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Successful Warm-Weather Infrared Inspections

Introduction

As a thermography instructor I have, on occasion, overheard other thermographers questioning the merits of using infrared for warm weather inspections. There seems to be this perception that thermal imaging can only be used successfully for cold weather work. Many of these discussions, understandably, tended to emanate from courses in more northern climates.

The reality is that thermal imaging can be used practically year round as a supplemental tool for energy audits in many types of climates, given the right conditions and equipment. Since I live in central Vermont, though, much of my IR experience in buildings (like that of my northern colleagues) has come from cold-weather work. So it was last summer, during a series of field trips throughout Vermont that I set out to see firsthand how successfully this technology could be applied to warm weather inspections. I was quite pleased with the results.

Infrared for Building Applications

All objects radiate some amount of infrared energy. Generally speaking, the warmer something is, the more it radiates. An infrared camera detects this radiation and converts it into a thermal image, displaying the various apparent surface temperatures as different colors or shades of gray to indicate varying intensities of heat energy (brighter = hotter, darker = colder on most palettes).

Many infrared systems are able to discern temperature differences of as little as 0.05°C (.09°F), sensitive enough to detect thermal patterns on the surfaces of walls in buildings that can reveal sub-surface details such as framing members or insulated cavities. Although most cameras display temperature values, this feature is typically not required for buildings work. Rather what we as building thermographers are most often interested in are the qualitative differences in thermal patterns on the surfaces of walls that reveal sub-surface problems such as missing insulation or areas of air leakage.

While infrared cameras are relatively easy to operate, it is the task of interpreting the image, to determine whether an anomaly really exists in the building system that turns out to be the most challenging aspect of this technology. Inspecting buildings with thermal imaging is arguably one of the more complicated applications of IR, requiring qualified operators that have proper infrared training, a solid knowledge of building systems, and a keen understanding of thermodynamics.

What Type of IR Camera Can Be Used

With a few exceptions, pretty much any infrared system sold for building applications can be utilized for warm weather inspections. For best results, though, it is recommended that the thermal imager meet at least the following minimum specifications for conducting a warm-weather building inspection:

- Thermal sensitivity of 100 milliKelvin (mK) (0.10°C/.18°F) or better
- 70mK (0.07°C/.13°F) or better can be very helpful
- A minimum 120x120 detector array
- Wide angle or normal lens
- Rugged and user friendly
- Digital image storage with post-processing and report software

The most important parameters to consider are those of thermal sensitivity and detector array size. For thermal sensitivity, the lower value indicates a more sensitive camera that can detect smaller temperature differences.

For example, a 70mK thermal sensitivity translates into the camera's ability to see a 0.07°C (.13°F) temperature difference on a surface. When large temperature differences across a building envelope exist, say during very cold mid-winter conditions up north, this is less of a concern as most anomalies in a wall typically jump right out at you when inspecting from inside a home.

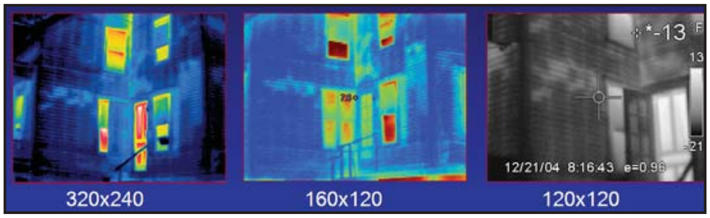


Image 1. All three resolutions seen above are sufficient for residential infrared inspections and provide the thermographer with enough detail to locate areas of missing insulation or air leakage.

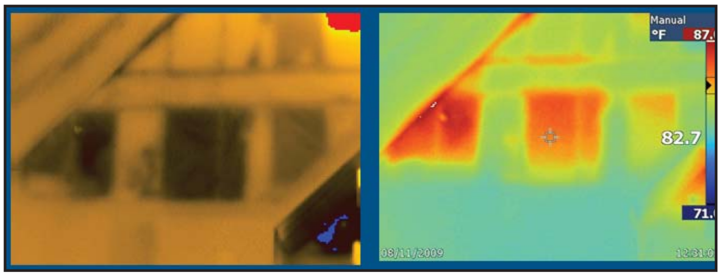


Image 2. Missing insuLation that shows up as relatively cooler areas during the winter when it is colder outside (darker sections, left) will appear to be hotter during the summer and show up as a warmer area (right).

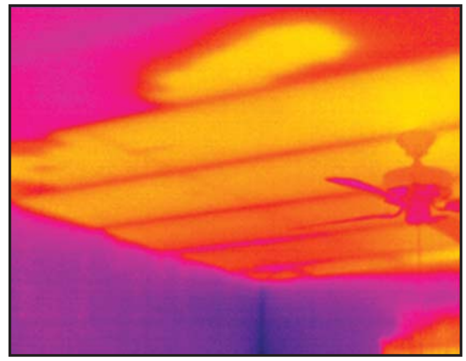
However, when the inside-to-outside temperature differences are closer together, having a system with a lower (that is, better) thermal sensitivity value can pay off considerably. This greater thermal sensitivity allows the thermographer to work in more marginal conditions and ultimately inspect more hours and days in a given year when smaller temperature differences make it more challenging to find anomalies.

As for the size of the detector array that one should consider, any system between 120x120 and 320x240 is fine for residential work (see Image 1). Larger buildings might require a larger detector array (or the option for a telephoto lens). Generally speaking, for most residential applications, anything above 320x240 is not necessary, but would certainly work well. Low-resolution systems, those with array sizes of less than 120x120, are simply not sufficient. In fact, the new RESNET infrared guideline sets a thermal sensitivity ceiling of 100mK and a minimum detector array size requirement of 120x120. Most, but not all, cameras designed for building applications meet these requirements, so be sure that you understand what you are getting before your buy.

Conditions for Warm Weather Inspections

Just as with cold-weather inspections, you need a temperature difference across the building envelope to drive heat transfer and generate thermal patterns in a wall system. Industry standards such as the American Society of Testing and Materials (ASTM) C 1060 and the new RESNET infrared guideline for buildings state at least an 18°F/10°C (inside surface to outside surface) temperature difference for conducting insulation inspections.

It is also important to remember that during warm-weather inspections, where it is hotter outside and colder inside, the direction of heat flow (assuming steady state conditions) is opposite of what one encounters in cold weather. The temperature of a cavity with missing insulation that appeared cooler during a wintertime inspection will now be hotter during warm weather, again assuming steady-state conditions (see Image 2).



Cooler ceiling joists and warmer bays indicate areas of missing or misplaced fiberglass insulation during a warm-weather inspection.

To check for air leakage, ASTM E 1186 states a 9°F (5°C) difference is needed while the RESNET IR guideline says a minimum of 3°F (1.7°C) is sufficient. In my experience, the proposed RESNET standard better reflects the true capabilities of modern infrared systems, especially those with 70 mK or lower thermal sensitivities.

Obviously, the greater the temperature difference you are working with, the better your ability will be to see both insulation and air leakage issues in a building any time of year. Success, of course, is still very dependent on the many environmental conditions encountered as well as the building construction type.

Inside Versus Outside

During warm weather inspections, it is typically best to focus your efforts on the interior. Working from the exterior can be very difficult unless it is something you plan to do first thing in the morning or late at night. Daytime inspections from the outside during warm weather conditions typically reveal little as the entire exterior is saturated by solar loading. Regardless, a narrow span setting and a high-contrast color palette might be needed to help define thermal patterns on the surface. If your particular infrared system has the ability to manually adjust level and span in the field, this can be very helpful because the "auto adjust" may not be adequate in some situations.

This is especially true if you are working with a masonry building as seen in Image 3 below. Additionally, because most building IR cameras now only have LCD displays (and not viewfinders), seeing what is on your screen outside in broad daylight is often a challenge as well.

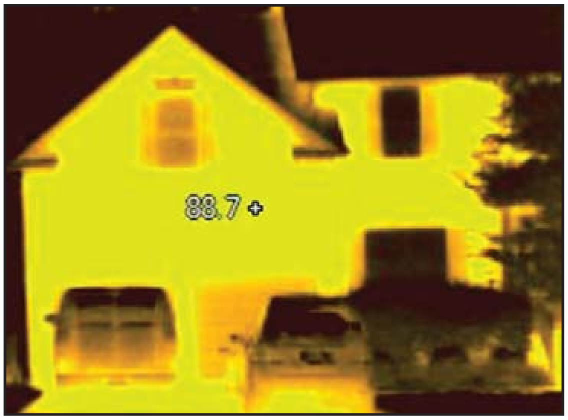


Image 3. A residential home in North Carolina with brick fascia that has been saturated by solar loading.

Regardless of the time of day, always remember to keep the exterior in mind, noting where the sun has been and how that might have impacted thermal signatures on the inside. Thanks to the affects of the sun you will also encounter issues related to differences in the thermal capacitance of building materials (wood, brick, stucco, concrete) that can create confusing patterns at anytime during the day or night.

The "Swing" Seasons: Spring and Fall (and Sometimes Summer, Too)

During the so-called swing seasons of spring and fall (and sometimes summer depending on where you live) it is common for the building thermographer to start off their inspection day in 'winter conditions', go through 'spring/fall' by mid-morning, and finish up in 'summer mode' by afternoon. This is especially true during the summertime in more northern climates where outside temperatures can be around 45°F (7°C) at 7:00 a.m., warm up to 70°F (21°C) by 11:00 a.m. and hit 85°F (29°C) by afternoon. If the interior temperature stays somewhat consistent at 70°F throughout the day, the direction of heat flow (and the pattern you are looking for) will certainly vary depending on what time you show up! This also reinforces the importance of documenting the environmental conditions you are encountering at the time of inspection. Air temperature, sky conditions, and wind speed are just some of the important data points to record for your report and will certainly help with your analysis.

The sun's position on the building can also create a situation where one encounters eastern and southern facing walls showing summer-like patterns while the western and northern facing walls are still in winter mode. At this point determining whether all the wall cavities in a building are either empty, full, or some combination of the two, can be difficult.

The worst cases are cloudy days when the inside-to-outside temperature difference is less than a few degrees and there is no solar loading to assist with thermal transfer through the wall. Inspections during these times are typically among the most challenging that you will ever do; sometimes, quite simply, it does not work.

As an example, I was out one day last summer in northern Vermont conducting field training with a group of thermographers from a state weatherization agency. We pulled up to a house that had all of the windows open on a 68°F, cloudy day. Good luck! It took a few minutes to convince the somewhat reluctant homeowner why, in August, he needed to close his windows and turn on the furnace. Both ASTM C 1060 and RESNET recommend that there be a minimum temperature difference of 18°F (10°C) between the interior and exterior wall surfaces for at least four hours prior to testing. Even though these conditions were far from ideal, this was the only chance that we had to work together due to scheduling. We eventually did spot some anomalies at this location, but it was certainly not a preferred situation. Had this been an actual infrared inspection for a client, the best option would likely be to re-schedule, unless you could artificially alter the inspection conditions as we did (something the RESNET guideline also suggests).

Solar Loading

During cold-weather inspections, thermographers always need to be aware of solar loading and its effects. Thermally charged exterior walls can reverse thermal patterns seen on the interior of a building. In many cases this pattern reversal can be misinterpreted as an uninsulated wall when, in fact, solar loading has simply reversed the direction of heat flow causing the studs to warm up and appear hotter than the cavity; a classic pattern of an uninsulated wall in cold-weather conditions.

It is common to encounter a situation where the inside ambient temperature may be warmer than outside but, because the sun is heating the exterior wall surface, it is now hotter than the interior, sending heat flow in the opposite direction of what the thermographer is expecting.

These issues with solar loading are also a concern when conducting warm-weather inspections, although, in some cases, it can actually help thermographers more easily identify problem spots in a building.

This infrared shot (see Image 4) of an east-facing wall was taken mid-morning on a mild summer day and shows apparent missing insulation in the exterior wall cavity (lighter, brighter area above the window). The inside temperature was slightly warmer than outside, but because the sun had been charging the wall for well over an hour, heat transfer was moving from outside to inside. Where there was less insulation, there was a greater amount of energy passing through the wall revealing an empty cavity adjacent to ones that were apparently full.

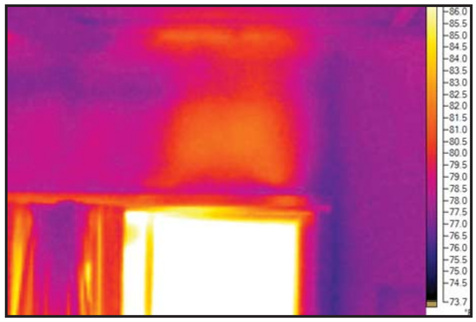


Image 4. This photo was taken midmorning on a mild summer day and shows apparent missing insulation in the exterior wall cavity.

Thermal Capacitance

Thermal patterns associated with the thermal capacitance of building materials can create confusing patterns during both warm and cold weather inspections. Both ASTM C 1060 and the RESNET IR guideline state that the effects of solar loading can last for up to three hours on light frame buildings and as much as eight hours on masonry structures. That is the amount of time recommended for direct sun to be off a surface before conducting a thermal inspection. A tall order any time of the year, this can be especially troublesome during warm-weather.

In this example (see Image 5), captured on the outside of a building during warm weather conditions, the framing members appear to be hotter than the cavities (a classic pattern of an uninsulated wall in the cooling season). The relatively higher thermal capacitance of the wood studs, however, could be another explanation of why we are seeing this particular thermal pattern and the wall may in fact be fine. Depending on the amount of moisture that is present, wet building materials react even more slowly to temperature changes, appearing relatively cooler in the morning hours before the sun has charged the surface and warmer in the evening after it has been warmed by the sun and air temperature throughout the day.

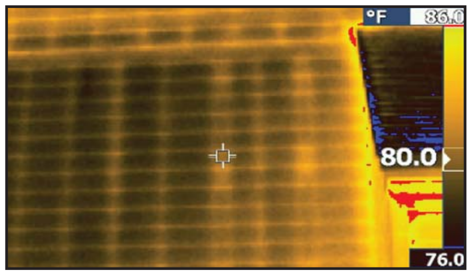


Image 5. The framing members appear to be hotter than the cavities (a classic pattern of an uninsulated wall in the cooling season).

This is also seen in concrete foundations. The uninsulated concrete wall (see Image 6) appears to be warmer than the wood siding of this building; a pattern that you often encounter when interior temperatures are warmer than outside. Yet in this example the outside air temperature was about equal to that of the interior. The foundation likely appeared warmer simply due to its higher thermal capacitance, not because of any additional heat transfer through the wall.

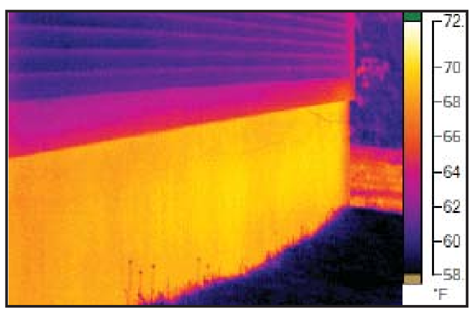


Image 6. In this example, the outside temperature was about equal to the inside temperature.

Exterior Surface Characteristics

I mentioned earlier that inspections from the exterior are generally not practical on a sunny day in warm-weather conditions. At the very least, however, you should still conduct a visual inspection of the exterior to discern the position of the sun and note any variances on the exterior surface. Are there differences in siding color? Is a soffit overhang or an adjacent building casting a shadow on the wall? Are there trees that are shading a section of the wall? All of these, given enough time to heat, can affect interior thermal patterns.

This infrared image (see Image 7) was taken last summer in northern Vermont from inside a residential home. The thermal pattern of apparent missing insulation between the roof joists is clearly seen at top with the warmer bays and relatively cooler framing members. The wall, however, showed a somewhat more confusing pattern that was initially difficult to interpret.

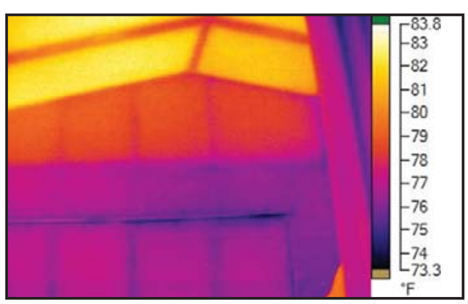


Image 7. The thermal pattern of apparent missing insulation between the roof joints is clearly seen at the top.

The top quarter of the wall appeared to be warmer than the bottom part, but both were still cooler than the ceiling. Was there missing insulation here and we were seeing the level? Varying wall thicknesses? Different angle of the sun? Possibly, but nothing was discernable to any degree of confidence…at least from the interior!

Instead it turned out to be different colors of siding (painted vs. unpainted wood) as seen in Image 8 from the outside. The darker painted surface absorbed more of the sun's thermal energy, heating up the painted portions of the wall more than the unpainted areas.

Image 8. Was there missing insulation here?

Always Use a Blower Door

Regardless of the season, using a blower door is highly recommended. As with cold-weather inspections, operating a blower door during warm-weather scans enhances air leakage patterns that are not typically seen with the natural stack effect. It is also beneficial when you encounter a situation where the inside-to-outside temperature difference is marginal. The blower door helps drive warm or cool air movement patterns across the envelope, making "swing season" and summer inspections both possible and practical.

Typically depressurizing to about 20 Pa is sufficient and provides enough of a draw to move air so its effects can be seen thermally. It can take up to a few minutes (sometimes more) for the pattern to emerge, but as the blower door is running watch for sources of warm air infiltration. This approach certainly works for air leakage and can possibly help reveal insulation patterns that are not seen naturally.

The use of a blower door helps make summer inspections possible.

During warm-weather inspections, air leakage sites can also be affected by both warm and cool air. You are likely to encounter both types of thermal patterns (hot and cold) depending on the source of the infiltration. Warmer outside air or exterior surface temperatures (such as those sources with solar loading or coming from the attic areas) are going to appear warmer than the surrounding wall surface.

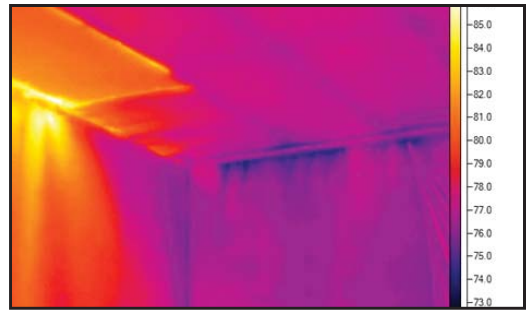


Image 9. Hot and cold thermal patterns appear next to eachother in this photo.

Air infiltration from the north side of a house or entering from the basement will appear to be cooler. In many instances it is likely that you will see both right next to each other in the field of view, indicating two potential air leakage pathways! (See Image 9)

Warm-Weather Inspections Can Be Effective

With the right training and a keen understanding of the conditions, thermal imaging can be utilized very successfully for warm-weather inspections. While having an infrared camera with the right specifications is also important, there is no substitute for proper training and experience.

When you do conduct a warm-weather inspection, always plan on working either inside only or at night/early morning on both sides of the wall for the best results. Keep in mind that whatever time you choose, if you are aware of the sun's impact on the structure, you can use solar loading to your advantage to help bring out thermal patterns in a wall. Knowing whether you are in winter or summer mode is critical so continually ask yourself in which direction is heat transfer occurring.

Helping you throughout all of this is the use of a blower door, a building thermographer's best friend. Use it to drive air movement and create associated thermal patterns that are not necessarily seen in natural conditions.

So have at it! If you are a thermographer who lives in a hot climate, you likely already know how great a tool IR can be for warm-weather inspections as it helps you define thermally deficient areas where improvements can be made to reduce cooling costs. For thermographers like myself from northern climates, the implication here is that we can conduct successful scans throughout the year, including spring, summer, or fall. No longer do we need to be confined to the cold, winter months for our infrared work in buildings.

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