

# Think Thermally

October 2001

Practical news for practicing thermographers

## See inside:

- Expand Your Thermal Library
- Infrared Camera Tip
- *in the Press...*

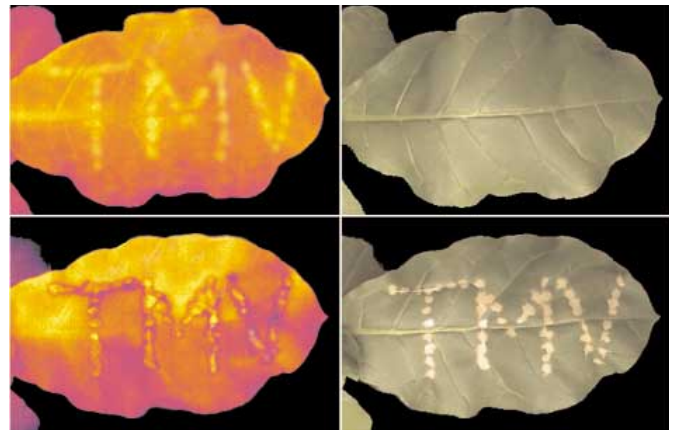
See **Thermal Solutions®** special insert for updated event information



## Feverish Plants: Hotspots Highlight Disease

Laury Chaerle and Dominique Van Der Straeten  
Department of Molecular Genetics, Ghent University, Belgium

Plant leaves control transpirational water loss by regulating the aperture of microscopic valves called stomata. In case of water shortage, stomata close, resulting in decreased transpirational cooling. The ensuing leaf surface temperature increase is readily visualized by thermography. Stomatal closure is mainly controlled by the level of the plant hormone abscisic acid. However, multiple other factors influence stomatal aperture. Salicylic acid (SA), a central compound in the defense reaction of plants against pathogens, was previously shown to decrease transpiration.



### ...cell death starts to emerge as dark points at the center of the thermal hot spots...

During the infection of resistant tobacco by tobacco mosaic virus (TMV), SA accumulates before the manifestation of cell death. By using thermography, a local increase in temperature was monitored before visual symptoms became apparent. This is exemplified by the top left image, where localized infection was carried out following a pattern forming the letters TMV. The upper thermal (left) and visual (right) images were taken at an early time-point, 40h post infection. Although the hot spots clearly

visualize the infection pattern, no visible signs of cell death are apparent. The lower images, captured 5 days later, show an extensive cell death pattern.

Initial experiments indicated the necessity of stable temperature and still air conditions to monitor reproducibly the local spots of higher temperature at the sites of viral infection. A positioning system (see photo at far left), enabling to study several plants in a single experiment, was therefore integrated into a custom-built growth chamber.

A kinetic analysis of the appearance of thermal and visual symptoms is represented by five chronologically arranged images (see *inside back page*) of a tobacco leaf, the left side of which was infected. To obtain sufficient resolution, three subimages were captured per leaf. On the first thermal and visual images, taken 28h after infection, no symptoms can be distinguished.

*continued on inside back page*

## Expand Your Thermal Library!



We are pleased to inform our readers of the recent publication of three new books relating to thermography. We are also proud that some of our staff and many of our graduates had a role in writing the books.

McGraw-Hill published the book,

**Handbook of Nondestructive Evaluation**, edited by Chuck Hellier. This book is a primer on all the major methods of NDT, including infrared. Mr. Hellier is President of HELLIER, one of the largest NDT training companies in the world. He invited John Snell and Rob Spring to co-author a chapter on thermography. "We're thrilled to work on this project with Chuck and McGraw-Hill, knowing it will fill an important gap in the traditional NDT world," said Snell.

The American Society for Nondestructive Testing (ASNT) continues to round out their Handbook series with the long-awaited publication of **Nondestructive Testing Handbook, Infrared/Thermal**. The project was first conceived and outlined nearly ten years ago, then stalled for a number of years waiting for a qualified technical editor. The editor, with able support from ASNT, needed to be able to volunteer enough time to get the job done.

Dr. Xavier Muldague, Professor at Laval University, proved to be the perfect person for the job. Dr. Muldague, well known to many of us for his previous publications and pioneering work in materials evaluation, invited leading experts in the industry to author and review the various chapters of the book. He also included a number of articles and papers previously published by ASNT. We were pleased to see a number of the papers originally published at our first Thermal Solutions® conference (produced by Snell Infrared for ASNT in 1995). Parts of the book may be beyond the needs of many practicing maintenance thermographers, but it is a welcome resource that will serve us well for many years to come.

Another new publication due out soon is **Alien Vision** by Austin Richards, Ph.D. of Indigo Systems. This fascinating visual tour takes you beyond the range of human sight and explores the electromagnetic spectrum with imaging technology. Dozens of images and clear, concise text make this an intriguing, accessible technical book. Dr. Richards will be presenting an excerpt from his book at Thermal Solutions® 2002 in Orlando, Florida.

Several infrared-related reference materials are now available at the **Snell Infrared Online Webstore**.

If you want to expand your thermal library, these books are a great place to start!  
Go to <[http://www.snellinfrared.com/\\_store/](http://www.snellinfrared.com/_store/)>  
or call us at 800-636-9820.



### Infrared camera tip of the day:

Invest in a high-quality, blackbody reference; an adjustable, medium range device will cost about \$2500. Why invest? You can then check the calibration of your radiometric imaging system as often as necessary. We typically recommend our students conduct a formal check on a weekly basis. For those in research & development, daily calibration checks are often the norm. These checks are an important component of a quality assurance program.



Investing in a blackbody can also mean you no longer need to send your camera back to the manufacturer for annual service. These service checks, sometimes little more than a calibration

check, often cost several thousand dollars and require your camera to be out of service for weeks on end. With a black body reference you always know the actual condition of your radiometric system. Call us for a free form to document your camera calibration checks.

### To the N<sup>th</sup> Degree!

If you happen to be driving along Interstate 15 between southern California and Las Vegas, look for this modern landmark. This thermometer, the world's tallest, can attest to some of the highest temperatures in the country. Temperatures in excess of 120° are often displayed in the summer. Now that's what we call a *thermal phenomenon!*



# We have a *solution* for you in 2002...

## Thermal Solutions®

Begin the New Year with a *solution*... Thermal Solutions®! Join us in Orlando January 21–24 for the premier infrared thermography conference of 2002. This exciting and educational conference presents the latest technical knowledge in infrared and provides valuable opportunities for professional interchange among participants. Thermal Solutions® provides the interface for industry experts and real world thermographers to share information and experience. This venue is guaranteed to expand your thermal knowledge and improve your effectiveness—saving you and your company money.

The core of the conference is the presentation of technical papers. Twenty-four papers will focus on condition monitoring and reliability, and an entire track devoted exclusively to nondestructive testing will be added this

year. All presentations will be yours to take with you in a full-color conference proceedings. This will give you valuable reference material for years to come.

The pre-conference short courses provide opportunities to participate, learn, get answers, and take a manual back to work with you! You'll have your choice of six three-hour courses offered Monday, January 21st. In the morning choose one of three concurrent courses: *Advanced Signal Processing for Thermographic NDT*, *Conducting Effective Roof Surveys* or *IR Software Overview and Report Writing Workshop*.

That afternoon select from *Maintenance Optimization in Electric Utilities*, *Mechanical Applications for Infrared* and *Inspecting Heaters, Furnaces and Boilers Inside and Out*.

There will be several vendor exhibits of infrared imagers, point radiometers, communication companies (both print and web) and other associated technologies displaying their products. The exhibits give you the opportunity to see what's new in the industry and try out the latest equipment.

Wednesday afternoon two exciting and adventurous field trips have been scheduled. Take the fast track to fun and adventure at Daytona Speedway where you'll experience a behind-the-scenes VIP tour. Or, experience outer space here on earth at Kennedy Space

Center and take an awe-inspiring journey into space.

The conference officially begins Monday night at the

opening reception, where you'll be entertained as well as informed. Enjoy a fascinating keynote address by Austin Richards, Ph.D. Dr. Richards will take you on an enthralling visual tour beyond the range of human sight, exploring the electromagnetic spectrum with imaging technology.

This conference provides a variety of learning opportunities that will give you the knowledge you need to discover new solutions to your thermal challenges.

**Orlando, Florida  
January 21–24, 2002**



- **Gather insightful information on the latest thermography applications**
- **Take a full-color conference proceedings back to work with you**
- **Try out the latest equipment at the vendor exhibits**
- **Build lasting professional contacts with thermography colleagues**
- **Stay involved in the infrared industry**
- **Learn from the six educational short courses**
- **Have fun on your choice of field trips**
- **Find solutions to your infrared program problems**
- **Be proactive and share your experiences with your peers**

## Daytona USA Speedway VIP Tour

Experience the ultimate adventure on this behind-the-scenes tour. You'll be taken to places that few race fans get to go. Tour the Winston Tower Suites and the Daytona Club, usually reserved for corporate heads and celebrities. These suites are fourteen stories above the start/finish line. Observe the spectacular view of Daytona International Speedway and the surrounding area. At 150 feet up, you'll feel like you're on top of the world! Then you'll literally be on the fast track... a thirty-minute see-it-all tour takes you to the NASCAR garages, Pit Road and around the world-famous thirty-one degree banks. You'll actually cruise the racetrack in a tram and experience the scene from the driver's viewpoint. Also visit Daytona USA, a one-of-a-kind interactive motorsports attraction featuring a variety of hands-on activities. Use technology to design and test drive a stock car, talk with one of



your favorite NASCAR drivers using laser disc technology, and examine the design features of a NASCAR Winston Cup stock car at DuPont's Technology of Speed. You'll see Jeff Gordon's car come apart in front of your eyes. Stop by the Pepsi Theater for a film experience: "The Daytona 500" takes you to race day and puts you in the middle of the action on a three-story-tall screen.

## Kennedy Space Center Exploration

Experience outer space here on earth. This tour brings you face to face with a real astronaut in an innovative program consisting of a question and answer session, mission briefing, video footage, space artifacts and personal stories of space travel as told by those who have lived it. You'll see the Flight Deck, where astronauts fly the orbiter during actual launch and landings, and the Mid-deck, where shuttle crews work on experiments, sleep and eat. See the rockets that launched astronauts and machines into space. See and actually touch a piece of Mars, walk through the Mercury Mission Control Room, and take an awe-inspiring journey into space on a five story tall IMAX screen.



## Condition Monitoring Partial Paper Listing

Nina Olinger, General Motors

*The highs and lows of current available and temperature relationships*

Brett Monroe & Tom Kremser, Monroe Infrared Technology

*Applying IR to slow rotating U-joints*

Andrzej Oscilowicz, General Motors

*Troubleshooting motors with infrared thermography*

Norm Gaver, HSB Thermography Services, Inc.

*Thermography in the paper mill; detecting moisture irregularities*

Bruce C. Smith, Life Cycle Engineering, Inc.

*The benefits of thermographic surveys during ship building and overhauls*

Luther G. Hill, Jr., EPRI Solutions

*Using infrared technology to inspect overhead transmission line components*

Brian Yarbrough & Jim Nelson, HSB Thermography Services, Inc.

*Renewable fuses: protection or self-deception?*

Stuart Swanger & Marley Marlin, Pharmacia Corporation

*Implementation and challenges of using route data collection*

Rae Limerick, Primus V. Mtenga & Jeffrey Parzych, Florida State College of Engineers

*Quality control of concrete retrofit using infrared thermography*

Jim Gamble & Sheryl Lau, Abbott Laboratories

*Early detection with infrared inspections equals higher cost savings*

George A. Chrenka, Nu-Wool Co., Inc.

*The use of thermography with a Minneapolis blower door to determine air leakage in the thermal boundary of residential homes and to evaluate insulation performance and quality*

Tom Stivers, E. I. DuPont de Nemours & Company, Inc.

*Using infrared surveys as predictive and preventive maintenance on large refrigerant compressor units*

Jacques Frate, Hydro Quebec Research Institute

*Infrared thermography: a diagnostic tool to assess the status and the remaining life of equipment used on electrical power lines*

Karl Jessen, Entergy

*Various overheat situations found in annunciator/control panels for the steerspersons*

Jacques Lanteigne and Daniel Fournier, IREQ, Institut de recherche d'Hydro-Québec

*How to generate infrared images from finite element simulations*

Rob Spring & John Snell, Snell Infrared

*A unique thermal problem in double-glazed windows*

Daniel Fournier and Jacques Lanteigne, IREQ, Institut de recherche d'Hydro-Québec

*The use of finite element simulations for the interpretation of infrared images in electrical inspection: A practical case*

Richard N. Wurzbach, Maintenance Reliability Group, LLC

*Developing a comprehensive training curriculum for integrated predictive maintenance*

Bill Grondahl, Georgia Power

*Experience with adapting IR camera to aerial use and IR camera use in conjunction with resistive measurements*

Tony Rolland, Thermoscan Inspection Services Pty. Ltd.

*Communication - the 3 'R's and ABCD*

Robert Hammaker, EPRI Solutions, Inc.

*Optimization of maintenance in power plants*

David Gleaton, Westinghouse Savannah River

*Infrared thermography provides a safe and reliable method of inspection for high-level radioactive waste storage and processing facilities*

## NDT Partial Paper Listing

David Sass, U.S. Army Tank-automotive and Armaments Command  
*High speed thermal imaging*

Mike Ashbaugh, Sandia National Laboratories/AANC  
*Thermography in aircraft inspection*

Ron Predmesky, Ford Motor Company  
*Infrared inspection of tires*

Carl Bouvier, Lockheed Martin and Sam Russell, NASA  
*Thermographic Inspection of airspace tankage*

Paul Rutherford and Michael Fogarty, The Boeing Co.  
*IR nondestructive inspection capabilities for composite repairs of metallic structure*

# Short Course Summaries

## **Conducting Effective Roof Surveys**

*Peter Brooks, Infrared Analyzers*

All infrared testing applications can be valuable, but probably no application has as much consistent potential for saving big money as roof moisture surveys. The investment of a small amount of time and money often results in savings of tens, or even hundreds, of thousands of dollars. The testing is based on simple theories, but the actual production of an accurate roof survey is plagued with issues of weather dependency, reflectivity, image transience and numerous types of false positives and negatives.

Drawing on Peter Brooks' twenty years of roof moisture survey experience, this short course will provide you with the practical knowledge you need to accurately locate and document moisture damage in flat roofing systems. The majority of the class will be concerned with infrared testing, but the other two common test methods will also be briefly discussed. Thermographers of all ability levels are invited to attend this short course, as this will contribute to lively discussions and a rich classroom experience.

## **IR Software Overview and Report Writing Workshop**

*Roy Huff and Greg McIntosh, Snell Infrared*

This course is divided into two sessions: the first session will include an overview of how and why infrared software can be used to assist in evaluation, analysis, and report generation. The discussion will encompass the many common features of software from a number of manufacturers and third parties, with a focus on the use of software to increase efficiency. The second session will be a hands-on workshop where specific user issues can be addressed, with a particular focus on report format, generation, and the use of templates. Participants are encouraged to forward specific problems and topics that they wish addressed ahead of time via email to the Thermal Solutions® webmaster at info@thermal-solutions.org.

## **Advanced Signal Processing for Thermographic NDT**

*Steven Shepard and Tasdiq Ahmed, Thermal Wave Imaging, Inc.*

The use of active thermography for commercial NDT continues to gain acceptance, as improvements in IR camera and computer technology, and increasingly sophisticated signal processing methods are integrated into commercial systems. In active thermography, the surface of the part is typically heated with a brief light pulse, and the cooling behavior of the part is recorded with an IR camera. The data from the camera is used to construct an image of the subsurface structure of the part, which may include delaminations, trapped water and corrosion. However, the process of inspecting structures that span large areas (greater than a few square feet) remains a cumbersome, time-consuming task. In this instance, several individual shots covering small portions (~1 sq. ft.) of the total area are acquired, processed and viewed separately. Although the time required to collect the data may be as little as 5 seconds per shot, processing and evaluation all of the collected data may

require several additional hours. TWI has recently developed MOSAIQ, a software program specifically for evaluating data from large area thermographic inspections, that significantly reduces the total inspection time, and improves the signal to noise, resolution and depth sensitivity of thermal inspection. Using a proprietary Synthetic Signal Processing approach, data from the IR camera is converted to a set of equations that are based on deviations from the well-known one-dimensional heat flow model, resulting in an order of magnitude reduction in the amount of data that must be stored and manipulated. To date, TWI has processed and analyzed structures made up of as many as 42 individual images as a single image in less than 5 minutes, and successfully detected indications that did not appear in the conventional thermal images.

## **Maintenance Optimization in Electric Utilities**

*Robert Hammaker, EPRI Solutions*

The goal of a power plant is to meet the customer's needs by maintaining the power plants' assets in the most cost efficient and effective manner. Plant Maintenance Optimization (PMO) is a process that has been developed to assist in meeting this goal.

PMO achieves the appropriate investment balance of Corrective (CM), Preventive (PM), Condition Directed (CD), and Pro-Active (PR) techniques for maintenance, integrating all diagnostic, maintenance, financial, and process data into the decision-making process. Implementing these strategies greatly reduces the cost of production while increasing reliability.

Although the primary focus of this short course is maintenance optimization for power plants, there is a great deal to be learned by all thermographers involved with a wide variety of maintenance situations.

## **Mechanical Applications for Infrared**

*Harold Van De Ven & John Snell, Snell Infrared*

Historically, infrared has been used for electrical inspections. Over the past few years, more and more people are finding new and innovative ways of applying this technology to mechanical inspections. This short course will give an overview of mechanical applications for thermography. Emphasis will be on rotating equipment. Special considerations of mechanical surveys, along with tips on getting better results, will also be discussed.

## **Inspecting Heaters, Furnaces and Boilers Inside & Out**

*Greg McIntosh, Snell Infrared*

This course will cover the basic theory and techniques associated with conducting inspections on the interior and exterior of process heaters, furnaces, boilers and other high temperature vessels. The topics to be covered will include measurements of high temperature surfaces on the outside of a vessel to evaluate insulation and refractory; measurements on the inside of vessels to identify process problems, measurements through different combustion atmospheres; and evaluating errors and disagreements with other temperature sensors.

# Thermal Solutions® Conference Schedule

## Monday, January 21st

- 7:00 AM Early registration/continental breakfast
- 9:00–Noon Short courses:  
*Advanced Signal Processing for Thermographic NDT*  
Steve Shepard & Tasdiq Ahmed, Thermal Wave Imaging, Inc.  
*Conducting Effective Roof Surveys*  
Peter Brooks, Infrared Analyzers  
*IR Software Overview and Report Writing Workshop*  
Roy Huff & Greg McIntosh, Snell Infrared
- Noon–9:00 PM Vendor exhibits open
- Noon–1:30 PM Lunch (provided for short course attendees)
- 1:30–4:30 PM Short courses:  
*Mechanical Applications for Infrared*  
Harold Van De Ven & John Snell, Snell Infrared  
*Inspecting Heaters, Furnaces and Boilers Inside & Out*  
Greg McIntosh, Snell Infrared  
*Maintenance Optimization in Electric Utilities*  
Robert Hammaker, EPRI Solutions, Inc.
- NDT paper presentations
- 6:30–9:00 PM Opening reception

## Tuesday, January 22nd

- 7:00 AM Registration continues/continental breakfast  
Vendor exhibits open
- 8:00 AM Keynote address
- 8:45–12:15 Condition monitoring paper presentations  
NDT paper presentations
- 12:15–1:30 Lunch (provided)
- 1:30–5:00 PM Condition monitoring paper presentations  
NDT user group meeting
- 5:00 PM NDT track ends

## Wednesday, January 23rd

- 7:00 AM Registration continues/continental breakfast
- 8:00 AM Keynote address
- 8:45 AM–12:15 Paper presentations
- 12:15 Box lunch provided
- 12:30 PM Field trips – buses depart hotel  
*Daytona USA Speedway*  
*Kennedy Space Center*
- 6:00 PM Buses arrive back at hotel

## Thursday, January 24th

- 7:00 AM Registration continues/continental breakfast
- 8:00 AM Keynote address
- 8:45 AM–12:15 Paper presentations
- 12:15 Closing remarks

## Register now for Thermal Solutions®

Orlando, FL January 21–24, 2002

Full Conference	\$945.00
NDT Track Only	\$495.00
Short courses	\$95.00 per course
Field trip	\$25.00

Register online or download a registration form at:

<http://www.thermal-solutions.org>

Call 800-636-9820 or e-mail

[info@thermal-solutions.org](mailto:info@thermal-solutions.org)

to have a registration form

faxed or mailed to you;

fax it back to us at 802-223-0460.

## Win a Three-Night Stay in Orlando!

When you register for the conference your name will be entered in a drawing to win three free nights\* at the Radisson Barcelo Hotel in Orlando. Every conference event you sign up for gives you another chance to win. For example, sign up for the conference, two short courses and a field trip for a total of four chances to win.

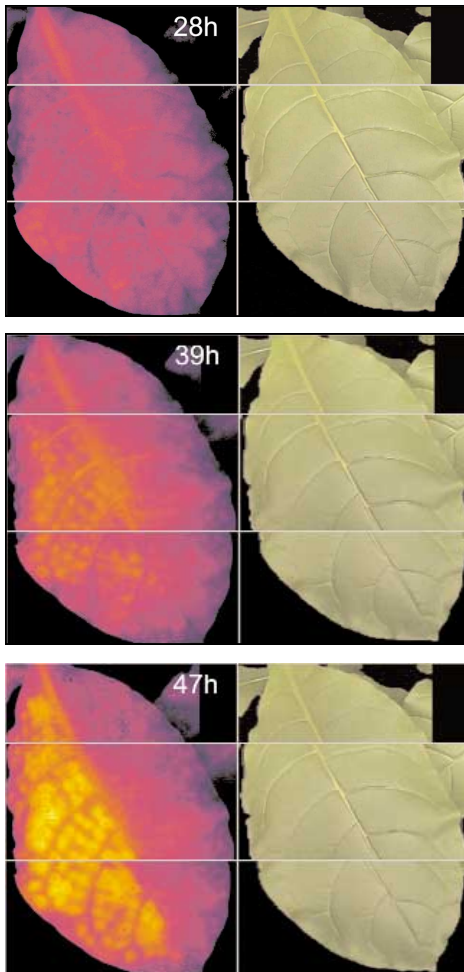
\* Certificate redeemable within one year of issue date.

\$100  
Value for  
Free!

## Eye Exams

As an added bonus to all who register for Thermal Solutions®, Snell Infrared will be administering an eye exam that complies with the standards of the American Society for Nondestructive Testing (ASNT) SNT-TC-1A. The exam, overseen by one of our staff, consists of two tests:

- Ishihara Color Deficiency Test
- Jaeger Eye Test



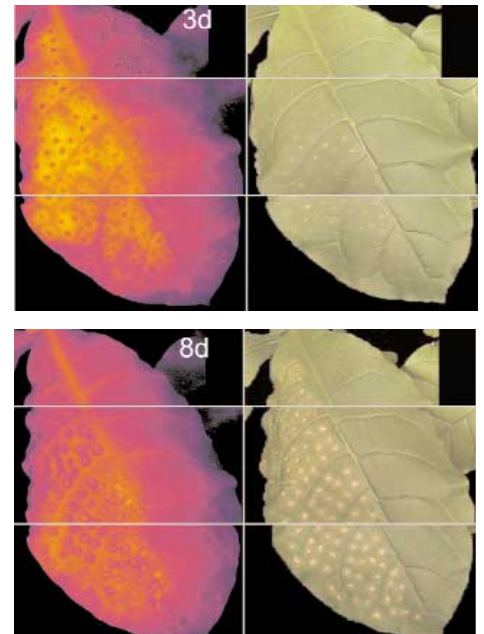
Hotspots, *continued from first page*

After 39h, thermal hot spots appear at the sites of infection, while no visual symptoms can be detected. At 47h after infection the left side of the leaf shows distinct spots of higher temperature at the sites of infection, reaching 0.4°C above the surrounding leaf surface temperature. No visual damage is yet apparent in the visual image on the right.

Three days after infection, cell death starts to emerge as dark points at the center of the thermal hot spots, and co-localized as pale areas in the visual pictures. In the last figure, captured 8 days after infection, the lesions have reached their maximal expansion. This corresponds to the area of maximal thermal effect, attained 6 days earlier (47h).

Meanwhile, the thermal effect has substantially faded. The start of the increase in surface temperature was found to coincide with the onset of SA-accumulation and with the decrease in stomatal conductance and associated lowering of transpiration.

High-resolution thermography clearly has the potential for early visualization of emerging stresses in plant leaves. For information on the plant thermography research project at Ghent University, Belgium: [www.plantgenetics.rug.ac.be/~lacha](http://www.plantgenetics.rug.ac.be/~lacha).



## ...in the Press

An article written by Robert K. Fogle and John E. Sturtevant, LB&B Associates (working at Goddard Space Flight Center) was featured in the August, 2001 issue of *P/PM Technology* magazine. The article, *Using Thermography for Testing VRLA Batteries in Uninterruptable Power Supply Systems*, was featured in the magazine's *Thermographic Analysis* section. The article focuses on the application of infrared thermography to inspect Valve Regulated Lead Acid (VRLA) batteries during routine preventive maintenance inspections and capacity load testing. Bobby and Jack also presented this paper at the 2001 Thermal Solutions® Conference in Orlando, Florida. To obtain a copy of the article, go to our web site and download a copy at <http://www.snellinfrared.com/>.

Congratulations Bobby and Jack!

You can reach *Think Thermally*® at:

**Snell Infrared**  
**P.O. Box 6**  
**Montpelier, VT 05601-0006**  
**Phone: 800-636-9820**  
**Fax: 802-223-0460**

**E-mail: <[thinkthermally@snellinfrared.com](mailto:thinkthermally@snellinfrared.com)>**

**Web Site: <<http://www.snellinfrared.com>>**



# Snell Infrared 2002 Course Schedule

## Level I

Jan 14-18, Montpelier, VT  
Feb 11-15, Phoenix, AZ  
Mar 11-15, Tampa, FL  
Apr 15-19, Indianapolis, IN  
Apr 22-26, Toronto, Canada  
May 13-17, Charlotte, NC  
Jun 10-14, Montpelier, VT  
Jul 15-19, Minneapolis, MN  
Aug 12-16, San Diego, CA  
Sep 9-13, Montpelier, VT  
Oct 7-11, Cincinnati, OH  
Oct 21-25, Toronto, Canada  
Nov 4-8, Dallas, TX  
Dec 2-6, Montpelier, VT

## Level I Review Course with Certification Exam

Feb 19-21, Montpelier, VT  
Aug 13-15, Montpelier, VT

**Thermal Solutions® Conference**  
**Orlando, Florida      January 21-24, 2002**

## Level II

Feb 11-15, Phoenix, AZ  
Apr 8-12, Charlotte, NC  
Jun 3-7, Montpelier, VT  
Sep 16-20, Indianapolis, IN  
Oct 28-Nov 1, Toronto, Canada  
Nov 4-8, Dallas, TX

## Level II Review Course with Certification Exam

Mar 5-7, Montpelier, VT  
Aug 20-22, Montpelier, VT

## Level III, Best Practices

Feb 12-14, Phoenix, AZ  
Sep 24-26, Montpelier, VT

## Specialty Courses

*Toronto, Canada:*  
Feb 6-7, Mechanical Applications  
May 22-23, Analyzing Products & Processes  
Sept 25-26, Electrical Applications  
Nov 13-14, Building Applications  
*Detroit, Michigan:*  
Mar 6-7, Electrical Applications  
Oct 9-10, Mechanical Applications

For more information on the Specialty Courses, call us at 800-636-9820

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