Expert Commentary

Infrared Detection of Water Damage

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The problem faced by most property owners is that moisture behind walls, over ceilings, and under floors is often impossible to detect until the problem is excessive and visible to the naked eye. Since the investigation and removal of infestations of not yet visible mold in structures is often difficult, technology is now being used to do what once was impossible.

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According to the U.S. Environmental Protection Agency, there is no practical way to eliminate mold spores in an indoor environment. The best way to control mold growth is to control moisture. Mold can begin growth in as little as 24 hours. Roof leaks and water pipe leaks are common sources of water accumulation that may cause mold growth.

Infrared Thermography

Technology has provided a tool that can be used by investigators, remediators, and consultants to detect and help eliminate mold infestations. The technological tool is called Infrared Thermography (IT). IT is a technique that produces an image of invisible (to the human eye) infrared light emitted by objects due to the heat, or lack thereof, in the object called its "thermal condition." The most typical type of thermography camera resembles a typical camcorder and produces a live television picture of heat radiation. More sophisticated cameras can actually measure the temperatures of any object or surface in the image and produce false color images that make interpretation of thermal patterns easier. An image produced by an infrared camera is called a thermogram or sometimes a thermograph.[1]

To understand IT as a tool it is necessary to understand how it works. Thermal or infrared energy is light that is not visible to humans because its wavelength is too long to be detected by the human eye. Thermal or infrared energy (IR) is the part of the electromagnetic spectrum that we perceive as heat. Unlike visible light, in the infrared world, everything with a temperature above absolute zero emits heat. Even very cold objects, like ice cubes, emit infrared. The higher the object's temperature, the greater the IR radiation emitted. Infrared allows people to see what their eyes normally

cannot see.

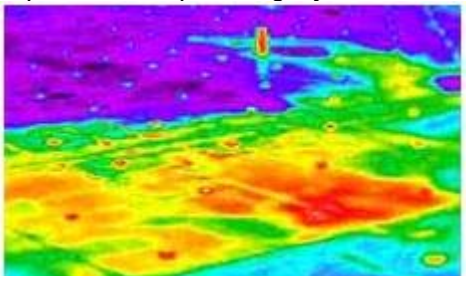
IT cameras produce images of invisible infrared or "heat" radiation. The IT camera can provide precise noncontact temperature measurement capabilities. The existence of moisture—a substance cooler than normal construction materials—can be used to detect conditions that promote mold growth. Mold related problems can be detected before the mold is visible to the eye or detectable by the nose. IT cameras are extremely cost-effective, valuable diagnostic tools in construction related problems of water intrusion and mold growth.

But finding a problem with an infrared camera is not a solution. It is the start of an investigation that will help the property owner or developer stop a problem before it becomes serious. An infrared camera image alone, without accurate temperature measurements, says very little about the condition of a structure or its susceptibility to mold growth. An infrared image without measurement can be misleading because it may visually suggest a problem that does not exist.

Infrared cameras that incorporate temperature measurement allow professionals to make well-informed judgments about the operating condition of a structure. Temperature measurements can be compared with historical operating temperatures, or with infrared readings of similar structures at the same time, to determine if a significant temperature rise will compromise the structural integrity or encourage mold growth.

Digital image storage, available on most FLIR[2] Systems infrared cameras, produces calibrated thermal images that contain over 78,000 independent temperature measurements that can be measured at any time with FLIR Systems infrared software products on standard PC platforms.

Used properly, a thermal imaging camera can provide valuable information during moisture assessments, remediation oversight, energy audits, roof and electrical system inspections and water damage investigations. Temperature difference caused by evaporation, radiation, thermal bridging, infiltration/exfiltration, and other sources must all be carefully evaluated. A thermal image, like the image of a roof below, looks like an impressionist painting by an artist on psychedelic drugs.



The inspector trained to properly use the IR camera can read the information to spot suspect areas that are not visible to the

naked eye. The findings can later be verified using electronic, data-logging moisture detection equipment and in some cases core samples from the roofs or walls.

The inspector uses thermal imaging and data logging moisture detection equipment to establish that the inspector assesses all areas of concern. The extra verification gives additional assurance that the findings from the IR camera are defensible. All property owners and their insurers faced with a claim alleging mold infestation can find these tools essential to the decision process and proper maintenance of the structure.

When suspect areas are found they can be visually documented using the IR camera. Images, like those obtained from an IR Camera, are easier for a layperson or nontechnical person to understand. Findings from the IR camera can be explained to the property owner or the insurer's personnel combined with the verification obtained by using data-logging moisture detection equipment with time stamp and/or destructive testing.

Using Technology for Mold Claims

The time saved using infrared, and the larger areas covered rapidly by an IR Camera, can save time and money by providing a faster, more efficient and more reliable survey. An IR camera can detect moisture located behind interior walls under the right conditions. The temperature difference created by the presence of moisture on the inside surface of a wall will appear differently than the surrounding area. IR and IT experts recommend that property owners or their insurers should use IR cameras and IT for moisture detection under the following circumstances.

- After any water damage event like a flood, broken water lines, equipment failure, roof leaks, etc.
- Before warranty expiration on new construction. (*In many cases, those damp basement walls are explained away as "during construction" moisture. It pays to make sure before warranty expiration*.)
- Before acquiring real estate suspected of having hidden moisture damage. (*Don't believe the story about the house has been vacant and closed up. Musty odors are caused by moisture.*)
- When basement walls are covered by finish materials, and the inspector cannot give a definitive answer on moisture issues.
- When suspected plumbing leaks have occurred from in-slab water supply and/or waste lines.
- When doors, windows, or other openings in the structure are suspected of leaking.

- When performing an energy audit of the building to determine areas of infiltration and exfiltration.
- To determine adequacy of insulation. Wet insulation is a poor insulator but is a great conductor of heat.
- Infrared inspection of the roof can determine potential for ice dams, plugged drains, and water retention that may cause roof damage and/or leakage.
- Locating hidden leakage and/or dampness under resilient flooring.
- Locating wet areas in non-accessible crawlspaces.

Infrared technology is especially useful for inspecting flat roofing systems and synthetic stucco systems, which rarely give any visual clues as to their condition or the location of leaks and moisture retention. Litigation involving synthetic stucco, or exterior insulating finish systems (EIFS), is rampant nationwide. EIFS exterior cladding is blamed by many property owners for retaining moisture behind. The property owners claim that EIFS, because it retains water behind it, promotes mold growth and rotting within exterior wall cavities.

IR technology is being supplemented with a living tool: dogs trained to sniff out the existence of mold. For example, Lab Results LLC,[3] brought the first certified Mold Dog™, Oreo, to the Northeast and provides a network of independent certified mold dog handlers ready to take on big jobs when needed. While a mold-detection canine can quickly find mold inside a home or commercial building, infrared thermal imaging has the edge on the exterior and in detailing—with imagery, the location, and extent of mold infestation.

Properly used under the right conditions, infrared thermography can serve as an early warning system for flat roofs that tend to retain water long before they actively leak. The technology also can detect temperature variations that an infrared thermographer would use to find moisture accumulation, condensation, infiltration, and leakage in wall systems and windows, all of which can provide an environment conducive to mold growth.

The combined use of Mold Dogs™ and infrared thermal imaging during EIFS inspections can be one of the most effective nondestructive and non-invasive method of surveying a property for potential mold and moisture problems. The combination can tell a property owner or potential buyer whether there may be a serious hidden problem, before any cutting or sampling is done.

Typical current inspection methods involve much guesswork and the random cutting of core samples or pieces of walls—both inside and out—to analyze for mold and moisture. A combined Mold Dog™ and infrared thermal imaging inspection can protect a potential buyer from acquiring a lemon property or from incurring repair and remediation costs far beyond a building's value.

Preventing/Removing Mold and Rot

A mold problem is a moisture problem, so when IR is used to find moisture, and it actually finds moisture, it becomes possible to prevent mold and rot from taking hold or to remove the mold that actually grows. Some examples of IR Cameras that can be used for IT inspections of structures to avoid mold growth follow. (The descriptions and photos were taken from the manufacturer's Web site and are not intended to be an advertisement for or endorsement of any of the products. For more information, see this Raytheon Web site).

NEW—First Look Palm IR 500. The latest and greatest thermal imaging camera from Raytheon. The new Palm IR 500 is the first radiometric camera from the company based on their exclusive BST detector technology. Early reports indicate that the image is much improved and temperature measurement should be accurate within range. The system looks like a winner and the Compaq IPAQ is a nice bonus. This is a fantastic imager for every application including predictive maintenance, energy audits, printed circuit board scans, and more.

Palm IR PRO Specials. Packages for the latest in thermal imaging performance. The IR PRO combines high resolution imaging, comfortable LCD viewing, and Digital Compact Flash image storage. We have special packages for Predictive Maintenance, Home Energy Audits, and Security/Surveillance applications.

Palm IR 250 DIGITAL. The venerable IR 250 has been much improved with its latest overhaul. "We have a completely new product here and it kicks butt!" The New digital detector produces a super crisp image and the variable digital zoom you have all been waiting for is finally here. Convenience features like numeric on-screen gain and level symbology and our newest value added packages make the IR–250 D an interesting proposition.

Palm IR 225. The newest addition to the NightSight

family is the IR–225 compact thermal imager. This new unit shatters the $10k barrier to bring you quality Raytheon imaging at the greatest possible value. This is one unit that you can truly afford to implement on a widespread basis.

Similarly, FLIR ThermaCAM® E4 infrared camera features image post-processing, plus alarming and multiple target spots in rugged 1.5 pound package. The Model E4 introduced the use of a radiometric JPEG (Joint Photographic Experts Group) image format that allows image post-processing on the camera or on a PC. As a result, the E4 also provides three independent, movable spot temperature cursors, and audible "beep" alarming for high, low, or temperature-difference thresholds.

The radiometric JPEG file format integrates thermographic functionality with the familiar, world-standard JPEG file format used in Web and other graphics environments. The E4 can store images as radiometric JPEG files, which retain full thermographic functionality. It can also store images as nonradiometric JPEG files. Both radiometric and nonradiometric JPEG formats can be readily inserted into standard word processing and desktop publishing applications.[4]

An IR camera can look at a wall after a fire and show where water has accumulated that would be invisible to the human eye. A modern advanced IR camera is literally a handheld personal computer that measures temperature with an advanced focal plane array detector. The most powerful cameras provide 12-bit recording, enabling users to view and measure a scene that contains very hot and very cold temperatures without losing the ability to measure thermal variations of less than 0.1 deg C.

Camera options, such as bar code readers for image tracking, have extended the functionality of IR imaging systems to match the needs of computerized maintenance management systems (CMMS). Bar code tracking offers accurate, operator-independent data entry that adds pertinent condition comments directly to the stored IR image. Even where bar codes are not used to identify equipment, the bar code standardizes all inspection comments associated with the image.

At the completion of an inspection task, stored images are usually transferred to either a stand-alone thermal analysis or reporting software package, or to the main CMMS. Regardless of the type of maintenance management system at a facility, the primary task at this point is to archive collected data and generate work orders for corrective actions. When required, a full range of image analysis software features allow the

user to extract temperature values from the stored images on any PC with the Windows operating system.

Real-Time Infrared

IR system suppliers are delivering real-time IR workstations that can measure dynamic temperature changes in equipment and processes. The call for more sophisticated application of IR imaging is often initiated after production and engineering departments have battled quality or efficiency problems in the construction of structures that encourage mold growth. The problems may range from poor adhesion of hot-set glues to quality variations in plastic films, from poor uniformity in glass products to roofing materials that are not water-tight; from windows that leak to water wicking up through concrete slabs.

It is not uncommon that as management pushes for increased quality that effective methods of testing quality and avoidance of water intrusion are needed by everyone in the business of owning or building structures. In these production situations, the new real-time IR thermal imaging systems are most useful. The systems consist of two primary components:

- A portable Pentium PC with a digital recording system and software integrated to acquire real-time digital video and to display it in color, extract temperature information, and record the real-time sequences for extended analysis, and
- A handheld, high-resolution FPA camera.

A key feature is the digital video interface, which transmits every temperature measurement pixel generated by the camera. The camera also can be disconnected from the system and used in traditional snapshot mode. What makes these workstations so useful for troubleshooting construction problems is their ability to acquire, store, and analyze sequences of real-time IR images of the structure under investigation or during construction. The system analyzes, displays, and stores up to 60 calibrated IR images every second. The systems use off-the-shelf components to make upgrades possible and ensure compatibility with traditional software.

A relatively slow and inexpensive 200 MHz Pentium PC with its high-speed PCI bus makes an excellent platform for thermal imaging. A digital frame grabber accepts the digital video transmitted by the camera and transfers it to the high-bandwidth PCI bus. High-capacity hard disk subsystems designed for multimedia applications store the data for subsequent review and further analysis.

Software analysis tools give the system a VCR-like user interface for controlling the digital video recording and

playback. Users first position the camera and adjust the viewing temperature range and then select the rate and length for which images are stored to the internal drive, ranging from 60 Hz for as long as 20 minutes, or as slow as one image every hour for weeks. Storage of the video can be initiated from the keyboard or a signal from the device under observation. Once data have been recorded, viewing controls (such as play, fast forward, rewind, slow motion, and time lapse) can be used to review the process, equipment, or event under study.

The software provides a full range of tools for extracting temperature data from the collected thermal image sequence. They range from simple points, areas, and lines to complex regions that help the user measure only specific components of interest. If live sequences reveal dynamic trends, a tool automatically extracts data from a sequence of images and generates a graph for review. Captured data can be exported to other systems so maintenance managers can integrate all maintenance test data into a CMMS.[5]