations associated with surface temperature differences of the surfaces viewed. The particular camera used by COMPANY A has a sensitivity of X.XºC at 30ºC. In all thermal images warmer surfaces appear lighter in color and cooler surfaces appear darker in color.

The enclosed plan of the building or area under investigation is marked for the areas mentioned under Inspection Results. The legend is as follows:

- Blue marker: wall area
- Yellow marker: ceiling area
- Pink marker: floor area

Percentage of anomaly area for walls, ceilings, and floor sections marked on the building plan:
1.
2.
3.

The following are a series of Thermograms and visual pictures and an explanation of the anomaly present, why is has occurred, and necessary steps to correct the problem.
1. Picture #1
2.
3.

Picture #1
Comments:
PROBLEM
RECOMMENDATION
INSPECTOR
ASSISTANT
CORRECTIVE ACTION TAKEN

CONCLUSIONS
The following recommended repairs are given in order from high priority to low priority.
1.
2.
3.
Company A Customer B
Just Around the Corner Address
Any Town, USA City, State Zip Code
The above observations and recommendations by this inspection are based solely on the limited data collected at the time of the inspection of the property. The purpose of the thermal imaging for the inspection performed on your property is to determine if problems were present concerning air infiltration and insulation. Company A offers its opinions in accordance with recognized building practices concerning air intrusion and insulation anomalies. It is up to the owner or other designee to review the enclosed data and recommendations and make prudent judgments based on feasibility. All conclusions and recommendations are based on the data taken at the time of the inspection and no guarantee regarding additional issues of air infiltration or insulation anomalies found as a result of any other source present or not present at the time of the investigation are made. Company A hereby certifies the conclusions and recommendations expressed in this report have been formulated by a reasonable use of building science principles and professional certainty. The conclusions are also based on the data and information collected at the time of the investigation along with

knowledge, skill, experience, training, and education.
Sincerely,
Thermographer
Certifications

Appendix B (Informative)
Inspection Form for Thermal Bridging and Thermal Bypass Investigations

Time of Inspection: Delta T: Date:
Camera make and model: Square feet of anomalies:
Percent anomalies (square feet divided by surface area of insulated walls):
Comments:

Initial IR scan performed: Yes ☐ No ☐

Blower door used? Yes ☐ No ☐ Delta P:
Time of inspection: Delta T:
Initial blower door run time before start of inspection:

Thermal changes to building components:

1. Dropped ceilings: Yes ☐ No ☐
2. Furrdowns: Yes ☐ No ☐
3. Walls around showers/tubs on exterior walls: Yes ☐ No ☐
4. Walls around fireplaces: Yes ☐ No ☐
5. Attic knee walls: Yes ☐ No ☐
6. Attic hot walls: Yes ☐ No ☐
7. Skylight shafts: Yes ☐ No ☐
8. Staircase walls: Yes ☐ No ☐
9. Ceilings bordering rim and band joists: Yes ☐ No ☐
10. Ceilings bordering cantilever floor areas: Yes ☐ No ☐
11. Duct chase: Yes ☐ No ☐
12. Flue shafts: Yes ☐ No ☐
13. Interior walls with penetrations in top plates (attic air) or bottom plates (over unconditioned crawl space or basement): Yes ☐ No ☐
14. Attic access panel: Yes ☐ No ☐
15. Recessed lighting: Yes ☐ No ☐
16. Attic dropped-down stairs: Yes ☐ No ☐
17. Whole house fan: Yes ☐ No ☐

Further investigation recommended: Yes ☐ No ☐
Comments:
Signed______________________________
Date_______________________________
RESNET Certification Number________________________

Appendix C (Normative)
Method for Converting Anomalies to Insulation Grading

(Section 805.4, measurements converted to square feet.)

Grade II Example Wall section is 8 ft x 8 ft.
Area A Area B Area A: 1/2”x 96”=0.33 sqft
Area B: 1/2”x 80”=0.28 sqft
Area C: 1”x 12”=0.08 sqft
Area D: 1/2”x 12”=0.04 sqft
Area C Area E: 1/2”x 16”=0.06 sqft
Area F: 1/2”x 8”=0.03 sqft
Area G: 3”x 6”=0.13 sqft
Area D Area H: 1”x 2”=0.014 sqft
Area E
Total anomalies: 0.96 sqft
0.96 sqft / 64 = 0.015 or 1.5%
Area F Area G Area H

Grade III Example Wall section is 8 ft x 8 ft.
Areas: A B C D E Area A: 1”x96”= 0.67 sqft
Area B: 3”x16”= 0.33 sqft
Area C: 1”x16”= 0.11 sqft
Area D: 1”x16”= 0.11 sqft
Area F Area E: 1”x 8”= 0.06 sqft
Area F: 1”x 6”= 0.04 sqft
Area G Area G: 1”x14”= 0.10 sqft
Area H Area H: 1”x10”= 0.07 sqft
Area I: 2”x18” = 0.25 sqft
Area J: 1/2”x12”= 0.04 sqft
Area I Area K: 1/2”x12”= 0.04 sqft
Area L: 1/2”x64”= 0.22 sqft
Total: 2.04 sqft
Area L
Areas: J K Total anomalies: 2.04 sqft
2.04 sqft / 64 sqft =
0.031875 or 3.18%

802 Appendix D (Informative)

Thermal Patterns

This section guides the Building Science Thermographer in conducting thermal analysis on the insulated wall, ceiling, and framed floor cavities in new and existing frame construction. The emphasis will be on insulation in the building cavities that is either malfunctioning or completely missing. The anomaly locations must be designated on a drawing, a video, on visual and thermal images, or with a removable marking device for ease in locating the area for correction.

1. Different thermal patterns occur as a result of differing wall conditions, which must be identified for proper interpretation of the thermographic images. Without knowing the exact conditions you are viewing with the camera (summer/winter, inside/outside, transient state/steady state), you cannot make the proper interpretation of the thermogram. The following general descriptions of exterior walls do not take into account any obstructions, which may be within the wall cavities.

    a. The wall below with warm (lighter) wall cavity areas and cold (darker) framing materials could be one of the following:
        - Uninsulated, when viewed from outside during the heating season.
        - Insulated, when viewed from inside during the heating season.
        - Insulated, when viewed from the outside during the cooling season.
        - Uninsulated, when viewed from the inside during the cooling season.

    b. The wall below with darker (cooler) wall cavity areas and warmer (lighter) framing materials could be one of the following:
        - Insulated, when viewed from the outside during the heating season.
        - Uninsulated, when viewed from the inside during the heating season.
        - Uninsulated, when viewed from the outside during the cooling season.
        - Insulated, when viewed from the inside during the cooling season.

    c. In addition, all patterns can be reversed when solar loading has affected the cavity.
    d. Interior partition walls will normally be viewed as a consistent solid color. The framing materials in the walls will not be distinguishable as in the exterior walls. But anomalies may be visible when attic or exterior air is allowed to enter the wall cavities.

2. Insulation Installed per Manufacturer's Recommendations
    a. Wall cavities will appear warmer, compared to the framing, when

viewed from the inside during the heating season and cooler, compared to the framing, when viewed from the inside during the cooling season.
   b. Wall cavities will appear cooler, compared to the framing, when viewed from outside during the heating season and warmer, compared to the framing, when viewed from the outside during the cooling season.
   c. The wall cavity areas should be uniform in color throughout the entire cavity, from top to bottom and side-to-side.

3. No Installed Insulation
   a. Wall cavities will appear cooler, compared to the framing, when viewed from the inside during the heating season and warmer, compared to the framing, when viewed from the inside during the cooling season.
   b. Wall cavities will appear warmer, compared to the framing, when viewed from the outside during the heating season and cooler, compared to the framing, when viewed from the outside during the cooling season.
   c. Convection may be visible in empty wall cavities as a color variation moving from darker at the bottom of the wall to lighter at the top of the wall for both the cool and warm sides of the wall.

4. Missing insulation within an insulated wall will produce well-defined shapes that will be inconsistent with the type of insulation filling the wall cavity and the building envelope construction features and the anomaly will have a relatively consistent temperature variation.

5. Gaps/Misalignments are areas where insulation is partially missing or not installed in contact with the intended interior finish.
   a. These areas where insulation is missing will appear as cooler areas on the normally warm wall cavities when viewed from the inside during the heating season and as warmer areas on the normally cool wall cavities when viewed from the inside during the cooling season.
   b. On the cool side of the wall inadequate insulation will appear as a warm area when viewed from the outside during the heating season and as a cool area on the normally warm wall cavities when viewed from the outside during the cooling season.

6. There are several other possible causes for irregular variations of the thermal patterns found on a wall including convection, varying densities of installed insulation, air washing (especially with fiberglass insulation) and thermal bridging. Note that warm or cold air exfiltrating from the conditioned space can hide or mask insulation defects when viewed from the interior.

7. The contrast between the stud and insulation should be consistent with the rated R-value. Studs will show closer to the insulation shade in a low-density application but will be consistent throughout the wall.

8. Direct sun on siding can make an interior scan of a void wall appear the same as a properly insulated wall. Construction details and conditions for the test must be confirmed.

802 Appendix E (Informative)

A *further visual evaluation* of the following areas of the structure may be helpful in verifying the causes and cures of problems.

1. Is the insulation installed in the building per manufacturer's recommendations?
2. Is there an air barrier or a moisture permeable material on the cold in winter side of the wall and is there a possibility of subsequent condensation and damage to wall components at this location?
3. Is the air barrier aligned with the thermal barrier throughout the building?
4. Is there an air barrier at floor joists meeting the attic or garage or where there are exposed insulation edges?
5. Is there slab perimeter insulation when required by code or program?
6. Are there air and thermal barriers at the rim and band joist (when possible to determine)?
7. Is there an air barrier behind the tub/shower and fireplace?
8. Are knee walls, hot walls, and skylight shafts insulated and have sheathing applied?
9. Is the framed floor insulation aligned properly (cantilever or over a garage)?
10. Are plate penetrations and flue shafts sealed?
11. Are the attic access panels, drop down stairs, and doors fully insulated and gasketed?
12. Do dropped ceilings, HVAC chases and furrdowns have air barrier aligned with the insulation?
13. Are recessed lighting fixtures air sealed and insulated?
14. Is there an insulated and gasketed cover on any whole house fan?
15. Have the common walls between multifamily units been air sealed?

Appendix F (Normative)
Recommended Course Content Building Science Thermographer training

Overview of Section 802 of the RESNET Standards (10% weight)
Qualities of acceptable data (6% weight)
Contents: Section 802.8
Accurate
Meaningful
Specific components
Specified conditions

Infrared camera basics (6% weight)
Basic Camera Parts
Controls
Menus
Storing Data
Range and Span
Thermal Level
Pixels
Color Palette
Hands-on practice

Heat transfer basics (8% weight)
Thermal capacitance
Conduction
Convection
Radiation
State change

Radiometric basics (6% weight)
Emissivity
Reflected background
Spatial and measurement resolution
Good measurement principles
Hands-on practice

Principles of building inspections (12% weight)
Defining the scope of service
Defining building type and components
Fundamentals (10% weight)
Conduction inspections
Seasonal differences
Interior vs. exterior

Patterns
Challenging situations
Air leakage inspections (8% weight)
Pressure dynamics
Using blower doors
Air leakage patterns

Windows (6% weight)
Reflectivity issues
Argon depletion
Industry standards relating to IR and building inspections (8% weight)

Report and analysis software (8% weight)
Managing data
Analysis functions
Creating reports: Section 802.8, 802 Appendix A
Course test

Field Work (12% weight)
The following will guide the inspection for *each* building. Buildings should, whenever possible, be representative of common building types:
Measuring and documenting conditions
Visualizing the building
Communicating with the occupants/owner
Modifying building conditions, as needed
Adjusting the imaging system for optimum results
Locating insulation
Exterior inspections
Interior inspections
Insulation types
Natural air leakage conditions
Using thermography with the blower door
Locating air leakage
Depressurization (recommended)
Pressurization (optional)
Documentation of findings
Imagery
Supplemental data
Review and discussion of work