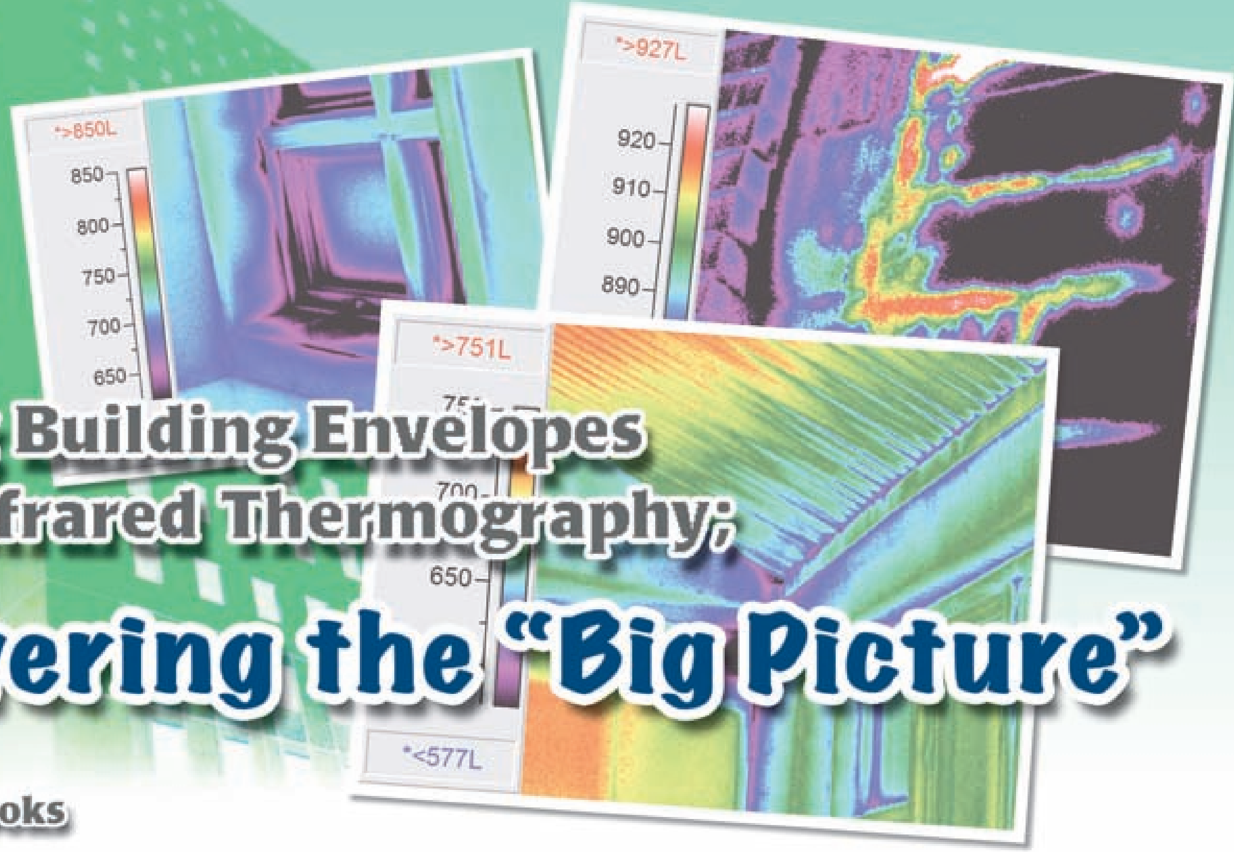


Testing Building Envelopes with Infrared Thermography:

Delivering the "Big Picture"

By Peter Brooks

The ability to professionally test and evaluate the performance of a building's envelope is quickly becoming essential to the proper management of today's commercial and institutional structures. Several factors are accelerating this trend: rising energy costs, proliferating government regulations, new construction techniques and materials, growing concerns about occupant health, and escalating litigation. Specific issues, such as moisture damage, frozen pipes, ice dams, occupant discomfort, and high heating costs also drive the growing demand for professional building envelope analysis.

In our practice, we frequently find that substantial investments in both money and effort have failed to address the root causes of a building's performance problems, even though a properly conducted infrared survey could have quickly and affordably provided the information needed to guide cost-effective repairs. This article will offer a practical overview of the appropriate use of infrared thermography in the testing and analysis of building envelopes.

The building envelope is generally considered to include the roof, ceiling, floor and wall assemblies, vertical fenestration and skylights, slab edges, and below-grade walls.[1] ASTM C 1060 (2003) sums up the envelope as "the construction, taken as a whole or in part, that separates the indoors of a building from the outdoors."[2] One of the major challenges in assessing building envelope performance is integrating the performance of these components into a holistic understanding of the envelope as an interdependent system.

While specialized testing techniques are available to evaluate individual components quantitatively, infrared thermography is the only technology able to deliver the "big picture" of the building envelope as a complete system. The qualitative, practical information generated by thermographic testing can be a useful guide to the cost-effective testing of specific components using other forensic techniques. Infrared building envelope analysis can also reveal previously unrecognized faults, affording an opportunity to make repairs before these faults lead to larger problems that may be much more expensive and disruptive to abate.

Prior to conducting an infrared building envelope survey, a professional certified thermographer must assess the potential impact of preexisting conditions on the accuracy and reliability of infrared test results. Such conditions include, but are not limited to: solar loading, seasonal temperature variations, current weather conditions, and the thermal impact of HVAC operations. The thermographer must also determine that an adequate temperature differential (delta-T) exists between the interior and exterior of the building. Whenever possible, infrared testing should be performed on both interior and exterior surfaces. Any areas of suspected moisture damage should be subjected to additional physical testing when infrared test results are inconclusive or fall below a minimum level of confidence.

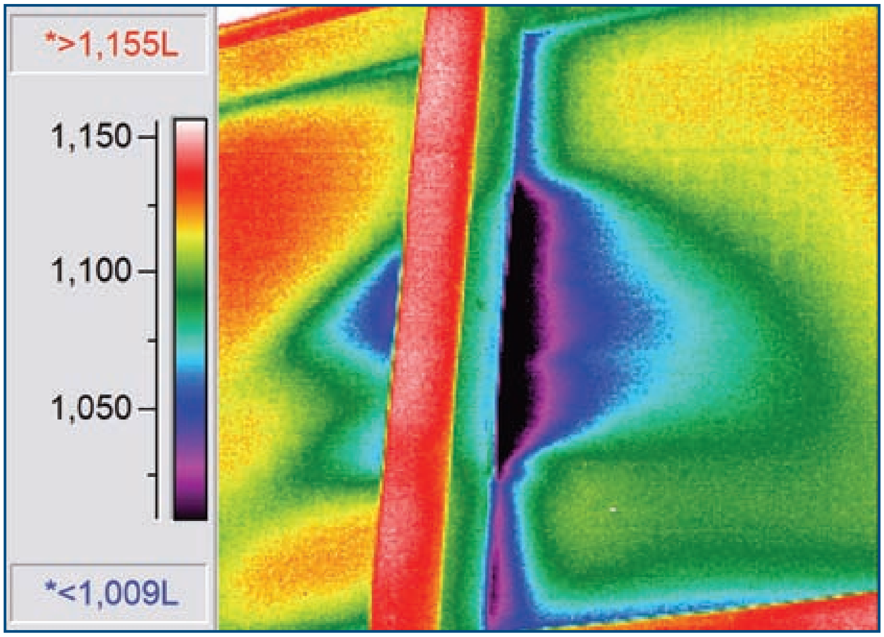
Losing Energy through Conduction and Air Leakage

Virtually all of the thermal envelope deficiencies identified by thermographic testing involve the conduction of heat through building materials or the infiltration and exfiltration of air through gaps in the building envelope.

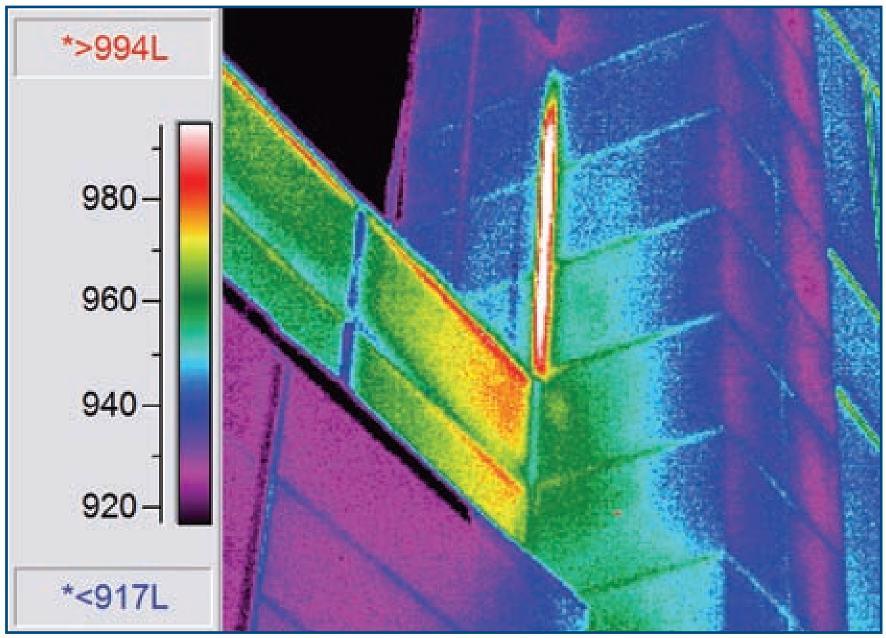
Conduction problems often result from moisture damage to building materials, including leakage of exterior water into the building envelope, failure of piping systems, and condensation of moisture vapor within the structure. Moisture significantly reduces the R-value of building materials, resulting in a dramatic increase in the conduction of heat through moisture-damaged components. Other typical causes of conduction losses through the envelope include missing or improperly installed insulation and unintended thermal bridging of structural components.

In many cases, moisture damage is suspected or even established before testing begins, but the locations and extent of damage are in question. Under proper testing conditions, the transfer of heat energy through conduction faults generates a thermal "signature" that the thermographer interprets to locate the underlying problem. Thermography often supplies enough information to guide cost-effective repairs with little (if any) need for invasive confirmation.

While conduction losses can sometimes be substantial, leakage of air through the building envelope (termed infiltration and exfiltration) is typically a much more significant source of building energy loss and occupant complaints. Common findings include problems with air and vapor barriers and air leakage through poorly performing windows, doors, and joints.



Thermogram 1 – Cold air infiltration due to gasket failure can seriously affect occupant comfort.

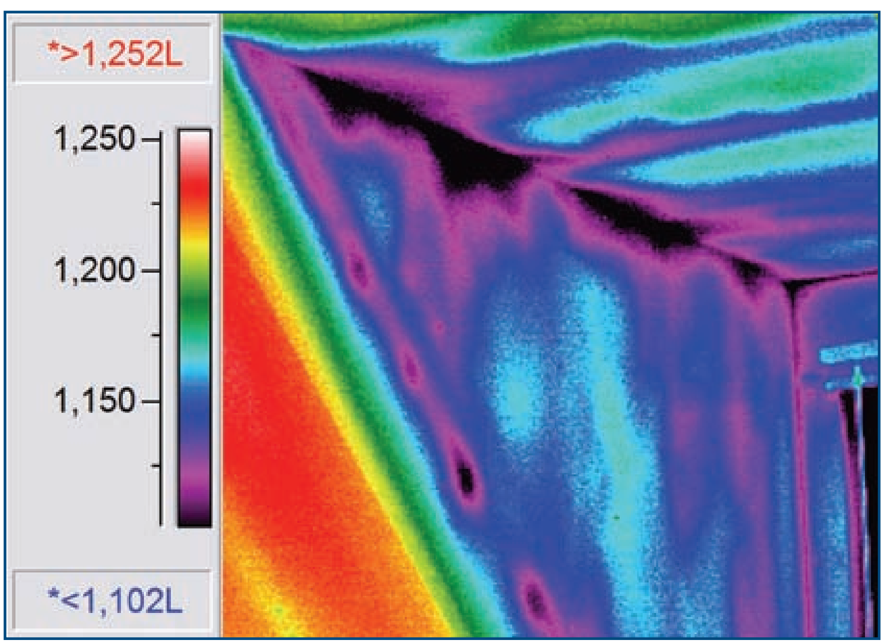


Below: Thermogram 2 – "Stack effect" is exacerbated by significant warm air exfiltration near the top of the building.

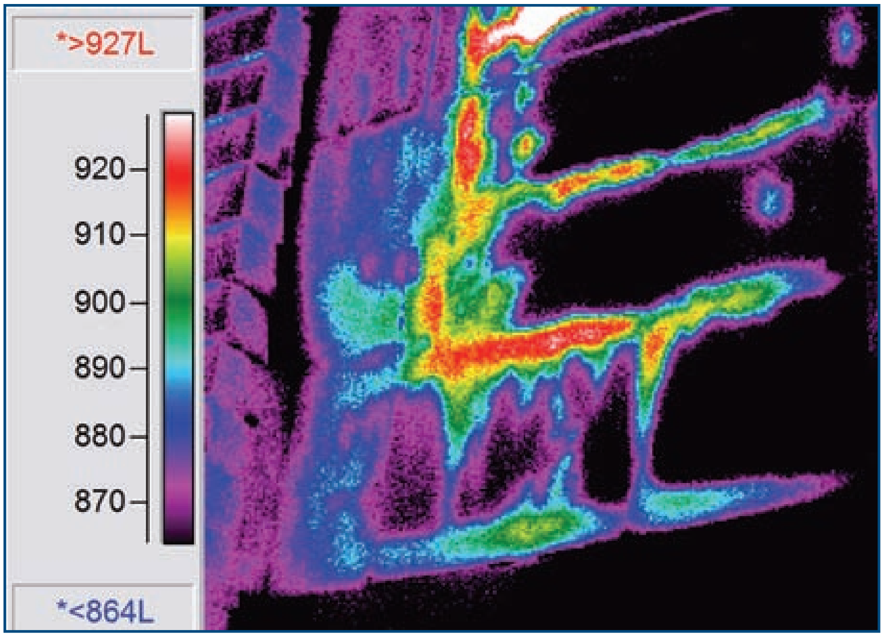
Occupant Comfort

Buildings that are too warm or too cold can substantially reduce employee efficiency and occupant comfort. Recently, a large office building in New York that was constructed with insulated metal panels was tested with an infrared camera. While the metal panels themselves were performing well, gaskets between panels and between the panels and window glazing allowed so much air transference that, on windy days, it was impossible to maintain the building's temperature at a comfortable level. Infrared testing revealed that the building was suffering from significant "stack effect" issues, with warm air escaping near the top of the building while cold air was infiltrating at the lower levels. *Thermogram 1* illustrates substantial cold air infiltration through leaky gaskets in the insulated metal panel system. *Thermogram 2* was taken of the outside of the building near the top and documents a typical area of substantial warm air exfiltration.

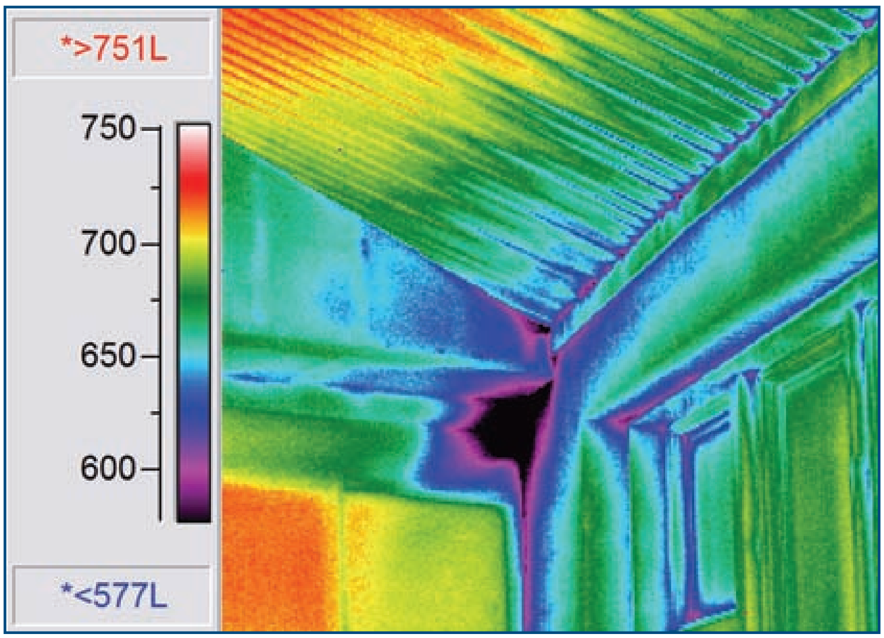
In some situations, conduction losses can also have a profound effect on occupant



Thermogram 3 – Substantial conduction losses were creating very cold temperatures on the interior of this newly renovated dormer.



Thermogram 4 (above) – Thermography is an ideal tool for isolating water-damaged areas in EIFS systems.



Thermogram 5 – Defective air/vapor barriers can create significant cold air infiltration problems.

comfort. A 150-year-old college building in which the attic had been converted into offices for professors and staff was similarly scanned with an infrared camera. After renovation, the entire floor of the building was experiencing very chilly interior temperatures, frozen pipes, and water damage.

Thermogram 3 depicts an office dormer wall and ceiling. In the lower left-hand corner of the thermogram a section of the pitched roof where the insulation is performing well can be seen. The wall and ceiling of the dormer are extremely cold due to poorly installed insulation and an inadequate exterior air barrier. The institution used the findings of the thermographic testing to guide an intensive effort to correct the detected problems.

Moisture Damage and Mold

Proactive approaches are always superior to reactive ones when dealing with moisture and mold. Thermographic inspection is a primary forensic tool for pinpointing the moisture damage that sets the stage for mold growth in walls and roofs. While infrared testing does not directly identify mold, early and accurate identification of water-damaged areas is the most effective and affordable component of any comprehensive plan for addressing and preventing mold colonization.

Roof consultants are all too familiar with the fact that moisture infiltration in the building envelope can begin in the roof system. A school district in Vermont had serious mold infestation in the summer of 2006. A combination of roof leaks and high interior humidity had created a mold bloom throughout substantial areas of the facility.

After spending $4.5 million on mold remediation and renovation at the elementary school, the district moved into a proactive mode. An infrared inspection was performed to locate leaks and potential mold sites in the low-slope roofing system of the high school. In total, 39 distinct areas of water-damaged roofing were identified. The school district is now moving aggressively to repair these areas and prevent further mold infestation.

Exterior insulation and finish systems (EIFS) may absorb water through joints and through breaches in the surface. Thermography is often employed to locate areas of moisture infiltration in EIFS installations. *Thermogram 4* illustrates the typical amorphous heat patterns associated with water damage in an EIFS assembly.

Catastrophic Failures

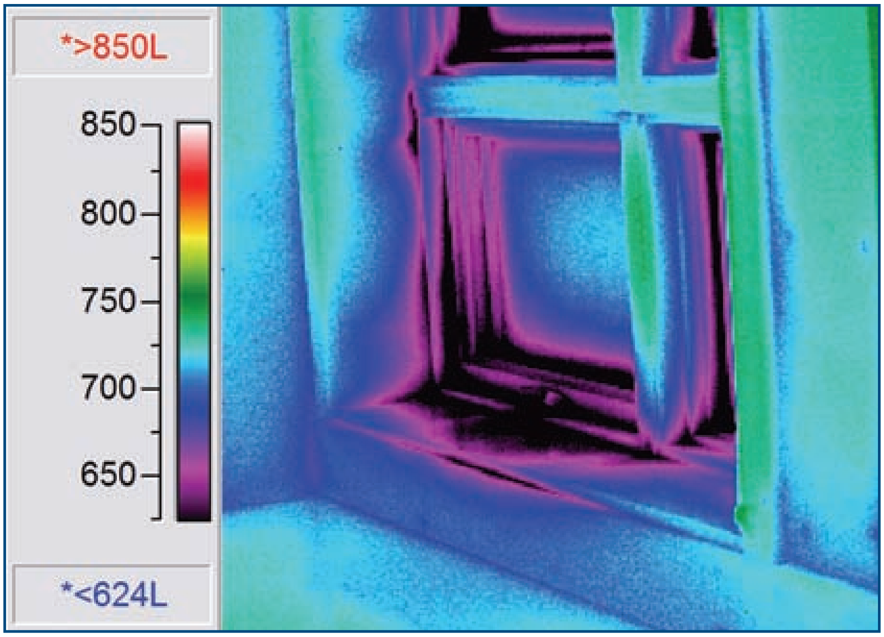
Non-destructive testing to identify the causes of catastrophic failures can be an invaluable aid to the facility manager. Several years ago, a wood-framed, fiberglass-insulated office building was tested following a serious incident of moisture damage. The sprinkler system in the attic had burst during an especially cold weekend, inundating the entire building.

When the thermographer arrived to conduct a visual inspection, the recovery team was removing all of the carpet and furniture and cutting out the base of the drywall on the interior partitions. Locating and mitigating moisture problems on the interior walls was relatively easy, but a big question remained: how much of the approximately 10,000 square feet of exterior wall system had been compromised?

Rather than stripping all of the interior drywall or doing random spot checks with a capacitance or impedance moisture meter, infrared thermography was employed to isolate areas of moisture damage in the exterior walls. Amazingly, despite the severe damage to the interior, only two small areas of moisture-damaged insulation were found in the exterior walls, saving the owners tens of thousands of dollars in demolition and construction costs.

Post-Construction Evaluation

Many newly constructed or renovated buildings have hidden design and construction deficiencies that can create serious problems in the future. Certified thermographers were recently asked to perform a quality control inspection of new construction on a college campus. *Thermogram 5* depicts an interior view of a wall/cathedral ceiling joint illustrating substantial amounts of cold air infiltrating through an inadequate air and vapor barrier. *Thermogram 6* reveals significant cold air leakage typical of the performance of the newly installed awning windows. Substantial differences in performance between two roof rakes are documented in *Thermogram 7*. In all, over 50 significant problem areas were identified.



Thermogram 6 – Even newly installed windows can have serious performance issues.

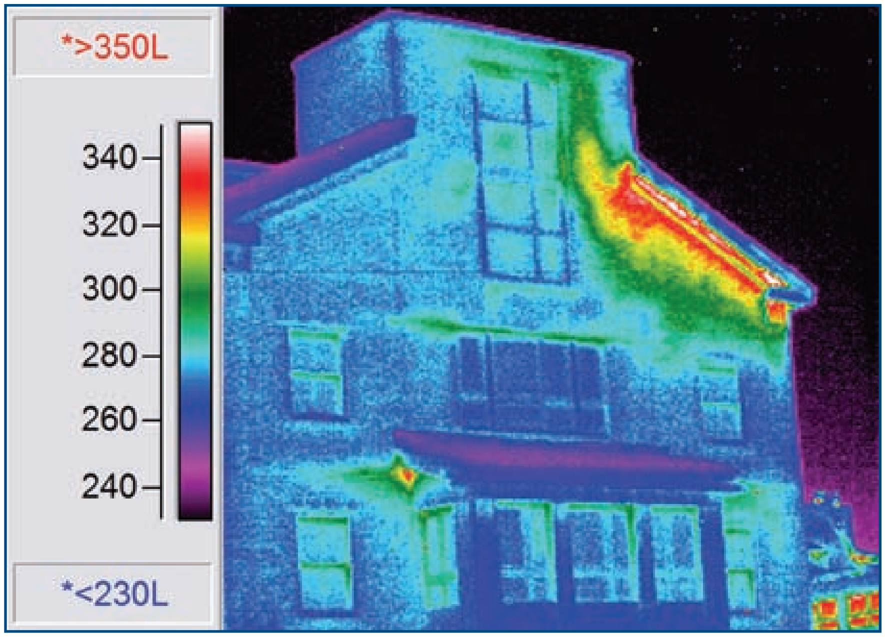
Dispute Resolution

Impartiality is key in any effort to resolve disputes involving substantial financial investments. A major advantage of high-quality thermographic testing is the unbiased nature of the findings. In such situations, it can be advantageous to have all interested parties on site during the infrared test. Once the causes of the problems are isolated and objectively documented for all to see, the parties responsible for the detected problems are much more likely to abandon rhetoric and "finger pointing" and to accept their responsibilities. In many cases, previously warring parties end up working cooperatively to come up with quick and cost-effective solutions.

Conclusion

New designs, materials, and installation techniques have created a situation in which the performance of the building envelope is much more critical to the health of the structure than in the past. Many of the problems we see today are not new to the construction industry but were previously much less problematic because older building materials and techniques were more forgiving. Nonetheless, today's emphasis on greater insulation levels and increased airtightness has great potential to produce better performing buildings that provide greater occupant comfort and substantially reduced energy consumption.

To make this happen, designers and builders are reacting to and incorporating many new concepts and materials. However, we will continue to encounter problems with design, materials, and workmanship that must be addressed to protect the health of occupants and the integrity of the building. Thermography promises to play an increasingly important role in designing, constructing, and maintaining trouble-free, energy-efficient facilities.



Thermogram 7 – Thermographic evaluations of new construction often reveal significant building envelope problems.

References

1. Commercial Envelope Requirements of the 2006 International Energy Conservation Code, U.S. Department of Energy Building Energy Codes Program.
2. *Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings, C 1060 – 90* (re-approved 2003), ASTM.

Peter Brooks

Peter Brooks has over 40 years of experience with facilities, including 15 in residential and commercial construction and contracting. He is also a Certified Thermographer with over 25 years of experience providing infrared services. Brooks is a recognized expert in the field of nondestructive testing and has trained thermographers at the national level in the methods and techniques of infrared testing. He is employed by Infra-red Analyzers Inc. of Williston, VT.

Russian Standards Body Signs MOU with ASTM

The national standards body of Russia has signed a Memorandum of Understanding (MOU) with ASTM International. The agreement was penned by Grigory I. Elkin, head of the Russian Federal Agency on Technical Regulating and Metrology (GOST R), and James A. Thomas, president of ASTM International, during a meeting at the Russian Federal Agency's headquarters in Moscow. The Russian federation joins 47 other countries that have also signed MOUs with ASTM, providing them full access to ASTM's collection of 12,000 standards – an important source of technological know-how to advance manufacturing productivity and product quality.

ASTM is one of the largest developers of international standards in the world, utilizing a process that embraces the principles of the World Trade Organization's Technical Barriers to Trade Agreement. Established in 1898, ASTM's standards are now accepted and used as international standards in 75 countries.

Nevada Nixes LEED Credits

The Nevada Senate on May 2 passed a temporary measure to suspend property tax breaks on private commercial projects achieving a LEED rating, due to a projected $110-million state budget shortfall. Projects had been granted up to a 50-percent, 10-year tax break for a silver LEED rating or higher. A "flood" of new planned LEED projects followed passage of the 2005 law, but only one building has presently been approved for the tax abatement to date. Discussion is ensuing concerning a possible maximum annual limit on abatements or grandfathering of those LEED projects currently underway.

— ENR