Moisture Investigations Using Thermal Cameras

By Lew Harriman

Thermal cameras have proven to be useful tools for investigating moisture problems in structures. Moisture influences how building materials respond to temperature fluctuations in their environment for two common reasons:

1. **Thermal Inertia.** Dry parts of a building material respond more quickly to temperature changes than wet parts of that same material because moisture adds thermal mass.
2. **Evaporation.** Moisture from damp parts in a dry building is nearly always evaporating. Heat to "power" that evaporation comes partly from the material itself. Therefore, as moisture evaporates, the result is a slightly reduced surface temperature.

To investigate moisture problems in a building, these phenomena can be measured and displayed as images in real time by modern infrared (IR) cameras.

Interior Moisture Investigation

"Figure 1" (*see below*) shows a classic example of an IR image that helps locate areas of suspected excess moisture. The IR camera measures the heat coming from all surfaces and displays surface temperatures as one of 256 shades of gray (darker grays represent cooler temperatures). In this case, moisture from a flooded floor has entered the gypsum wallboard by capillary suction. As that moisture evaporates, it consumes some of the heat in the wallboard, slightly reducing its surface temperature.

Although thermal images are helpful, it is important to remember there are many, many reasons other than moisture that cause surface temperature differences inside buildings.

For instance, in that same water-damaged building, "Figure 2" (*see below*) pictures a thermal pattern that suggests moisture in the ceiling, and this image supports that expectation—until the IR investigator realizes the pattern is caused by cooled air leaving the four-way supply air diffusers.

Similarly, "Figure 3" (*see below*) is a thermal image showing a pattern that suggests rain water leakage through an exterior wall. However, the dark areas do not indicate moisture. Rather, they show evidence of cool outdoor air being pulled into the ceiling through construction joints.

Since all temperature differences are not necessarily caused by differences in moisture content, investigators cannot escape the use of moisture meters. While these devices have significant shortcomings, they are absolutely necessary to assess the relevance of surface temperature differences during moisture investigations.

"Figure 4" (*see opposite page*) helps illustrate this point by showing the surface temperatures of a water-damaged ceiling. The 37-year-old caulking putty sealing the drain of the tub/shower combination in a bathroom above this ceiling was slowly leaking, which the homeowner (this author) realized when the ceiling began to show water stains. Fortunately, the wife of the homeowner reminded him that he—a building science consultant—has always cautioned his clients to never assume that a temperature difference in a thermal image is caused by evaporating moisture, until it is checked with a moisture meter.

After such a useful spousal reminder, the investigator measured and documented the moisture content of the ceiling (*see "Figure 5," opposite page*). That photo shows the current best practice for

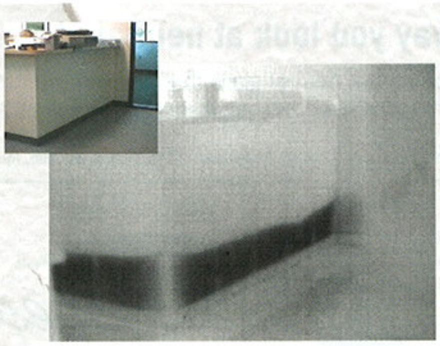

Figure 1: Classic post-flood water damage.

Figure 2: Supply air diffusers.

Figure 3: Cool air infiltration.

confirming the results of thermal imaging. The line of adhesive notes is annotated with moisture content readings from a capacitance-based moisture meter, using its wood moisture equivalent (WME) scale. Note that at the center and right side of the image, meter readings confirm the presence of elevated moisture. However, readings at the left end of the line of notes show that the temperature difference there has nothing to do with moisture. Those cool surfaces are caused instead by cool air infiltrating through the building (cool air was being pulled by the stack effect in a long construction joint immediately above that location).

So, while thermal imaging is an immensely helpful tool for locating suspect areas, the technology does not, by itself, provide certainty. Thermal images must be accompanied and supported by moisture content readings before one can reach robust conclusions.

Exterior Moisture Investigation

Turning to the exterior of buildings, one now-classic use of thermal imaging is for assessing the extent and location of water leakage into buildings clad with exterior insulation and finish systems (EIFS).

The installation of EIFS has advanced a long way since the 1980s, when some applications were the subject of widespread and costly litigation due to moisture infiltration. Nevertheless, even today, musty odors in EIFS-clad buildings sometimes beg the question of whether rain is leaking into the building. Thermal imaging is well-suited to assist the investigator in locating the water-penetration points in EIFS systems—provided the weather cooperates, trees and shrubs do not block the camera's view and any temperature patterns caused by moisture are not erased by the sun.

"Figure 6" (*see page 14*) is an example of water infiltration into an EIFS-clad building. The image was taken during the winter, on the east face of the building, immediately after sunrise. The radiant heat of the sun very quickly warms the surface of the EIFS—a cladding that excludes radiant heat from the building by reflecting or holding solar heat on its surface. Here, moisture has leaked into the system, and is illustrated by the greater thermal mass of the damp insulation (which keeps the surface slightly cooler than the surrounding dry insulation). Eventually—probably within an hour or less of sun exposure—the thermal patterns on the surface will be gone. The sun will heat the entire wall to nearly the same temperature, regardless of the differing amounts of moisture under the surface.

"Figure 7" (*see page 14*) shows another key aspect of exterior investigations: the importance of keeping track of the overall thermal environment, plus the sun's position as it creates shadows that move hour-by-hour. Meter readings here confirmed there is moisture below the corners of the window. But the pattern at the base of the wall is simply splash water from snow melting from the roof above. Without the visual image, it would be easy to assume—incorrectly—that the cool spot on the wall beside the window is caused by sub-surface moisture. The reality, though, is that the visual image shows the cool spot is simply a shadow cast by the light fixture on the adjacent wall.

Once again, an investigator cannot be 100-percent certain the shadow was the only cause of the cool surface pattern until the moisture content at that exact location is measured. In most cases, however, the difference between moisture and sun shadows will be readily apparent—as long as the investigator

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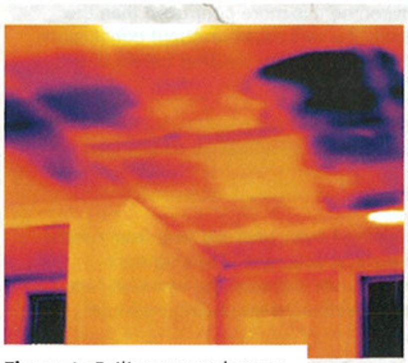

Figure 4: Ceiling water damage.

Figure 5: Ceiling moisture measurements.

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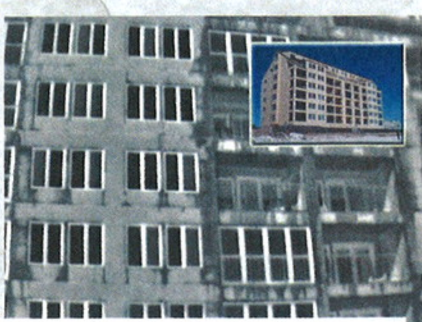

Figure 6: Moisture in an EIFS-clad building.

Figure 7: Three patterns—sun shadow and splash water, along with moisture, in EIFS.

looks carefully at the entire situation and remains aware of the time of day and position of the sun and its shadows.

This underscores a key point. When you go outside the building, you are entering a "thermal jungle." The sun, clouds, rain, nearby trees, dark night sky and nearby buildings all collide in a complex thermal mixture of time-dependent influences that affect the surface temperatures of any building exterior. So, again, moisture meters are essential.

How Much Documentation?

Photos of moisture readings help clarify the meaning of thermal images and both record results and support conclusions with greater certainty and clarity. Beyond moisture readings, any report should document the time of day; air temperature; wind speed; current and past weather; and the face of the building undergoing thermal imaging.

That said, such technically robust documentation is expensive and not always essential. Often, the only need is to plan a plausible next step in locating and fixing a moisture problem. An oral report, plus a few thermal images, may be the only documentation required for further investigations.

The cost of a robust and reliable report (one from which an equally qualified expert could later reach the same conclusion as the original investigator) often triples or quadruples the cost of a thermal imaging project. Detailed written documentation is usually requested only for the nastiest and most costly construction defect litigation. Even in those situations, the monumentally complex construction contract issues often trump building science, weather and the laws of physics. Actual measurement-based evidence is not always welcome or useful to legal professionals.

In Conclusion

With regard to moisture investigations, don't be distracted by the absolute temperatures and dramatically colored images available from thermal cameras. Instead, focus on understanding a building and its thermal environment, and on interpreting the patterns shown by those thermal images. Finally, keep in mind the importance of confirming any initial hypotheses with moisture meter readings. JNIBS

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Infrared (IR) Camera Savvy for Moisture Investigations

More pixels are better, and so is a wide field of view. Low-cost cameras often have IR sensors with very few pixels and narrow lenses, e.g., arrays of 60x60 or 100x100 and a narrow-view, focal length of 35 mm and above. Images from low-resolution, narrow-view cameras are rarely detailed or wide enough to show the patterns useful for locating subtle moisture problems. Sensors with 320x240 pixels in a camera with a wider-angle lens (focal length of 24 mm or less) have proven much more useful for moisture investigations.

Lower thermal sensitivity provides better images. The most useful metric to predict the probable clarity of a thermal image is a camera's "thermal sensitivity." The lower the thermal sensitivity, the better the image. Thermal sensitivity of 0.07°C or less has become a minimum requirement for cameras used in managing water damage restoration (when water sources and locations are better understood). When the investigation is "forensic" in nature (when either the path or the source of moisture is not well understood), however, cameras with a sensitivity of 0.05°C or less produce much sharper and more useful images. *[Editor's Note: Degrees measured in Celsius or MilliKelvin are the most commonly used metrics by camera manufacturers.]*

Moisture meter readings are essential. Without meter readings to support the thermal images, any conclusion remains an educated guess. Such conclusions may still be correct–but they are much less certain to be so.

Outdoor moisture investigations are more complex than indoor investigations. The indoor thermal environment is more controlled than the outdoor environment, so there is much less confusion about the source of surface temperature patterns. Be very cautious about conclusions based on outdoor images. The building, its environment and orientation–along with the time of day or night, plus the weather before and during the imaging session–should all be well-documented.

Thermal images only show surface temperature patterns. Keep in mind that there are many reasons for surface temperature differences other than moisture, as shown by the images in this article.

Don't focus on temperature accuracy. The infrared energy coming from any surface is the sum of its emitted heat, plus any heat from nearby sources that may be reflected towards the camera by that surface. In spite of the implied two-decimal-place accuracy of temperature measurements in thermal images, the absolute temperature values measured by a camera cannot be accurate because the emissivity and reflectivity of any surface are never known during building investigations. It's the thermal patterns that provide answers during moisture investigations–not the accuracy of the temperature measurements.