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Infrared Thermography Heats Up

By Dan Drollette, Senior Editor

It was nearly 90 degrees outside the ThermoSense symposium at the SPIE meeting in central Florida. The hotel conference center was surrounded by sunbathers enjoying its plentiful swimming pools and man-made waterfalls. Meanwhile, inside meeting room P/Q, lecturers were discussing how infrared thermographic imaging systems could be used to ensure that buildings stay warm above the Arctic Circle.

An infrared camera system is a tremendous aid to finding the causes of a structure's heat loss - the largest obstacle to energy conservation. The US Department of Energy calculates that 38 percent of the average building's energy losses are due to air leaks caused by leaky walls, windows and doors; the remainder of the heat being conducted, radiated and convected out of the building because of inadequate [or improperly installed] insulation, structural defects and design faults. These problems can often be easily remedied once they are located, but they tend to remain hidden to the naked eye. Infrared imaging systems greatly increase their detection.

The use of infrared camera systems to find sources of heat loss is increasing worldwide. Conference speakers came from as far away as Lapland to present their findings. Kai Ryynanen, a researcher with Rovaniemi Polytechnic School of Technology in Finland, said that in the land of the midnight sun, detecting even the smallest draft is a priority. By using a combination of air pressure tests and infrared camera images, he found that even brand-new showcase homes at the school's Arctic Circle Housing Fair contained minor faults. When he compared them to images taken a year later, he found that these flaws worsened profoundly: As the buildings settled into place on their foundations, their insulation sagged, their weather-stripping separated from the walls and tiny gaps widened at the junctures of their walls and ceilings. By identifying the precise location of each minor flaw early, builders can fix them before they escalate into larger problems. Consequently, his colleague Timo Kauppinen, research scientist at VTT Building and Transport in Oulu, Finland, averred that thermographic scans should be used routinely, as a standard part of the process of certifying that structures meet building codes for airtightness and energy efficiency.

And the systems' applicability is not limited to the far north. They can be used to ensure that any structure is properly built with interiors that stay warm in winter and cool in summer, maintained Greg Stockton of Stockton Infrared Thermographic Services, Inc. of Randleman, N.C. Representing one of the few American firms in this field, Stockton uses a combination of three different camera systems to conduct energy efficiency and quality control checks of department stores, strip malls, warehouses, and public buildings for corporate, industrial and institutional clients. He uses one camera system for the visible spectrum, one for the infrared region, and a borescope –a device for spot-checking of difficult-to-reach interior spaces. In business for the past 11 years, Stockton has found that Americans pay more attention to energy conservation as oil and natural gas prices have increased. "We've done more heat loss surveys in the past three months [since energy prices went up] than in all of last year," he said.

First principles

Stockton likened any building to a heat sink. The sun heats it during the daytime, and this heat energy dissipates at night. Whenever there is a substantial difference between the building's interior temperature and the temperature of its immediate exterior surroundings, it is easy for a thermograph to pick up a building's problem areas, allowing owners to zero in on spots needing preventive maintenance.

In lay terms, Stockton described the process as "sitting outside on a cold night and watching the heat going out." He added, "If you want to tell what is happening inside a structure, you hit it with heat and watch it cool off. Or you can do the opposite; cool the interior with air conditioning on a hot day and watch the heat come into the building. But what he called a “transient” –a change in temperatures is needed to create the conditions conducive to seeing problems.

To image transients in the infrared region, he uses any one of six different infrared camera systems. Stockton relies on cryogenically cooled focal plane array or forward-looking infrared systems. He said that the Mitsubishi M-600 is better for spatial resolution-needed for far away aerial infrared applications, but prefers the Model 390 ThermaCAM made by FLIR Systems, Inc. of Boston for building surveys, because it is more portable for field work. With very good thermal sensitivity and a 32degree wide-angle lens, he can get close to a building, while maintaining a large enough view of the building so that the column line-to-column line perspective can be maintained. (Buildings are built on a grid system from column to column.) Also, it is small enough to be carried on a commercial airliner.

The infrared cameras also allow him to examine other parts of the construction process. "I can see every nail in the sheetrock," he said. The systems

can detect electrical faults, potential roof leaks, and even insect damage: When termites infest a wall, they typically devour large sections. The missing mass shows up on the thermograph. Similarly, the technology can be used to find missing pieces of concrete in a building as small as a baseball in size, enabling building owners to check up on the quality of work done by the contracting crew. ("Contractors don't like me much," Stockton said.)

Other approaches

There are not many alternatives to infrared imaging, short of tearing a wall open. Sometimes, small holes are drilled in a random section of wall or ceiling and a borescope inserted to examine its interior.

In the past few decades, air pressure tests have been used to determine how well a building is sealed. Essentially, air is sucked out of the building's interior with a device called a blowerdoor, and the rate at which air flows back in from the outside is measured. This gives a general idea of how tight the building is, and whether the plastic vapor barrier inside its walls is intact. But the tests do not zero in on the locations of air leaks.

Ryynanen found that by combining air pressure tests with infrared imaging, the general condition of a structure could be determined and the leaks then pinpointed. In addition, depressurizing a building exaggerates any leaks, making them more readily apparent on the thermograph.

The future

To anyone with a memory of the last energy crisis, it may seem that using infrared imaging to improve energy conservation is old hat. But today's technology is more thermally sensitive, with higher spatial resolution. It's also smaller, lighter, more compact, and has the ability to record information in the form of digital stills or videos - a boon to users. "Technologically, we've got almost everything we want," maintained Stockton." Although I would like to see large format 640 x 480 pixel cameras with higher thermal sensitivity. Even then, it's not really a question of the detectors. It more a question of economics." At a price range of $30,000 to $80,000 per system, it is unlikely that infrared thermographic imaging systems will become items that individuals will buy at the local hardware store. And renting one costs several thousand dollars a week. In addition, users need to be able to understand construction techniques and building codes, and be able to interpret the images. “Understanding what you are looking at requires expertise”, said Kauppinen. “Wind, sun, shadows and rain can affect what appears on the thermographic image. Similarly, the density and porosity of the materials used in a structure can affect its thermal profile.”

Instead, Kauppinen calls for higher standards for professional thermographers, emphasizing more training, more reference materials, more guidelines and more interpretation of results. In any case, he expects more demand for infrared thermography. Stockton, a former building contractor said, "Conservation is coming. We have to start facing it someday. We in the US have to come in line with the rest of the world. I'm one of the few guys that likes to see the oil prices go up."

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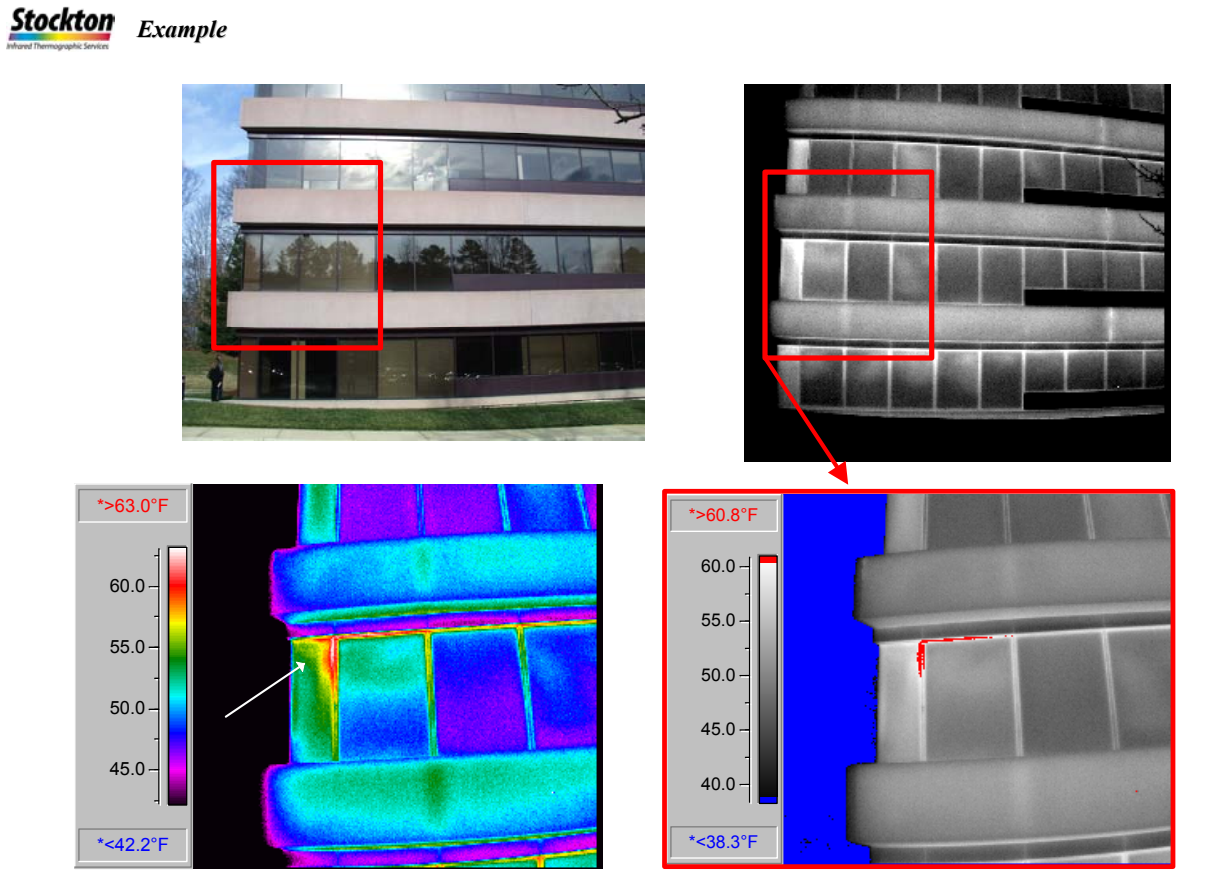

Figure 1: Infrared thermography can be used to make structures more energy efficient. The windows of this office building may look fine to the naked eye, but a thermograph readily revealed leaky window sealant. White and red colors show the areas with the greatest heat loss; blue shows the least heat loss. *All photos courtesy Stockton Infrared Thermographic Services.*

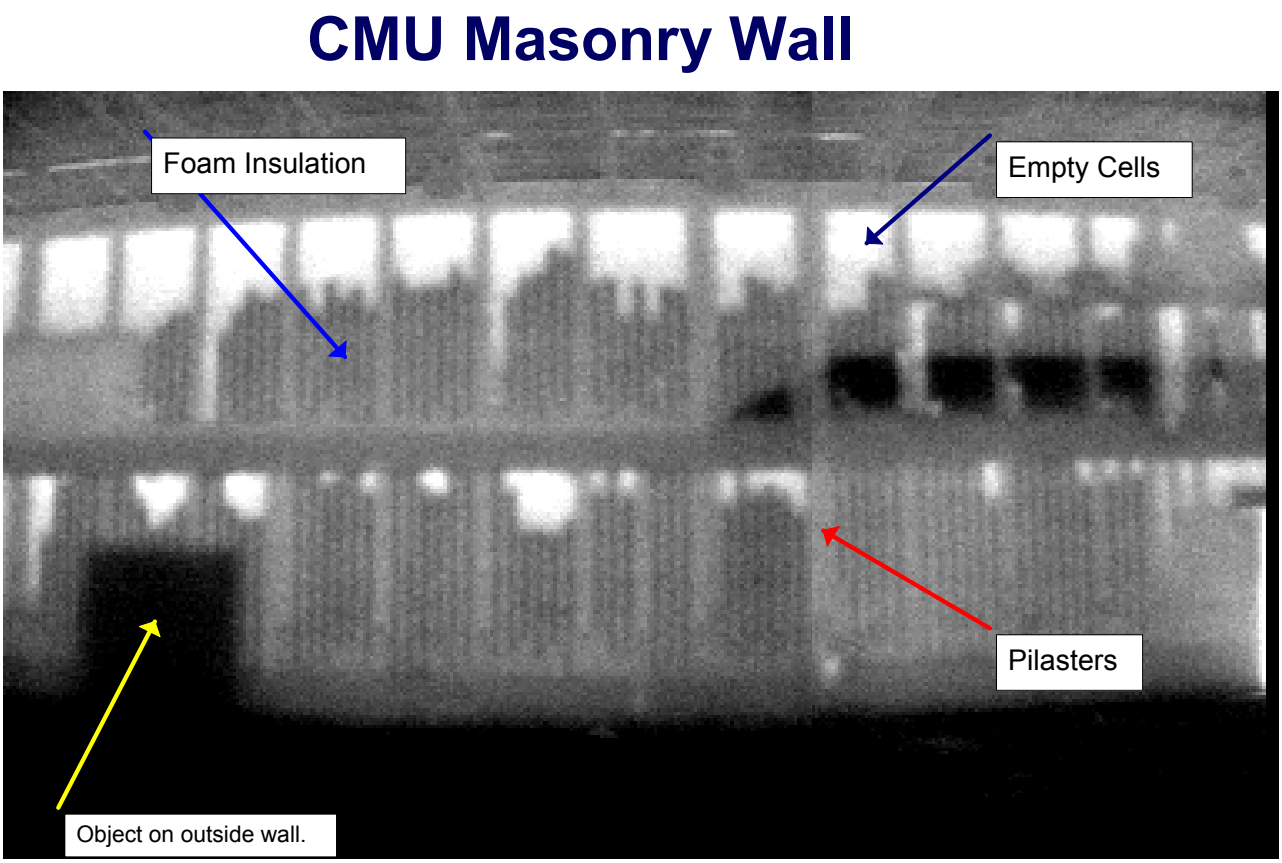

Figure 2: The system also allows users to see inside walls. Someone neglected to properly fill up all of this structure's interior wall spaces with foam insulation. Gray areas are filled, white areas are empty.

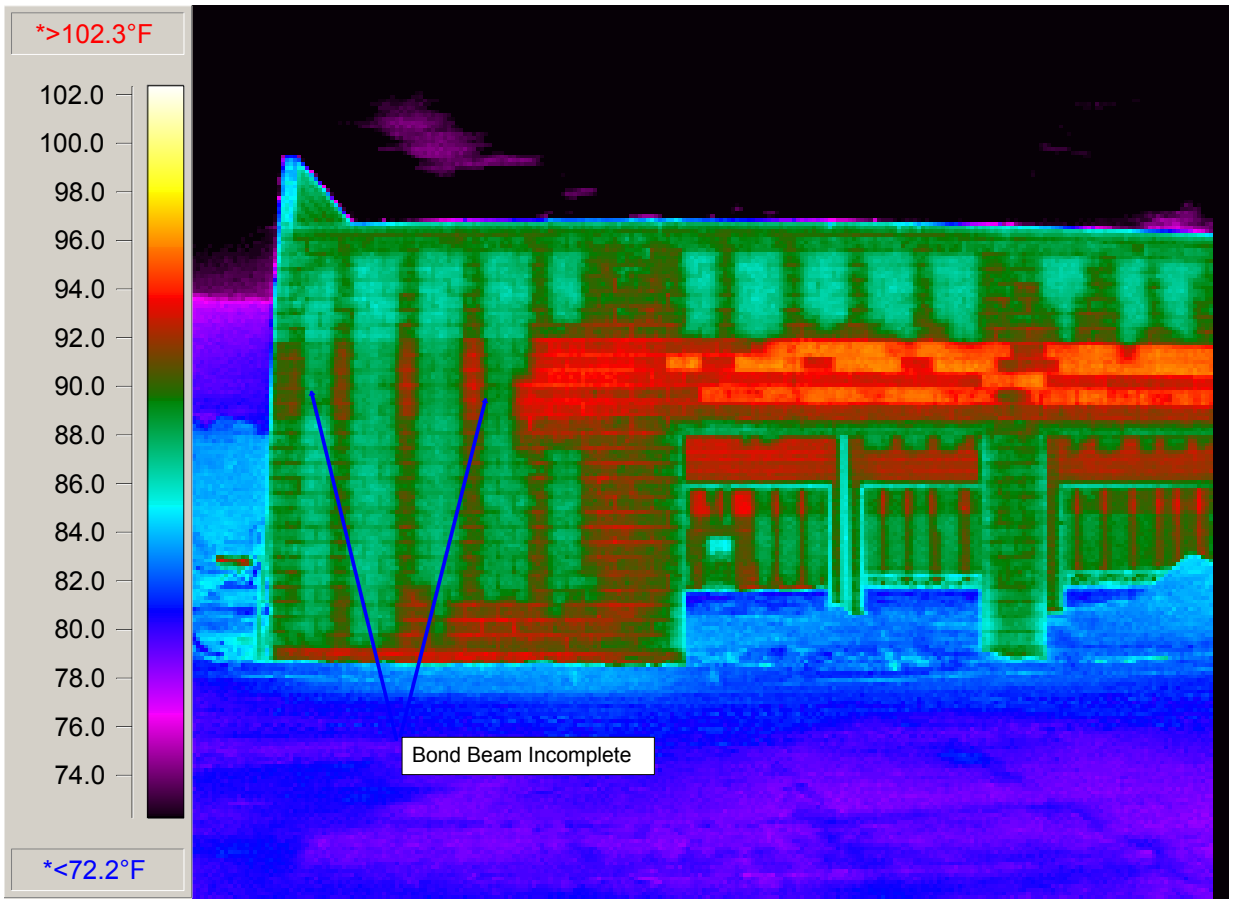

Figure 3: In addition to heat loss, IR thermography can be used for construction quality control. Slight differences in surface temperature allowed the system to see different amounts of mass in this masonry wall. What looked adequate in the visible range turned out to contain an incomplete horizontal bond beam in the IR region. Yellow and red equal the hottest areas; green and blue equal the coolest areas.