BREAKTHROUGHS IN INFRARED CAMERAS

Hundreds of relatively low-cost cameras were purchased last year for moisture detection and to diagnose basic energy-related problems.

By JOHN SNELL

I distinctly remember the first time I looked through an infrared (IR) camera. The house that my colleagues and I at Residential Conservation Services were working on, back in the early 1980s—a partially insulated, three-story balloon-framed Victorian—was a disaster. I didn't know much about infrared thermography, but I hired a guy who said he did. He came to the work site with a funny-looking camera (a Hughes Probeye) that cost more than I made in three years! It was incredibly awkward to use and the thermal image it produced was fuzzy—but with imagination, decipherable. Even so, my mind was blown!

In the past few years, however, the price for IR cameras has dropped by an order of magnitude, image quality has improved at the same rate, and cameras are finally being designed with the end user in mind. I recently used a new camera that looks just like a cell phone. It is many times more powerful than the one I first used 20 years ago, and it retails for a quarter of the price.

In the past several years, a strong interest has grown in using thermography to diagnose basic energy-related problems, for pest management, and to locate moisture more rapidly and thoroughly in water-damaged buildings of all sorts (see "IR Cameras and Moisture," p. 19). Contractors and insurance companies have been using IR thermography to verify that moisture-damaged buildings have been restored to a dry condition.

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Author John Snell used a modern $60,000, cryogenically-cooled, "portable" IR system in the early 1990s.

Becoming IR Savvy

Today's IR systems are easy to use. Anyone who can use a conventional video camcorder or digital still camera can quickly learn to get good thermal images. Don't forget, however, that accurate interpretation of the images requires not only good camera skills, but also an in-depth understanding of heat transfer, radiation physics, conditions for inspections, and basic building diagnostics. Buildings are very complex. Inspections are done in conditions that are often less than ideal. You must understand how that affects what you are seeing—and not seeing—in the thermal image. Without a solid foundation, you can expect to make mistakes; and don't kid yourself—some of them may be costly.

Good training options are available, but make sure the one you choose covers the camera you have and your application needs. For groups of five to ten people, specialized, on-site training focused on your needs and equipment probably makes the most sense. But be wary. The "certification" that some groups offer is not based on any standards. The true key to proving you are qualified isn't having a fancy piece of paper hanging on the wall. It is getting appropriate training and documented experience.

Standards for conducting building inspections do exist, and all thermographers should become familiar with them. The two most commonly used are the International Standards Organization (ISO) ISO 6781 "Thermal Insulation, Qualitative Detection of Thermal Irregularities in Building Envelopes, Infrared Method" and ASTM C-1060 "Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings."

The American Society for Nondestructive Testing (ASNT) provides a framework for qualifying thermographers that is based on training that complies with a fixed curriculum, documented experience of a given duration, and performance testing. ASNT-based certification is meaningful, relevant, and widely recognized. ISO also provides for qualification of thermographers through a similar set of criteria.

What You Should Look For

Some manufacturers have priced their systems to make it easy to add on a long list of features—all at a price, of course. Make sure you look at the total package price, including lenses, reporting and/or analysis software, data storage cards, LCD view screens, batteries, and training. This is an investment that must pay returns! Great choices exist for great systems priced below $20,000.

Key features to look for are: image quality, which is somewhat subjective and is based on detector array size and type, lens, and display; ease of use; field of view (FOV); image storage capacity; and report software. All new systems will store images digitally and provide simple software to easily create a report. Most, but not all, also have a video out signal, allowing for data to be recorded on a separate video recording device.

While not essential, the ability to measure temperatures can be very useful for building scientists. Several systems are fully radiometric, meaning that the entire image is calibrated for temperature measurement—while others can make a radiometric measurement only at a single spot in the center of the image. Either can work well. Separate spot radiometers are also available to supplement a nonradiometric IR camera; models suited to building diagnostics work are available for several hundred dollars. Nonradiometric or single-spot measurement is more than adequate for most uses.

Here are some other factors to consider.

Thermal Sensitivity

Thermal sensitivity is no longer the big issue it once was, since today's detectors can typically resolve temperature differences of 0.1°C (or 100mK) or less at 30°C—a remarkable feat! At least one supplier is selecting its most sensitive detectors—as low as 30mK—for cameras it's marketing especially to building professionals. While not essential, this extra sensitivity may allow you to work during non-ideal conditions to see details that might not be detectable with other systems.

Today's detectors, which produce an electrical response when infrared radiation is focused on them, are generally one of two types: amorphous silicone (aSi) or vanadium oxide (VOX). While the two types perform somewhat differently, either is suitable for building diagnostics work. Neither requires cooling, which is a big relief to anyone who has used a cooled system in the past. They also detect longwave infrared radiation, making them far preferable to earlier shortwave systems for use out of doors in the sunshine.

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New IR systems are well-designed and easy to use with a wide range of feature sets and prices to fit most budgets.

Regardless of sensitivity, images of surfaces colder than approximately 0°F (-18°C) will not be as crisp as images of warmer surfaces. Unfortunately, specifications for these low-temperature conditions are usually not available. For the most part, this is not a big problem, however, since users are seldom inspecting very cold building surfaces. (Don't store IR cameras in a vehicle during cold or hot weather, however; this can seriously damage the batteries and electronics.)

Cameras also have a temperature range in which the accuracy of the radiometric temperature measurement is assured. For most building applications, radiometric measurements are not essential, so this is not a big issue. Most, if not all, of the cameras on the market at this time should perform well out of doors in all but bitter Arctic conditions.

Lenses

An infrared camera lens will have a fixed field of view (FOV); it is not a zoom lens. The wide-angle lens is most useful inside buildings, where much of the contractor's work is done. Outside, especially for large buildings, a narrower FOV may be more useful, as the distances involved are typically greater.

The FOV for a lens is specified in degrees for both horizontal and vertical views. A lens with an FOV approximately 20° x 20° is typical for outdoor work, while a wide-angle lens with an FOV 40° x 40° will perform well inside.

While IR cameras do not have zoom lenses, many have an electronic zoom capability that simply magnifies the image. While this can be a useful feature, it does not improve resolution, and in itself it would usually not be a compelling reason to choose one camera over another.

IR systems come with three choices for focusing: manual, motor assisted, or fixed focus. While new users often develop a preference for one type of focus, each can work well and can yield sharp images.

The depth of field for new lenses is typically very narrow. Focus, regardless of the focus mechanism, is critical to getting good images, and, for radiometric systems, for getting good temperature measurements as well.

Resolution

An infrared system, like a digital visual camera, uses a matrix of very small detectors assembled in a rectangular array at the focal plane. For this reason the arrays are termed focal plane array systems, or in the jargon, FPAs. Two array sizes are in common use, 160 x 120 (19,200 detectors) and 320 x 240 (76,800 detectors). The array size as well as the lens used determines the spatial resolution of the camera at any given distance. Obviously, IR camera resolution is a long

way from the 3- to 8-megapixel resolution we are used to in visual digital cameras, but it is very adequate for most building diagnostic work.

Early 160 x 120 arrays were often quite pixilated compared to 320 x 240 arrays. Thanks to better design and image processing, however, both arrays now yield images of very high quality. Interestingly, these images are often remarkably comparable. Until recently the larger arrays were significantly more expensive, but the difference in price has shrunk notably in the past year.

While it is generally true that larger arrays are better, you should carefully consider two factors in making your choice. First and foremost is image quality. This is somewhat subjective and depends not only on the array size, but also on the lens, the processing electronics, and the display. The best advice is to try before you buy—under your typical work conditions. Some manufacturers will let you apply 100% of your camera rental fees towards the purchase of an IR camera—an excellent way to minimize your risk and be sure about your buying decision before committing to a purchase.

The second factor to consider is the spatial resolution that you need. What is the smallest detail that you will need to resolve at the given working distances? Spatial resolution is usually specified as an angle (in milliradians or mRad) called instantaneous field of view (IFOV). Stated simply, IFOV is a projection of the detector through the lens onto the scene, and the relationship is IFOV (in radians) x distance = spot size. Thus, if you are using a system with an IFOV of 2.0 mRad at a distance of 20 ft, you could resolve detail as small as 1/2 inch. As the IFOV specification increases, spatial resolution decreases.

As I said earlier, resolution is not usually going to be a limiting factor unless you are viewing large buildings outside at great distances where you simply cannot get closer. If you work mainly on large buildings from the exterior, a 320 x 240 system is probably what you should be using.

Other Considerations

Images are stored either on removable media, such as a PC card, or in the flash memory of the camera. When considering a camera, think realistically about how many images you need to store before downloading to a computer; usually you will not need to store more than 500. Downloads through a USB or FireWire port are, for the most part, fast and painless.

Most, but not all, IR cameras also have the capability to output a live analog video signal that can be played on a monitor or recorded on a VCR or camcorder—if it has video input. Digital video is currently available only on very high-end IR cameras, but I expect that to change in the future.

IR Cameras and Moisture

When moisture is enclosed in the building envelope, as it is in the case of wet insulation, this increases conductive heat flow (in either direction). Moisture will have a different, often higher, thermal capacitance than surrounding building materials. When exposed to air that is below the dew point, moisture will evaporate, causing the damp surfaces to cool. These features of heat transfer dynamics make an IR camera a useful tool in moisture detection. Unfortunately, the mechanisms of heat transfer are often complex and interrelated, depending on ambient conditions and type of construction. Simple guidelines can get thermographers started, but when signatures are contradictory, unclear, or non-existent, further investigation or testing is probably warranted.

When looking for surface moisture, make certain the air in the room is not saturated so that evaporation, and thus cooling, from any damp surfaces will take place. Increasing convective airflow over the damp surfaces usually enhances the thermal signature picked up by an IR camera. When trapped moisture is the suspected culprit, it is probably most useful to look first at the envelope when steady-state heat flow across the envelope is greatest—as during the dead of winter or the height of summer, for example. A 10°F (10°C) difference across the envelope is recommended in order to produce good, readable thermal signatures. It is difficult to look at surfaces that are in direct sunlight; in these conditions, inspection may be useful only from the interior.

When heat flow is transitional—that is, when the envelope is warming up or cooling down—it may be possible to locate trapped moisture, because wet materials change temperature at a different rate than similar dry materials. In this case, direct sunshine may actually be used as the heat source, from either side of the envelope, or room air temperature can be changed using the HVAC system.

Signatures get complex when two or three mechanisms are in play simultaneously and when conditions are less than ideal. A visual inspection, and a strong knowledge of construction details, will help you to focus on the probable source of the moisture. Many, but not all, sources are leaks at transitions and penetrations. Locating moisture trapped in the envelope is often made more difficult by the fact that the building materials themselves will influence both steady-state and transitional heat flow. The insulation on an external insulation and finish system (EIFS) building, for instance, thermally masks over the often subtle thermal signatures we are looking for. In other buildings, the synthetic stone cladding has a thermal capacitance that can hide the similar qualities of trapped moisture. In nearly all cases a high-quality moisture meter will prove useful to check and validate moisture content.

The dynamic range of the stored image is a very important specification to consider. A large (12- to 14-bit) dynamic range allows for image thermal level and span to be manipulated after capture. This is essential; an 8-bit image cannot be adjusted after it is stored. Cameras with an 8-bit range should probably be avoided.

The basic adjustments on all IR systems are similar; the two most important are thermal level and span (brightness and contrast, respectively). Controls for these and other functions may be buttons, pull-down menus, or a combination of the two. Some IR cameras have automatic image adjustment modes that can work very well, although it is important, in most cases, to be able to adjust the image manually when needed. While some camera designs are more functional, you can quickly become proficient at adjusting any of them to get great images.

Digital visual image cameras are incorporated into several IR systems. The advantage here is that the IR and visual image files are electronically mated. This is a boon if you end up inspecting a number of similar buildings in a day and have to create reports. Unfortunately, the image quality of these integrated visual cameras is often poor. Make sure you try before buying—at distances and in lighting conditions typical of your work.

It may be smarter to save your money and buy a good 3- to 5-megapixel digital camera instead, even if you will have to be more careful about managing the separate visual and IR image files. You can blow up a good, high-quality visual image and clearly see details—perhaps essential details—that you may have overlooked at the job site.

Some systems have in-camera voice or text annotation capability electronically tied to the image file. The annotations can be recalled later and inserted into the report document. Both of these features can be very useful, but the lack of either should not lead you to reject an otherwise good system. For better or worse, handwritten field notes will probably always be with us!

Reports are typically created in a custom software program, which can read the proprietary image format. Most IR cameras come with a basic image download package that allows the reports to be copied into various nonproprietary formats (such as Microsoft Word) and used in a document. Some report software, while useful, may be more detailed than you need. The high cost of this software is often hidden in the total cost of the system.

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The quality of the images produced by modern IR systems is remarkable. Missing and poorly installed insulation is easily seen in this home.

Many of today's IR systems display the image on generously sized LCD screens. These let you see the image easily and quickly show it to coworkers, contractors, or owners who are looking over your shoulder. Many of these displays have limitations, however, so beware. First, they may not work well in bright light or direct sunshine, although shields may be purchased to help address this issue. For most contractors, however, this is not a deal breaker, since most contractors don't do all their work under these conditions. Second, some displays are fixed and cannot be tilted. This is a more significant limitation and one that you should consider with care, since an adjustable display is useful, if not essential, for most building applications.

At least one supplier sells a fairly high-priced, optional heads-up display that, while it looks very cool, should be considered only after careful trial and evaluation. It is expensive, complex, and can be unsafe. It becomes very tricky for many people to adjust to seeing the image in one plane, pointing the camera in another and, if they are moving at all, navigating in a third plane. This can quickly lead to a fall or bump that can have serious repercussions. FYI, this display can be purchased directly from the manufacturer as well!

Many contractors who are considering purchasing an IR system will prefer a color image or a gray scale image. Here is the truth: Depending on a number of complex, interactive factors—as well as some subjectivity—some systems work better in gray scale and some work better in color. Generally, thermographers will work in either gray scale or a monochromatic color palette; reports often look more impressive in a full rainbow of colors, but that palette is extremely difficult to work in. Most software programs allow for the image palette to be changed later on. As you evaluate IR systems, try them in all palettes to see which one gives the best results.

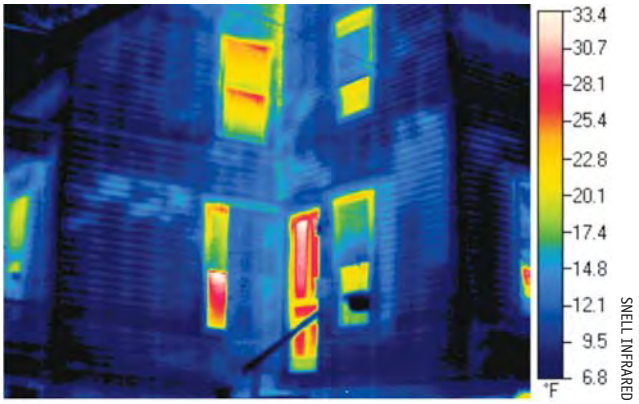
The frame rate of most cameras is either 30 or 60 frames per second (or Hz), but several cameras have slower frame rates. Although some salespeople may try to convince you otherwise, any of these will work fine for building applications with no perceivable loss of quality.

Some suppliers have added bells and whistles that may or may not be useful, such as a dew point indicator and emissivity lookup tables. Both can actually be misleading. Laser pointers may have value, but a separate pointer or flashlight can serve the same purpose at a much lower cost.

Batteries are getting better and better. Proprietary batteries now tend to be Ni-metal hydride or Li-ion, both of which will perform well, although they may be expensive. Other systems utilize AA batteries, regular or

rechargeable. If you will be doing much work in cold weather, consider buying an extra battery or two.

Expect that any IR system will need repairs at some point. A general rule of thumb is to budget 10% of the purchase price for annual maintenance. Most IR systems are fairly rugged, but an IR system should be treated with the respect due any costly piece of electronics. Interestingly, some can be dropped from 5 ft with no damage or interruption of function! Regardless of the system, you'll want to protect it from dust and damp. A thin-film plastic bag works well, as it is quite transparent to IR radiation.



Another view, under different conditions, of the same house pictured on p.20 shows how results can vary as circumstances change. Note the use of a "rainbow" palette and the inclusion of the radiometric temperature scale.

Radiometric systems will need to be recalibrated when they go out of specification. A simple procedure can be instituted to check calibration regularly; when necessary, the supplier will recalibrate the system. Unfortunately, some suppliers recommend recalibration annually. Not only is this an unnecessary—and often exorbitant—expense, but it offers no assurance that the system is actually within spec for the rest of the year.

Future Looks Good

The choices today for full-featured infrared systems costing less than $25,000 are astounding. And get ready—new technologies are in the works right now that will mean even more choices—systems that are very well suited to building diagnostics work at an even lower cost. As is the case with computers, however, the fact that the market is changing quickly is no reason to wait for things to get better or less expensive.

When choosing the right IR system for your business, analyze your current needs and see if today's systems make sense as an investment at this time. While there are many, often confusing or complex, choices confronting someone who is considering the purchase of an IR system, the good news is that it is hard to go wrong with any of the systems that are available in the market today. Do your homework, look at—and try—several systems, and then buy one as soon as possible so you can begin to reap the benefits of this remarkable technology now.

Consider the fact that a new IR system will last at least ten years. Even if you budget 10% annually for maintenance, the cost for the $15,000 system is $3,000 per year over its life. If the system is used on 100 buildings each year—a low figure—the cost for the infrared camera is only $30 per inspection. Even with other associated costs, the total cost of a production inspection is probably less than $100 per building.

John Snell of Snell Infrared, Montpelier, Vermont, has trained thousands of people to use infrared technology over the past 20 years. His company works with all the major suppliers of IR systems to provide their customers with training, while remaining 100% independent of the sale of any particular product. Even after 20 years, it still blows his mind to see good thermal images and to work with people who enjoy the technology.

FOR MORE INFORMATION:

To learn more about IR cameras, call Snell Infrared at (800)636-9820, or visit its Web site at www.snellinfrared.com. At this site you can view links to suppliers as well as a very active message board.

Suppliers of Infrared Imaging Equipment

Electrophysics Corporation
Building E
373 Route 46 W
Fairfield, NJ 07004-2442
Tel: (800)759-9577
Web site: www.electrophysics.com

Fluke Corporation
P.O. Box 9090
Everett, WA 98206
Tel: (800)44-FLUKE
Web site: http://us.fluke.com

FLIR Systems
16 Esquire Rd.
North Billerica, MA 01862
Tel: (978)901-8000
Web site: www.flir.com

Infrared Solutions, Incorporated
3550 Annapolis Ln. No, Ste. 70
Plymouth, MN 55447-5333
Tel: (800)760-4523
Web site: www.infraredsolutions.com

ISG
305 Petty Rd.
Lawrenceville, GA 30073
Tel: (887)733-3473
Web site: www.isginfrared.com

Mikron Instrument Company
1101 Elevation St.
Hancock, MI 49930
Tel: (888)506-3900
Web site: www.irimaging.com

Monroe Infrared Technology
P.O. Box 1058
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