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Technology

Staying on the Cutting Edge

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Restoration Dry Cleaning Claims

Moisture

Using Surface

By Lew Harriman

Fig. 1 Pipe Break in Low-rise Office Condo

A small water heater pipe break soaked about 7800 square feet over a weekend. Water seeped up walls through capillary action.

EDITOR'S NOTE: The actual infrared image contrast in these photos was sharpened for magazine printing. The images obtained on the jobsite with this technology will not be of the same quality depicted here.

"Are there any other sources of water?" and "Did you dry it all out?" At the beginning of the job, you always ask the first question. At the end of the project, the client wants a convincing answer to the second. In the past, both questions have been difficult to answer with full confidence.

Incomplete drying sometimes leads to drastic ethical and economic consequences. According to David Dybdahl, CPCU, ARM, the president of American Risk Management Resources Network, during 2002, the *uninsured* mold risk in the U.S. totaled $12 billion . . . roughly the same value as the total for all fire claims for that year.[1] To be clear, $12 billion is the value of mold claims which were *excluded* from policies—disallowed by insurance companies during 2002. So in 2003, these damages have become a current economic risk to the owners, builders, architects, engineers, consultants and restoration contractors involved with the buildings.

To help reduce such economic risks and to make drying decisions in a more consistent way, high-resolution infrared thermal imaging cameras can be a useful addition to the moisture detection tool kit.

Technical Basis of Thermal Imaging

All objects in the universe radiate energy in many wavelengths to all other objects in the universe. Part of that energy can be detected by

Detection
Temperature Patterns

infrared sensors. Combine tens of thousands of infrared sensors into a single chip, and then recode all their signals as varying intensities of visible light. The combined and recoded signals can then be assembled into a video image that shows a pattern of surface temperatures. Often, these patterns are caused by differences in moisture content.

To understand how thermal imaging relates to building inspections, it helps to understand some characteristics of infrared waves and their behavior in air.

Gamma rays and x-rays are very short. Radio and TV waves are very long. Our eyes function in a narrow slice of wavelengths near the middle of the spectrum. Human eyes only see wavelengths between 0.4 and 0.78 microns (400 to 780 nanometers). Infrared waves are much longer and lower in frequency than visible light—they vary from 1.0 to 24.0 microns in length.

Within the infrared band, the waves *most* useful for examining thermal patterns in buildings are those between 7 and 14 microns in length. These make up a large portion of the heat emissions from surfaces which have near-ambient temperatures. Also, the gases which make up air—nitrogen, oxygen and water vapor—*don't* absorb these wavelengths very well. So these 7 to 14 micron waves can travel

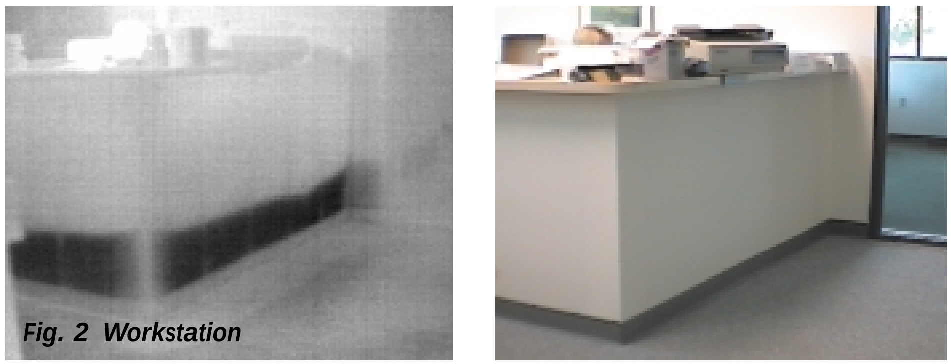


Fig. 2 Workstation

Water evaporating from the gypsum board slightly lowers the surface temperature, a pattern that is obvious when viewed through a high-resolution infrared video camera.

Fig. 3 Chair and Carpet

The thermal pattern clearly indicates that moisture remains in part of the carpet and in the lower portion of the wall

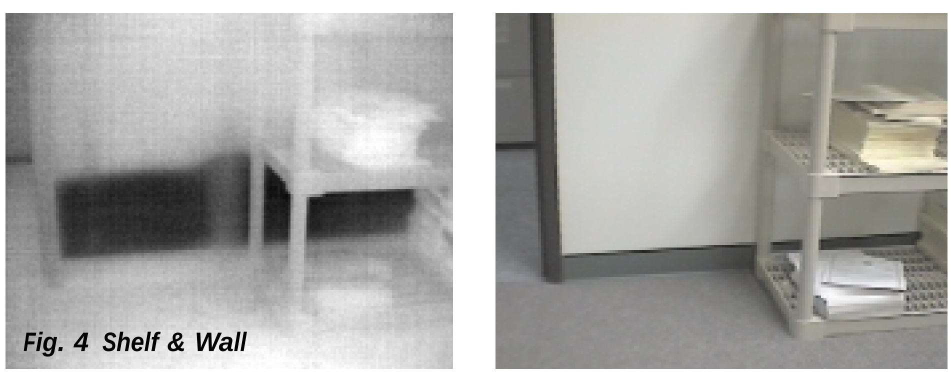


Fig. 4 Shelf & Wall

The visual image shows no indication of water damage. But the high-resolution infrared image allows the inspector to quickly identify suspect areas.

from a surface through the air to the sensor without much interference. Finally, the amount of emission in this particular range of wavelengths has a very strong dependence on temperature—small differences in surface temperature generate large differences in the amount of infrared energy that the surface emits.[2]

So the 7 to 14 micron infrared signal is relevant and strong, and it can indicate small temperature differences clearly.

Thermal Images are Not X-Ray Images

As you look at the images in this article, it's important to keep in mind that thermal cameras do not see moisture, nor do they actually "see inside the wall." They only show differences in surface temperature. To make an infrared camera useful for moisture inspection, the inspector must be able to interpret the origin of the thermal differences it shows.

Fortunately, in water-damaged buildings there is no question that significant moisture differences exist. With such large moisture differences, it's relatively easy to use thermal patterns to locate that moisture.

How Moisture Content Differences Create Surface Temperature Patterns

Excess moisture creates surface temperature differences in five ways. The first is the most common and most visually apparent in water damage situations:

1. **Evaporation.** Moisture cools the surface as it evaporates, so that moist areas appear cooler than dry areas. Figures 2 through 6 show this effect clearly. Water that soaked the carpet also wicked-up through the gypsum board walls. As that water evaporates, it pulls heat from the wall, creating a darker pattern in the moist areas.

2. **Thermal lag.** Water is dense, so it slows the thermal change of a porous material when ambient temperatures change. Moist areas appear cooler when the rest of the surface is warming up, or warmer when the rest of the surface is cooling down.

3. **Differences in thermal conductivity.** Moisture increases the density and therefore increases the heat flow through porous materials. Moist areas appear warmer than dry areas on the cooler side of the wall, and cooler than dry areas on the warmer side of the wall.

4. **Conduction.** Water cools or warms a surface by direct contact when water is flowing, dripping or moving by capillary suction away from a warm or cold source.

5. **Radiation.** If very warm or very cold water is present inside a wall, the outer surface of that wall can be changed as it absorbs heat from or releases heat to the internal water by radiation.

All of these processes are happening at the same time in the same building. But evaporative cooling usually dominates thermal images of moisture after a flood, fire or other water event, especially after the building has been stabilized and the source of the water eliminated.

Sources of False Signals

It's useful to remember that most thermal patterns on walls are not the result of moisture differences, and not all moisture differences produce thermal differences at the surface of the material. Six factors can create misimpressions:

1. **Cold inside corners.** Inside a room, air does not flow easily into corners. In almost all cases, this fact means that corners will appear cooler than the rest of the wall. This effect often creates a false impression of moisture problems in that part of the wall or ceiling.

2. **Sunlight shadows.** As the sun shines on the outside of the building, it slightly heats the inside surface. But if a tree outside blocks that sunlight, part of the wall will be cooler. This temperature difference can look like moisture when viewed from the inside of the building—where the tree itself is not visible.

3. **Electrical heat sources.** All walls hide electrical components, which generate extra heat. This can look like moisture in a situation where moisture appears warmer than the rest of the wall.

4. **Air infiltration/exfiltration.** Air constantly flows into and out of walls, changing both internal and surface temperatures. So insulation voids create thermal differences that can look like moisture differences when the inspector is not alert to that possibility.

5. **Layers and gaps in the wall.** Often, moisture-related temperature differences are "flattened-out" because the moisture is located inside the wall and not near its surface. Consider a brick exterior wall with an air gap for water drainage behind the brick facing. If there is excess moisture in the sheathing behind the air gap, the thermal pattern it generates is not likely to be reflected all the way through the air and through to the exterior surface of the brick.

6. **Modified images.** Digital enhancement of images is legitimate and common in thermography. False-color palettes are used to visually group areas that have similar temperatures. Also, contrast is sometimes enhanced to make a hazy pattern more distinct. And, of course, human nature guarantees there will always be a few thieves who would like to create a false impression of moisture problems to encourage business. But for moisture inspection, color-modified images tend to confuse rather than enlighten the client. So most inspectors prefer to

use grayscale images. The most certain way to avoid fraudulent images is to hire inspectors you trust.

Best Practices

To avoid misunderstandings, three basic practices are useful:

- **Confirm findings with moisture meters**
  Most inspectors use moisture meters to confirm any differences in moisture content suggested by an infrared image. The best inspectors also record the moisture content readings for both “dry” and “wet” portions of material in the infrared image.
- **Document the location of infrared images using visual images**
  One of the major benefits of using infrared cameras is visual documentation of drying completion. It’s very useful to record visual images of the initially affected areas so these same areas can be quickly found later—during the outgoing inspection.
- **Record locations of images on building floor plan**
  A simple sketch of the building’s floor plan is also helpful to indicate where each image was taken. And when as-built, dimensioned floor plans are available, marking the image locations and angles on a copy of the plans provides an even clearer picture of the extent of the problem and completeness of the solution.

Infrared Video Camera Characteristics

Camera costs vary between $10,000 and $60,000. But the most expensive cameras are not always the best for moisture inspection.[3] The most useful features include: more pixels, more lenses and visual video capability.

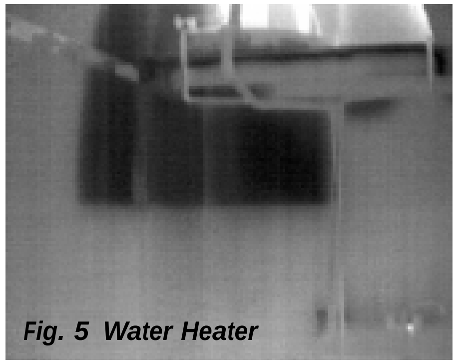


Fig. 5 Water Heater

This new heater replaced the one that broke and soaked the building. This pair of images shows that layers in a wall can hide the thermal patterns that indicate moisture. Moisture does not cool the tile surface low enough to create a thermal pattern.

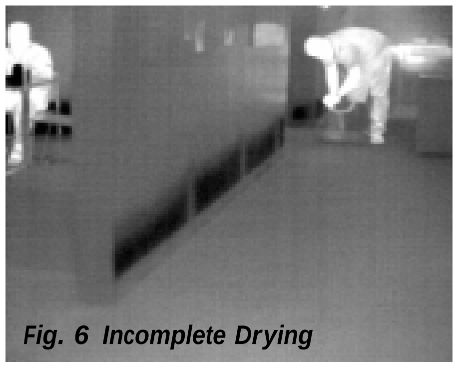


Fig. 6 Incomplete Drying

Technicians pack up the drying equipment because it appears the floor is dry. But the thermal pattern suggests there is more moisture that must be removed to ensure that mold does not grow inside the wall.

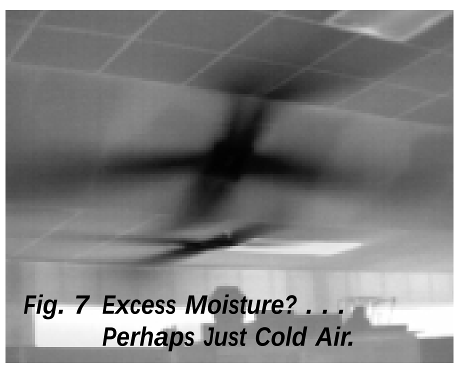
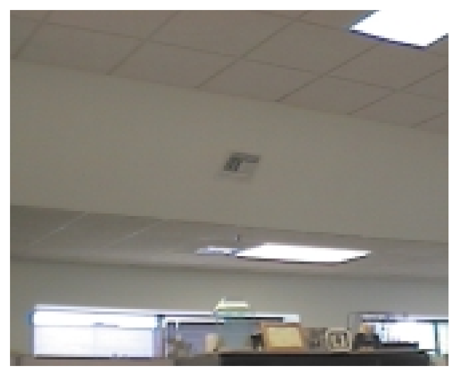


Fig. 7 Excess Moisture? . . . Perhaps Just Cold Air.



It’s essential to confirm the presence of moisture with moisture meter readings. Not all thermal patterns indicate a moisture problem. Cold air from the air conditioning system creates thermal patterns that can look like excess moisture.

- **More pixels**
  In current infrared video cameras, there are two choices of optical resolution: 76,800 or 19,200 pixels. In manufacturers’ specification sheets, these totals are usually expressed as the number of vertical and horizontal pixels. The 76,800 are described as 320 x 240 and the 19,200 are described as 160 x 120, but it’s more useful to keep in mind the total number of pixels. The 76.8k image provides four times more visual data than the 19.2k image.
  For moisture inspections, more pixels are better because you’re looking for very subtle patterns of

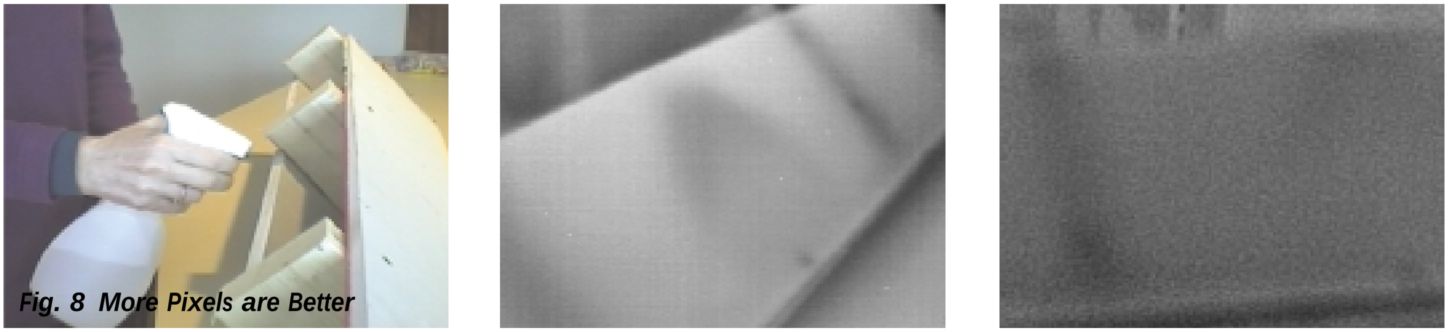


Fig. 8 More Pixels are Better

In many situations, the thermal patterns generated by moisture are not very obvious. Generally, the higher the resolution of the camera, the easier it is to locate moisture.

small temperature differences. With many pixels, you can see patterns that are nearly invisible to cameras with fewer pixels. The photos in figure 8 show why you'd prefer to be using the camera with the larger number of pixels.

- **Both wide-angle and telephoto lenses**
  For indoor work, a wide-angle lens is best because work areas consist of confined and crowded spaces. Using a telephoto lens indoors would be like looking at a wall through a narrow cardboard tube—the resulting "tunnel vision" would make it nearly impossible to see the wide patterns typical of moisture. So for all indoor work and for inspecting the outside of shorter buildings, a 25mm lens is optimal.

  For the less common case of inspecting the outside of medium-rise buildings, an additional 50mm lens would be helpful. And for really tall buildings or for surveys from airplanes or helicopters, a 75mm lens might be necessary.
- **Visual video along with infrared**
  Visual video allows the inspector to locate the area of concern because the inspector can see familiar visual clues. Also, for reporting the results to others, a visual reference to document the location of the infrared image is nearly essential.

Additional Unnecessary Features

Based on our experience, there are several high-cost camera features that will not help you find moisture:

- **Radiometric capability**
  There is seldom any need to know the exact surface temperatures in the image. It doesn't help to know that one part of the wall is at 76.25°F while another part of that same wall is at 75.96°F. By avoiding the radiometric capability, you save at least $5,000 and often up to $30,000, and you avoid the complexity of operation typical of radiometric cameras.
- **Adjustable emissivity correction**
  For the same reason you probably won't need radiometric capability, you won't need to make corrections for differences in emissivity between different surfaces. Those corrections are very important for measuring temperature accurately because different surfaces emit and reflect ambient infrared at different rates. But that fact normally does not reduce your ability to perceive patterns related to moisture content.
- **Industrial temperature range**
  Many fine and very costly cameras are optimized for industrial uses, such as where the inspector needs to measure surfaces with a broad range of temperatures—perhaps—40°F to 2000°F. But in moisture inspection, the inspector is much more concerned with very small differences in temperature in the range between 0 and 150°F—very narrow by the standards of industrial and scientific infrared imaging.

Typical Cost Ranges

Low-resolution infrared video cameras can be purchased for under $10,000. But these are usually used for safety, security and law enforcement purposes. In this author's opinion, their utility is questionable for moisture inspection purposes because they show limited detail and usually obscure subtle patterns.

For the high-resolution cameras most useful for moisture detection, expect to pay between $15,000 and $25,000, depending on what other features or lenses come with the device.

Beyond high-resolution, adding radiometric capability for precision thermal analysis would boost the cost to somewhere between $25,000 and $60,000. These cameras allow the inspector to perform functions beyond moisture inspection. But in the opinion of this author, they add more cost than what is necessary for moisture inspection.

Costs vs. Benefits

Benefits of this technology include improved job quality, higher profits and better profit protection.

Using a high-resolution infrared camera, a drying contractor usually earns more money because the images show the full extent of the job. This justifies the cost of the bid and avoids losses from underestimating the job. Also, the in-progress images help prevent the client or the adjustor from halting drying operations prematurely. Appropriate drying times allow more reliable results, which serves the client well while increasing the drying contractor's profit and reducing his exposure to post-project mold claims.

In general, high-resolution infrared imaging can help make moisture inspection more certain. The technology is either reasonable in cost or expensive, depending on your perspective. It's expensive compared to past practices—and cheap compared to the lost profits and lawsuits that have sometimes resulted from those past practices.

Acknowledgements

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Lew Harriman is director of research & consulting for Moisture Detection & Measurement Inc., which provides equipment and training for finding excess moisture in buildings. He is also a Certified Mold Remediator, and was the lead author for ASHRAE's recent reference book: Humidity Control Design Guide for Commercial Buildings. He can be reached at www.MoistureDM.com.