Think Thermally®

Practical news for practicing thermographers

Winter / 2007

In This Issue:

Understanding Emissivity– It's Only Skin Deep!

Dr. Roderick Thomas, CEng. FIET Level III Thermographer
UK General Manager – Snell Infrared International

Understanding emissivity and its effects are important if we are to produce meaningful reports of condition and especially if we are using temperature measurements as a tool to predict condition.

Emissivity is a property of all materials we encounter during industrial infrared thermography. Knowledge and skill are needed to understand if, when and how to correct for it. To better appreciate these difficulties, let's consider how they affect another thermographic application, namely medicine.

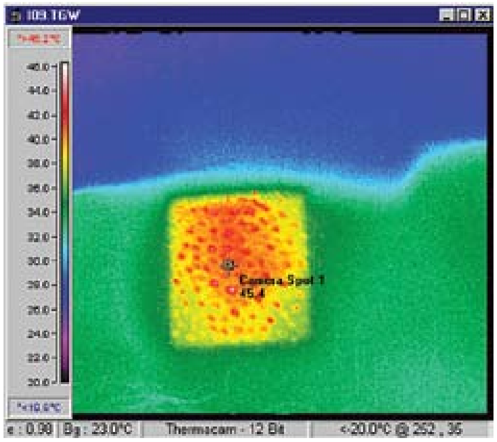

Image 1

In medical thermography we don't encounter the same range of emissivity values because human skin is almost a perfect emitter, or blackbody, with an emissivity that is approximately 0.98.

Even more extraordinary is what we see thermally after the skin has been "flashed" with a broadband lamp (Image 1). The image of the forearm, taken with a close-up 100µm re-imaging lens using a mid-wave infrared camera, is remarkable! Look closely and you can see one of the reasons why the skin has such high emissivity. With the skin illuminated in this way thermal contrast is sufficient to show that the outermost layer, or stratum corneum, actually consists of a large number of small cavities, each of which absorbs energy efficiently with little reflection.

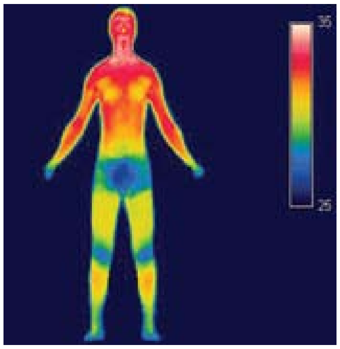

Image courtesy Dr. Peter Plassmann, University of Glamorgan, United Kingdom

Image 2

Skin acts as an energy exchange media between the central core and the environment. Thermal equilibrium of the body is connected with its physiological state, two principal factors being evaporation of moisture from the surface of the skin and blood flow. Perspiration and skin blood flow introduce variables that effectively alter the heat transfer rates.

When we look at the entire body, as is currently being done at the University of Glamorgan, United Kingdom, under the leadership of Professor Francis Ring, we see images that accurately portray surface temperature variations. In this particular image (Image 2, left) the scale represents the statistical mean

Continued on page 6

Thermal Reflections

John Snell, ASNT NDT Level III
President – Snell Infrared

Like most thermographers, I can still clearly remember the first time I looked through an infrared camera. I was in the rather challenging situation of having contested payment to a contractor who'd done a poor job of insulating a building for me. The thermal images were amazing! They also clearly showed that much of the building was, in fact, not insulated properly. With those results I was able to "negotiate" with the contractor to have the work completed correctly.

Twenty-five years later I am fascinated more than ever by the power of the technology. We have smaller cameras at lower prices with better image quality and radiometrics than ever before. We regularly show thermal images that are so persuasive no one can argue with them.

I am also amazed at how much of our work has nothing to do with the technology. In the end it is often about basic human communication. As we set up a job, gather and interpret the data, and pass it on to the next person in the chain, we must draw on our non-technical skills to ensure that our work actually makes a difference. Even though I had proof my insulation contractor did a bad job, I still had to communicate clearly and persuade him to re-do the work.

John Snell

Just as thermographers need to practice basic imaging and analysis skills, we also need to work on asking the right questions and listening carefully for the answers.

Without trying to sound like I have all the answers, I suggest we all take time to carefully listen as questions are being asked. We may be surprised at what we hear. The results of inadequate human communication are real and costly. Here are a few common examples:

- Some in maintenance estimate 50% or more of found problems are not repaired properly the first time. Many thermographers assume their "shorthand" reporting will be understood. Make a point to follow up on repairs and you'll find improved repair percentages.
- Tradesmen are often threatened by the findings of a thermographer because the thermal truth cannot be hidden. Thermographers need to find ways to report findings that are less threatening while still communicating necessary information.
- Managers often don't want to hear about the numerous problems a thermographer uncovers, especially when the maintenance system is already overloaded. The thermographer must take the time to consider their results within the larger overall context of asset health management.
- Customers may jump to conclusions about the temperature values shown on a thermogram. Take time to develop a coversheet explaining in simple terms the basics of what thermography can and cannot do.

Most of the thermographers I've had the privilege of working with in my 25 years of teaching understand they are part of a team. They realize they have a role but cannot accomplish much by themselves. Of course, we are all proud of our great thermal images. Let's work at our communication skills with our co-workers and customers so we are just as proud that together we can find solutions.

Think Thermally® is a publication of Snell Infrared, providers of training, certification and support services for thermographers.

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Infrared and Motor Circuit Analysis

As much as I would like to tell you infrared thermography is the only condition based monitoring tool you will ever need, I would be doing you a disservice. While thermography is extremely versatile, sometimes it is not the best diagnostic tool for a given application. Instead it is one tool in our condition based maintenance toolbox. As we have mentioned in previous articles, correlation of technologies can be very beneficial. If the asset is critical we should be applying all appropriate technologies at the proper inspection frequency to know and understand the health of the asset.

During a recent routine infrared inspection, Snell Inspections technician, Jeff Cordova, observed an abnormal thermal pattern on a pump-coupling-motor asset (Image 1).

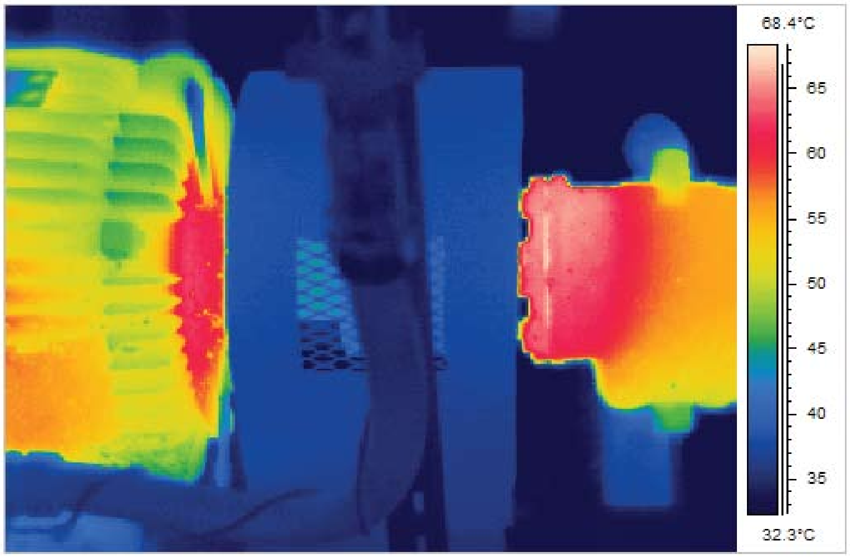
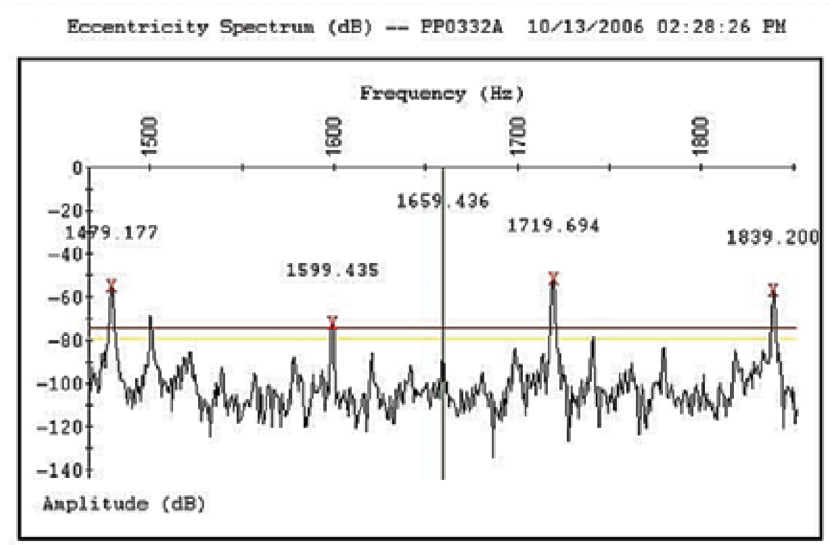


Image 1

Hot inboard bearings on both the motor and pump needed to be reported but when it came time to make a repair or follow up recommendation, Jeff wanted to review the results of other technologies first. He contacted another Snell Inspections technician, Jeff Nantz, who conducts routine online and offline motor circuit analysis on this asset, to discuss any recent MCA testing results. The following graph (right) represents the results of the eccentricity test ran on the asset.



Graph 1

The eccentricity test is performed on an energized AC induction motor and is designed to identify non-uniformity of the air gap between the stator and rotor. This non-uniformity may be caused by mechanical looseness, misalignment or soft foot conditions. Analysis of this graph requires looking at the sidebands of eccentricity at +/- 60 Hz and +/- 180 Hz. In the case of the above graph we find three sidebands 20 dB above normal noise levels indicating an alarm condition.

What's the next step? We have two technologies pointing to an abnormality. One option will be to check the results of another technology if available. Vibration analysis or mechanical ultrasound may provide more details. A simple visual or strobe light inspection may be helpful as well.

The information was turned over to the maintenance manager and it was his decision to plan and schedule an alignment. During the alignment process it was also decided to replace the coupling insert.

To be continued. Please check back for part II of this Lesson From the Field in the Spring 2007 issue of "Think Thermally."

Greg McIntosh, P.Eng.,
Managing Director, Snell Infrared Canada

Cold Weather Performance Issues with Infrared Cameras

Now that winter has finally settled in, I would like to give some thought to the various issues surrounding the use of infrared cameras outdoors during cold weather. Let's look at the relevant figures of merit of infrared cameras that relate to cold temperatures: Storage Temperature Range, Operating temperature range, Object Detection Range, Calibration Range, Thermal Stability (Drift) and Thermal Sensitivity.

Storage Temperature Range

This is the range of temperatures that your equipment should be stored at. We often don't think about this temperature range when leaving our camera in the trunk of a car. In winter the trunk temperature may depress below ambient (on a clear calm night) or on a warm summer afternoon it can easily get as high as 70°C (158°F). Not only should you always ensure your camera is stored well within the manufacturers specified range, but it should also be stored at a temperature close to that expected when you first start to use it: otherwise it will take longer for your camera to stabilize (see Thermal Stability).

Operating Temperature Range

This is the range of ambient air temperatures in which your camera is designed to operate. When working in extreme cold some users enclose their cameras with an insulated cover: One user we know even used his battery powered 'electric socks' to keep his camera warm. A general rule of thumb is that if the environment is too extreme for you to work in, it's probably too hot or cold for the camera as well.

Detectable Temperature Range

Often called simply 'Range', this specifies the limits of detection for the cameras detector. While the upper limit of the Range is often the saturation point for the detector, it is at the lower end which is difficult for the manufacturers to specify. Some say it is when the specified sensitivity, Noise Equivalent Temperature Difference (NETD), of the instrument is no longer valid. Others say that it is the lower limit of valid calibration. Some don't even state how it was determined. But if you are performing cold weather work you need to know and, more importantly, should know this lower limit before you even buy a camera.

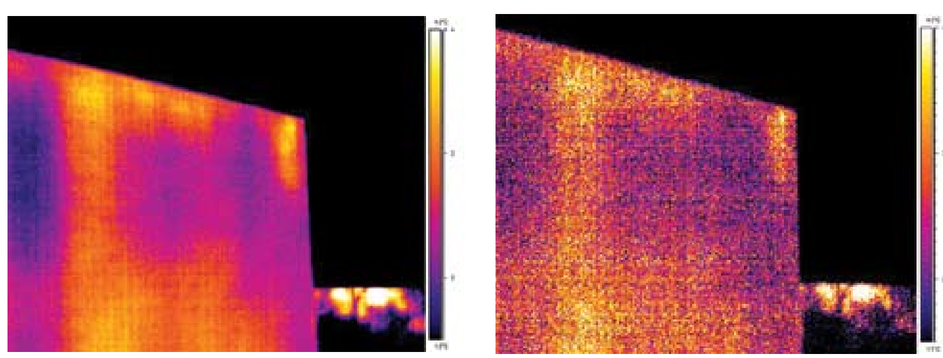
Calibration (or Measurement Range)

Calibration range has to do with maintaining the instrument within specified accuracy limits (typically +/- 2°C at lower temperatures). Some camera manufacturers for instance will indicate an operating temperature range of -15°C to +55°C (5°F to 131°F) but the calibration range is only valid for 0 to +45°C (32°F to 113°F). Others will specify one accuracy for objects above 0°C (32°F) and a less accurate figure when measuring below 0°C (32°F).

Thermal Sensitivity

This is the figure of merit for how 'nice' your image appears when the thermal Span is narrow. Thermal sensitivity or how small a temperature difference your camera can detect is often expressed in milliKelvins or mK. (a milliKelvin equals 1/1000 of a degree Celsius). Modern infrared cameras have sensitivities ranging from 20 mK to 200mK. Unfortunately most of these figures are specified for a warm surface, typically at 30°C (86°F) (e.g.: a 20 mK camera can, in theory, detect the differences between 30.00 and 30.02°C on a blackbody.)

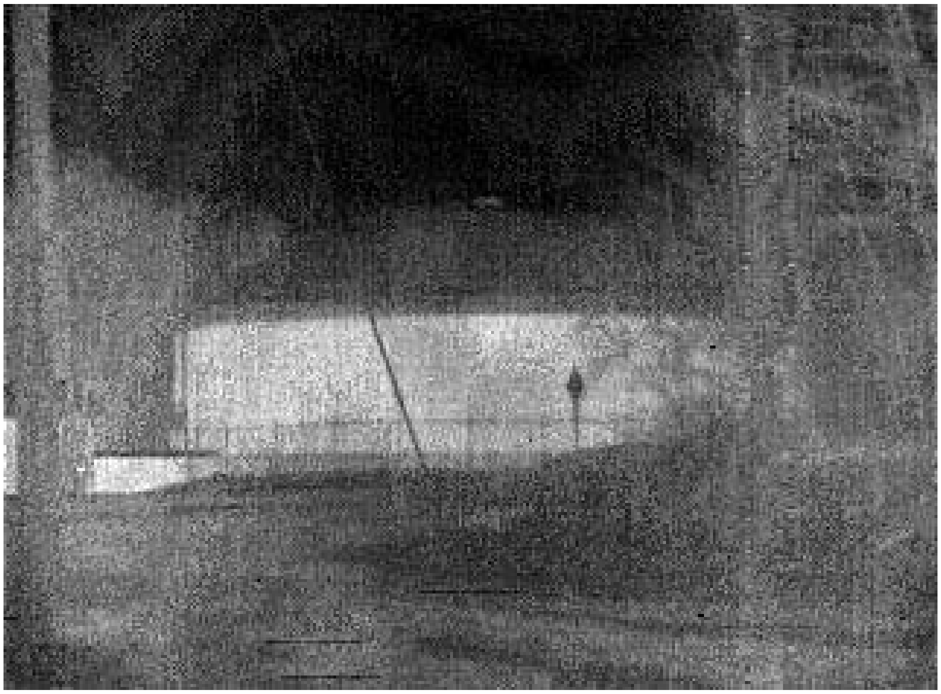
A simple way to test for NETD performance is to store an image of an object which is thermally uniform (e.g. a lens cap or the inside page of a book) and then in software create an area analysis box which calculates the standard deviation. The standard deviation



Some cameras are less sensitive than others at sub-zero temperatures. A lower sensitivity results in an image like that shown on the right which is 'grainy' or looks like it is snowing.

will be an indicator of the NETD of the camera. Have the camera observe the same uniform surface but now typical of the object temperatures you wish to inspect. The change in standard deviation will indicate the degradation factor of the NETD with temperature. Most camera manufacturers will not specify how their thermal sensitivity degrades at low temperatures.

You may notice when observing cold surfaces that your image appears "grainy" or appears like it is "snowing". This happens as you lower the span to try to observe the temperature differences on a cold surface but the camera has lost sensitivity because of the colder object temperature (remember Stefan-Boltzmann in Level I and II?). In instrument terms the signal-to-noise-ratio has dropped. The loss of sensitivity will depend on many camera design parameters including such things as detector (type, size, and temperature), number of lens elements, f-number, optical path design, thermal stability, electronics and signal processing.



Camera instability at cold temperature will often appear like you are looking through a dirty window, or the edges of the image will appear colder or warmer. This tank level, taken at -12°C ambient air temperature, still clearly shows up because the water in the tank is still well above freezing.

Thermal Stability

This factor is often not explicitly defined, although may appear in the operating recommendations for your camera: e.g.: how long you should wait after startup before making a measurement; or the suggested time interval or situation for performing a non-uniformity correction (NUC). After startup, when moving a camera from one thermal environment to another the instrument must be given time to thermally stabilize. On cameras with an automatic NUC function you will notice the shutter close frequently after the change and less frequently as the camera stabilizes. If your camera does not have this automatic function then you should manually perform one. Not only may measurements be affected (an instability in measurement due to this change is called instrument ' thermal drift') but you may observe that the edges of the screen appear to be cooler or warmer, or the image looks like it is 'dirty'. A NUC may help clear this effect, particularly if your camera is capable of performing an 'external' NUC and you use a uniform surface that is as cold as or colder than the objects you wish to observe.

Condensation

One issue you need to be careful of is condensation. When your camera has been used in a cold environment and then brought inside, the camera surfaces may be below the dew point of the inside air and condensation may form on the camera surfaces, including the lens. In some cases where the camera is not tightly sealed (e.g. the lens is changed) condensation can sometimes form on the inside of the camera. Lightly wiping the camera or lens may remove the condensation but it will re-appear as long as the surface remains below the dew point. Rapidly warming the camera with, say, a hairdryer is also not recommended since it will create camera thermal instability and could thermally shock the camera materials such as the lens. It may also be possible to temporarily seal the camera in a clear plastic bag, using it in this way until it has warmed above the dew point. Whenever possible, perform your inside inspections first and then move outside to avoid condensation.

Conclusion

The bottom line: when inspecting during cold weather, don't assume that your camera (or you!) will perform adequately or efficiently. And, if cold weather inspections are an essential part of your business, make sure – before you buy! – that you try out the camera(s) under the kinds of cold weather conditions in which you expect to be working.

Understanding Emissivity – It's Only Skin Deep!

Continued from page 1

of 15 morphed and aligned full-body views, all of males, 18 to 30-years old, in Body-Mass Index (BMI) group 2.

On further examination of the body it can be seen that there are colder and warmer areas, most of which are expected and which relate to our understanding of heat transfer. Because of this direct relationship, we understand what's happening below the skin! Variable emissivity on human skin is potentially a problem due to the use of various skin preparations, such as creams and make-up, which, therefore, should not be used prior to the examination.

Compare this to a different "body" – an industrial furnace (Image 3), for example, and it is clear we also need to understand or characterize its emissivity. The thermal image of the furnace shows overall surface temperature variations up to 80°C (176°F), assuming emissivity is uniform.

Even without knowing the emissivity we can infer the warmer spots probably correspond to defective refractory lining, however, we would also need to ensure they are not the result of localized burners. To eliminate this possibility, knowledge of the internal construction, furnace operation and location of burners is required.

This sort of infrared inspection is usually carried out as part of qualitative thermography program to identify patterns or differences without regard to their exact temperature. The next stage, if necessary, may involve gathering quantitative data and trending it over time to better predict condition severity. Many electrical systems and machines will have similar heat transfer characteristics based on their internal construction. Accurate measurements must account for emissivity of the surfaces.

The casing of the motor (Image 4) was coated with a regular industrial paint and, thus, exhibits a uniform, relatively high emissivity. There is however an uncharacteristically large temperature difference on the drive end (left) of the motor. Clearly this is the

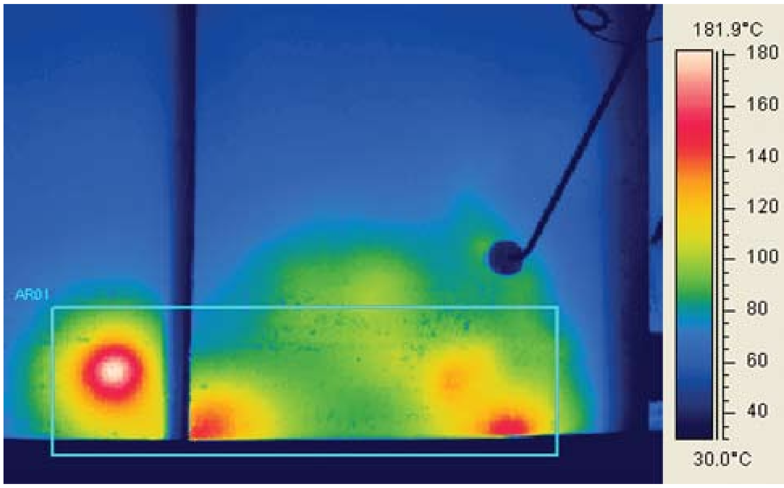


Image 3

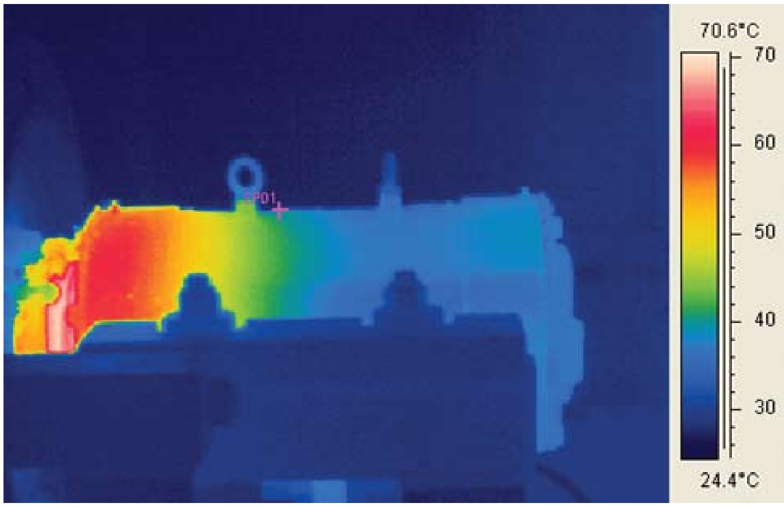


Image 4

end where energy is transferred and work is done and allowance is made in this case by incorporating twin-race bearings. To understand the thermal image and for meaningful reporting, we again need basic knowledge of the internal make-up, operation and location of key components of the motor and drive train. In this case the problem was that the bearings required lubrication.

Whenever considering the impact of emissivity and machine operations, here is a good checklist to follow:

- Characterize the emissivity of the surface and ask "is it uniform?"
- Is emissivity high? Almost any non-metallic, painted, surface usually has a high emissity. If "yes," can you identify any temperature differences or thermal anomalies?
- Have you taken load conditions into consideration?
- What are the influences on heat flow of the machine itself? How does the internal hot/cold spot end up being seen on the surface?
- How do environmental conditions – wind, convection, ambient air temperature – affect surface temperature?

Only after considering all of these complex and inter-related factors can we make sense of the thermal images we see and the radiometric temperatures we measure.

2007 Thermography Training Schedule

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LEVEL I	DATE	$1,595
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Cincinnati, Ohio	April 16-20	
Toronto, Ontario	April 30-May 4	
Kansas City, Missouri	May 14-18	
Minneapolis, Minnesota	June 4-8	
Montreal, Quebec (French)	June 4-8	
Toronto, Ontario	June 18-22	
Montpelier, Vermont	July 16-20	
Toronto, Ontario	August 13-17	
San Diego, California	August 13-17	
Charlotte, North Carolina	September 10-14	
Manchester, New Hampshire	September 17-21	
Toronto, Ontario	September 24-28	
Indianapolis, Indiana	October 15-19	
Toronto, Ontario	November 5-9	
San Antonio, Texas	November 5-9	
Montpelier, Vermont	December 3-7	
Toronto, Ontario	December 10-14	

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Toronto, Ontario	May 7-11	
Charleston, South Carolina	June 4-8	
Montpelier, Vermont	July 16-20	
Montreal, Quebec (French)	September 10-14	
Cincinnati, Ohio	September 10-14	
San Antonio, Texas	November 5-9	
Toronto, Ontario	November 12-16	

LEVEL III	DATE	$1,950
Montpelier, Vermont	June 4-8	
Toronto, Ontario	October 22-26	

BUILDING SYSTEMS*	DATE	$1,095
Charlotte, North Carolina	February 27-28	
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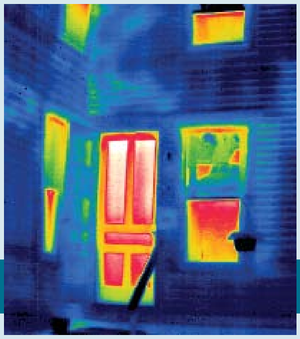
Cincinnati, Ohio	September 20-21	
Montreal, Quebec (French)	November 21-22	
Toronto, Ontario	December 6-7	



ELECTRICAL APPLICATIONS*	DATE	$1,095
Toronto, Ontario	February 19-20	
Charlotte, North Carolina	March 1-2	
Indianapolis, Indiana	April 10-11	
Montreal, Quebec (French)	June 14-15	
Cincinnati, Ohio	September 18-19	
Toronto, Ontario	November 29-30	

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Available. Please Call.

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Bridgend, United Kingdom	October 22-26
Johannesburg, South Africa	November 12-16

LEVEL III	
Johannesburg, South Africa	February 26-28
Johannesburg, South Africa	November 19-21

ELECTRICAL APPLICATIONS	
Johannesburg, South Africa	March 1-2

MECHANICAL EQUIPMENT	
Johannesburg, South Africa	November 22-23

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