THERMOGRAPHIC APPLICATIONS AND LOSS CONTROL

EXECUTIVE SUMMARY

This paper provides insurance professionals, particularly those involved in loss control activities, with information and resources to assist in the discussion and development of infrared inspection programs.

You will find here a discussion of:

- The nature of infrared energy and the history and development of thermographic cameras
- Applications for electrical conductors, transformers and switchgear, other machinery applications, steam systems and HVAC systems, building envelopes, the food industry and VOC gases
- Certification of Levels I, II and III thermographers
- Principal professional associations for thermography
- Guidelines for:
  - Electrical and mechanical systems
  - Building and insulated roof guideline standards for infrared inspection
  - Measuring and compensating for reflectance, emittance and transmittance
  - Measuring distance/target size values for quantitative infrared
- Preparations for infrared inspection
- The methodology of setting up and monitoring an infrared program and general comments concerning third-party services
- Sources of information

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ABOUT INFRARED THERMOGRAPHY

A picture's worth a thousand words – no matter what part of the electro-magnetic spectrum is used to paint that picture. Thermography is the use of an infrared imaging and measurement camera to show and measure thermal energy emitted from an object. Thermal, or infrared energy, is light that is not visible because its wavelength is too long to be detected by the human eye; it's the part of the electromagnetic spectrum that we perceive as heat. Everything with a temperature above absolute zero[1] emits heat. Even very cold objects, like ice cubes, emit infrared radiation. The higher the object's temperature, the greater the infrared radiation emitted. Thermography cameras allow us to see what our eyes cannot. They produce images of invisible infrared or heat radiation and provide precise non-contact temperature measurement capabilities. Nearly everything gets hot before it fails, making infrared cameras extremely cost-effective diagnostic tools in many diverse applications.

WHAT IS INFRARED ENERGY?

Infrared energy is similar to visible light, but with a longer wavelength that is invisible to the human eye. While visible light energy is emitted by objects only at a very high temperature, infrared energy is emitted by all objects at ordinary temperatures.

Since thermal imagers sense infrared energy, which varies with the temperature of objects, the image generated provides a thermal signature of the scene. Infrared energy from objects in a scene is focused by optics onto an infrared detector. The infrared information is then passed to sensor electronics for image processing. The signal processing circuitry translates the infrared detector data into an image that can be viewed on a standard video monitor.

Thermal imaging systems not only let us see in the dark, but they also enhance our ability to detect objects at critical moments – when they are heating up due to some malfunction. Warmer objects such as people and animals stand out from typically cooler backgrounds. Thermal imaging systems see better than the unaided eye in daylight, night and most poor-weather conditions.

[1] *Absolute zero is the temperature of -273.16˚C (-459.69˚F), the hypothetical point at which all molecular activity ceases.*

INFRARED TECHNOLOGY AND THERMAL IMAGERS

Sir William Herschel discovered infrared radiation in 1800. An astronomer, he built his own telescopes and was very familiar with lenses and mirrors. Knowing that sunlight was made up of all the colors of the spectrum, and that it was also a source of heat, Herschel wanted to find out which color(s) were responsible for heating objects. He devised an experiment using a prism, paperboard and thermometers with blackened bulbs in which he measured the temperatures of the different colors. Herschel observed an increase in temperature as he moved the thermometer from violet to red in the rainbow created by sunlight passing through the prism. He found that the hottest temperature was actually beyond red light. The radiation causing this heat was not visible; Herschel termed this invisible radiation *calorific rays*. Today, we know it as infrared.

His son, Sir John Herschel, more interested in photography, managed to record the heating rays on the infrared side of the spectrum by creating an evaporograph image using carbon suspension in alcohol. He termed this image a *thermogram*. This laid the foundation for the sophisticated thermal imaging devices that are used today in military, industrial and medical applications.

Human eyes are designed for visible light, but two species are known to detect infrared – some snakes and beetles. Even though infrared is not visible to the human eye, skin can sense infrared. When beside a campfire, we feel the warmth of heat radiated from the fire.

The sensor in an infrared thermometer collects a small amount of energy (usually 0.0001 watt) radiated from the target, generates an electrical signal that is amplified by a precision amplifier and converted into voltage output. A central processing unit digitizes the signal by a 16-bit analog-to-digital converter. An arithmetic unit solves a temperature equation based on Planck's Radiation Law, compensates for the ambient temperature and emissivity resulting in a temperature reading within a fraction of a second after you push the *read* button on an infrared thermometer.

An infrared camera is a non-contact device that detects infrared energy (heat) and converts it into an electronic signal that is then processed to produce a thermal image on a video monitor. The signal can also be used to and perform temperature calculations. Heat sensed by an infrared camera can be very precisely quantified, or measured, allowing us to not only monitor thermal performance, but also identify and evaluate the relative severity of heat-related problems. Recent innovations, particularly detector technology, the incorporation of built-in visual imaging, automatic functionality and infrared software development deliver more cost-effective thermal analysis solutions than ever before.

Infrared thermography is the only diagnostic technology that allows instant visualization and verification of thermal performance by searching out anomalies and allowing the thermographer to quantify them with precise, non-contact temperature measurement and document them automatically in seconds with professional easy-to-create infrared reports.

Infrared thermography is a proven effective, predictive maintenance (PM) technology that quickly, accurately and safely locates problems, prior to failure, indicated by thermal anomalies. Some studies have reported as much as a four-to-one return for every dollar spent on infrared inspection as a result of identifying potential component failures and preventing the much greater costs associated with manufacturing downtime, production losses, power outages, fires and catastrophic failures.

Improvements in thermography have led to great strides in creating practical applications in:

- Loss control applications (for example, in recreational maritime vehicles)
- Home and building inspections
- Security
- Healthcare
- Business
- Industry (e.g., the chemical industry)
- Environmental hazard detection
- Visual enhancement for equipment operators and for night use

One recent and timely application detects potential problems in chutes and hoods used in coal fuel derivation and application.

THERMOGRAPHY AT WORK

During the post-World War II years, many governments developed extensive military applications of thermographic technology. As the field developed, applications were found for peacetime industrial and medical use.

COMMON PROBLEMS EASILY DETECTED BY INFRARED

The untimely shutdown of electrical distribution equipment and primary mechanical systems often results in lost production, higher operating costs, dissatisfied customers and lost profits. A major industrial engineering and insurance organization recently revealed that over 30% of their total losses resulted from electrical problems.

ELECTRICAL CONDUCTOR WEAKNESSES

- **Broken strands** – These hot spots are found at the supports for cables. Where there is consistently high wind, hot spots may occur on transmission lines.
- **Spiral heating** – This is found on stranded wire which is heavily oxidized. The problem will show up on the camera monitor as a hot spiral from one connection to another connection or to a clamp. Poor connections show as a load imbalance between the strands.
- **Grounds** – Grounds will show up, because there is usually an abnormal current leakage to ground. If all three phases of a feeder seem hot, a temperature reading over 30 degrees ambient may indicate overloading.
- **Conductor terminations and connections** – A high percentage of problems occur in terminations and connections and especially in copper-to-aluminum connections. They show up as hot spots. A splice or lug connector should not be warmer than its conductors if it has been sized properly.

OTHER ELECTRICAL CONDITIONS

- **BUS DUCTS** – Unbalanced loads and high resistance in bus and fuse connections
- **EMERGENCY POWER** – Poor battery terminal connections, dead cells in batteries, defective or inoperative contacts
- **LIGHTING** – Poor connections and overheating ballasts
- **TRANSMISSION AND DISTRIBUTION** – Loose/corroded/improper connections, inoperative capacitors, failed lightning arrestors, poor breaker connections, overloading

TRANSFORMERS AND SWITCHGEAR

There are two common types of transformers – dry and oil-filled. Each can provide either single or three-phase power.

Porcelain masking on transformer bushings can hide serious problems. A hot spot near the top of a bushing usually indicates a bad connection. When there are internal problems in the transformer, they will usually show up near the bottom of the bushing. Any suspicions can be confirmed with a turns ratio and dielectric test. If an entire bushing is uniformly warm, or has a hot spot somewhere other than on the top or bottom of the bushing, the bushing is probably bad, which can be confirmed with a power factor test.

Radiators (on oil-filled transformers) – There should be even heating on all radiator fins, except for variation due to air flow, loading and ambient temperatures. If some fins are cold, there are two possible problems, low oil level or oil flow blockage, either of which can be disclosed by thermographic inspection.

Dry transformers are usually found in medium- and low-voltage distribution substations. They are air-cooled and will show up as quite hot. Some models, especially newer ones, have screened openings for ventilation that can be used for thermographic inspection. The iron in these transformers is hot. It will heat the bus work and cause substantial infrared reflection. An exceptional hot spot in the iron indicates a short.

If temperatures are uniform over the transformer winding, but there is a difference in the temperature of two windings, there may be an unbalanced load.

A hot spot on a winding may point to shorted turns or bad iron. A turns ratio and dielectric test will help confirm the diagnosis.

Resistors can appear almost anywhere in an electrical system. Frequently, they will show up on the camera monitor as very hot. In fact, heaters used in switchgear, bus ducts and outside control cabinets are all resistors. Though resistors usually look hot, heating should be even over the energized portion.

A capacitor has two conductive surfaces which are separated by a dielectric barrier. Capacitors function as power factor correctors. When energized, all units should have the same temperature if the KVAR size is the same. A high uniform temperature is normal; a cold cell indicates either a blown fuse or a bad cell.

Coils are used to concentrate magnetic fields and consist of multiple turns of conductors. Typical types of coils are air core (used as chokes or inductors) and iron core (used to create magnetic fields or generate mechanical action). When energized, coils of all types will show heat on all surfaces. A defective coil will not be hot and will show up as a dark area on the camera monitor.

In a switch, two metal surfaces act as conductors when they are brought into contact. Usually, problems are restricted to the contact surfaces. Poor contact usually shows up as a hot spot on the camera monitor.

A fuse is a metal conductor that is deliberately made to melt when an overload of current is forced upon it. Major problems indicated as hot spots on the camera monitor are caused by loose mechanical stab clips, corroded or oxidized external contact surfaces or poor internal connections which are bolted or soldered.

Circuit breakers are switching devices that make or break an electrical circuit and serve the same function as a fuse. Common types are air, oil bath, molded case or vacuum. Problem areas are indicated as hot spots, which are caused by corroded or oxidized contact surfaces, poor internal connections or defective bushings.

Control equipment includes meters used to measure current, voltage or resistance, relays used to make or break circuit, indicators used to visually display an electrical impulse, and current and Potential Transformers (CTs and PTs) used to vary current and voltage in a system. Hot spots on a thermographic monitor indicate wire connection problems or shorts due to grounding in the system.

OTHER MACHINERY APPLICATIONS

Slip rings, commentators or brush riggings are typically found on electric alternating current (AC) or direct current (DC) rotating machinery. When resistance abnormalities in these conductors exist, the abnormalities will show up as cool, rather than hot, areas.

Motors convert electromagnetic forces into mechanical forces. The three common types of motors are induction, synchronous and direct current. Problems in motors usually occur within "T" box connections, visible conductor connections, rotors or bearings. All of these problems involve overheating that is readily documented by an infrared camera monitor. Three-phase motor loads should be balanced, but lighting and single-phase loads may be unbalanced.

Bearings are devices used to reduce the friction between two moving surfaces. The most commonly used bearings are sleeve, roller, ball or thrust bearings. Problems can be found by comparing surface temperature. Overheating conditions are documented as hot spots and are usually confirmed by comparing similar equipment.

Typical items that can be scanned for mechanical friction and stress forces include gears, shafts, couplings, V belts, pulleys, chain drive systems, conveyors, air compressors, vacuum pumps and clutches. Abnormal thermal patterns may develop where there is friction or mechanical flexion; usually these patterns show up as hot spots.

HEAVY-DUTY EQUIPMENT – Overheating brakes, tires, bearings, pulleys, gears, gear or pulley misalignment, and transmission/gearbox overheating

HYDRAULICS – Defective seals, overheating lines and unequal flow

INTERNAL COMBUSTION ENGINES – Valve or injector malfunction, blocked radiator tubes and oil coolers

MECHANICAL DRIVE TURBINES AND SMALL TURBINE GENERATOR UNITS – High lube oil temperature, high bearing temperature, drain valve blockage, steam trap blockage, faulty stop/control valve operations and leaking shaft seals

PRESSES – Defective bearings and V belts, gearing fit, adequacy of lubrication, and clutch and brake efficiency

PUMPS, COMPRESSORS, FANS AND BLOWERS – Overheated bearings, compressor discharge temperature, high oil temperature, broken or defective valves or rings, and misalignment of drive belts and gears

STEAM SYSTEMS AND HVAC SYSTEMS

The ability to accurately evaluate steam trap operation, valve or joint leakage, insulation effectiveness, underground system leakage, and restricted or blocked condensate return lines can pay dividends in energy conservation, save countless maintenance hours and reduce unscheduled steam system downtime.

Finding boiler refractory or insulation breakdown, blocked cast iron sections, scale buildup, hot gas leaks and furnace tube blockages also can pay dividends in energy conservation, save countless maintenance hours and prevent boiler failure.

Accurately detecting refrigeration and air conditioning air leaks, energy loss, heat exchanger, refrigerator and air conditioning efficiency and clogged condenser/heat exchanger tubes, will prevent inefficient operation and wasted energy.

BUILDING ENVELOPE

Moisture in building materials can destroy structural integrity and nurture mold. The first step in moisture problem remediation is to quickly and accurately locate and remove all sources of moisture. Thermography can identify surface temperature variations of the building envelope, which can indicate problems in a building's structure, thermal bridging, moisture content and air leakage.

Common building diagnostics applications have loss control implications, including improved roofing surveys, building energy audits, moisture detection and mold remediation.

Water leakage is the number one cause of damaged insulation and substrate, corrosion and weakening of metal decks and building structure, even structural collapse and the growth of mold. Infrared cameras instantly show what's wet and what's dry with little or no physical disassembly and minimal disturbance of inhabitants.

ENVELOPE – Heat loss, missing/deteriorated/misapplied insulation, air leakage, moisture problems in walls' structure, dew on inner walls, window seal failure and room airflow

HEATING SYSTEM – Inefficiencies in radiant ceiling panels, slabs, radiators, panel heaters, carpet heaters and electric blankets

ROOF – Leaks and moisture intrusion

CONCRETE – Bridge deck delamination, rebar deterioration and problems with embedded heating systems and steam lines

FOOD INDUSTRY

The food industry must maintain tight control of food temperatures during the transportation of perishables during preparation and processing, and all the way through storage in wholesale and retail environments. Infrared cameras are the ideal solution for assuring that temperature tolerances are maintained throughout. In addition, infrared thermography can instantly reveal the condition of electrical and mechanical systems in the factory, warehouse, retail stores and refrigerator trailers, including cooking vessels, ovens, heat exchangers, compressors, electrical connections, freezers, motors and motor control centers, breaker panels, disconnect switches, transformers, substations, switchgear and circuit breakers. The infrared camera can instantly reveal problems with minimal disturbance of operations.

One new technology advance in infrared imaging cameras allows the technician to spot methane and other volatile organic compound gas leaks quickly and easily. Capable of rapidly scanning large areas and even miles of pipeline, new highly specialized infrared cameras deliver real-time thermal images of gas leaks. These leaks appear as "black smoke" onscreen allowing the technician to spot fugitive gas emissions through a revolutionary process that inverts the physics of fugitive volatile organic compound gas leaks.

GENERIC APPLICATIONS

DRYER ROLLS – Condensate buildup and high bearing temperatures

OVENS, FURNACES AND OTHER REFRACTORIES – Flame impingement, coke buildup on tube surfaces, faulty burners, refractory deterioration and inefficient or malfunctioning heaters

TANKS FOR THE STORAGE OF FLUIDS OR GASES – Determination of fluid levels, inadequate insulation, leaks, and defective valves

STANDARDS

Cameras, support software and training have advanced from the early stages of recognizing a cow at 400 feet, a spot[2] of 25, to modern cameras capable of providing both visual and infrared images and determining a spot of 300 (1 inch at a distance of 25 feet). Prices have dropped to as low as lease fees of under $100 monthly. It is only natural that some level of professional skill is required to operate the machinery. Accordingly, professional standards have developed.

The Society for Nondestructive Testing recognizes three levels of thermographic skills as determined by the thermographer having met certain guidelines and certification requirements.

LEVEL I INFRARED CERTIFICATION

This basic level certification indicates the ability to properly use infrared cameras to calculate accurate, repeatable temperature measurements. The Level I thermographer understands critical camera parameters, such as emissivity, reflected ambient temperature and distance to target and can perform infrared thermographic interpretation. Level I thermal imaging applications include predictive and preventative maintenance, condition monitoring, quality assurance and forensic investigations. Level I thermographers are trained in infrared theory, heat transfer concepts, equipment operation and selection, standards compliance, image analysis and report generation. They are also trained to identify and document thermal patterns caused by improper design, workmanship or material failure. Applications include electrical distribution systems, mechanical systems, steam systems, refractory systems, underground piping, active thermography, building envelopes and flat roofs.

LEVEL II INFRARED CERTIFICATION

The Level II infrared thermographer has higher operating skills and can develop new inspection procedures and applications, utilizing infrared trending or software programs, performing advanced

[2] The ratio of distance to size of an area that can be reliably measured is sometimes referred to as "spot".

non-destructive testing applications, and has attained superior measurement skills for improved accuracy and diagnosis. Level II thermographers are certified in advanced infrared theory, equipment calibration, error sources, cross-verification with contact thermometers, advanced equipment operation, use of windows and filters, assigning temperature limits and repair priorities and quantitative report generation for predictive and preventative maintenance, condition monitoring, quality assurance and forensic investigations.

LEVEL III INFRARED CERTIFICATION

At this level, a thermographer has the skill, knowledge and experience necessary to initiate and manage an infrared thermographic program. The Level III thermographer has an advanced understanding of the information necessary to direct other thermographers in providing written procedures and purchasing suitable equipment.
The Level III Thermographer has mastered the latest applications, hardware and software, current industry standards and specifications, marketing and promoting of an infrared inspection program, thermography as legal documentation, as well as heat transfer analysis software, current industry certification criteria, and how to develop and implement standards-compliant written practices and procedures.

GUIDELINES

Successful infrared thermographers need written procedures that provide a basis for accurate and repeatable infrared inspections. In 1997, guidelines were adopted by the American Society for Testing and Materials and are available from that organization or from the Infraspection Institute (http://www.INFRASPECTION.com).

- ***Guideline Standard for Infrared Inspection of Electrical and Mechanical System.*** Part 1 of this guideline defines the roles of all persons involved in the inspection including the end user, thermographer, and qualified assistant. Part 1 also specifies report content for properly documenting qualitative and quantitative infrared inspections. Parts 2 and 3 specify temperature limits for electrical and mechanical equipment and outline a number of proven methodologies for prioritizing exceptions. Part 2 also includes the IEEE formula for calculating maximum allowable temperature for operating electrical components.

- ***The Guideline Standard for Infrared Inspection of Buildings and Insulated Roofs*** outlines practices for specifying and safely performing infrared inspections of building envelopes and insulated roofing systems and defines the roles of all persons involved in the inspection, including the end user, thermographer and qualified assistant. It specifies report content for properly documenting qualitative and quantitative infrared inspections along with requirements for verifying infrared data.

- ***The Guideline Standard for Measuring and Compensating for Reflectance, Emittance and Transmittance*** sets out simple, proven techniques for measuring and compensating for the most common error sources in quantitative thermography and may be applied in laboratory or industrial environments.

- ***The Guideline for Measuring Distance/Target Size Values for Quantitative Infrared Cameras*** outlines a simple methodology for determining spot measurement size for quantitative thermal imagers. Practicing thermographers need spot size information to determine how close they need to be for accurate temperature measurements. Although spot measurement size is a critical imager specification, meaningful spot size information is infrequently provided by manufacturers of imaging radiometers.

While there is agreement on thermographic practices, similar agreement does not exist on the frequency of testing. Third-party vendors recommend inspection as frequently as quarterly. Some experts recommend sophisticated matrixes and inspection inventories with frequency based upon criticality of equipment or process and the operating environment involved. The insurance industry recommends inspection frequencies from one to five years based upon conditions noted at prior inspections and operating environment. All groups and experts recommend inspection upon installation of new equipment, a major repair or upon a rebuild, with a follow-up inspection no more than one year later.

PREPARATION FOR INFRARED INSPECTION

Performing an infrared inspection that will provide the best information and greatest savings possible requires skilled personnel working together as team. Prior to this point, we have discussed the nature and responsibilities of thermographic inspection. This section outlines the procedures equipment users or operators can perform to expedite the inspection and help control inspection time and costs. To help the inspection team perform the most cost-effective infrared inspection possible, at minimum, a document should be prepared detailing the following requirements.

- An electrician or electrical engineering assistant familiar with the history, layout and function of the electrical system is essential to the inspection process. This person should have experience in opening cabinets or removing covers of the equipment that will be inspected in a manner that honors all company safety procedures, as it will be their responsibility to perform this function. Most infrared contractor personnel will not open cabinets or remove covers. The electrician should have an ammeter to measure the loads of operating equipment as required.

- The thermographer's progress is usually limited by the rate at which cabinets can be opened and the equipment exposed. If possible, a second assistant to open and close all cabinet doors and covers should be provided. This person, or the first assistant, should obtain any company permits or permission required to open some of the cabinets prior to the thermographer arriving to avoid delays and expenses.

- A general route through the facility should be prepared, keeping in mind that a complete inventory of the electrical equipment will be compiled as the inspection team progresses. This routing can be general in nature; however, the more detailed the routing the better. The aim is to prevent backtracking as much as possible.

- Equipment to be inspected must be under normal load, with any access doors removed or opened. If any equipment has door switches that cannot be over-ridden, the inspection team must be made aware of them to prevent inadvertent interruption of operations.

- The inspection preparation document should be distributed to all people involved and to all operations personnel affected by the inspection.

KEY STEPS AND SERVICES

The steps in starting a program are:

- Develop and present information to justify the program

- Meet with management to promote infrared technology and plan for using infrared technology

- Develop the right team to bring infrared thermography on line effectively

- Create a team mission statement

- Structure a plan with aggressive yet achievable goals

- Identify and prioritize equipment to be inspected
- Establish methods to inspect specific equipment
- Develop inspection forms that result in successful corrective action
- Develop standard operating procedures that will keep the program successful
- Integrate company safety policies and procedures with inspection methods

Any predictive maintenance program needs continuing support to respond to change as well as to cope with unforeseen problems. Support services should include:

- Technical support to get answers about either imaging equipment and/or the equipment inspected
- Image analysis
- Review of reports and forms to assure that they are effective
- "Program CPR" if the program is in trouble
- Professional infrared thermographers who can travel anywhere in the world to meet emergency infrared thermography needs, fill in for an ill staff member, or consult on a difficult technical issue
- Assistance in integrating thermography into existing predictive maintenance programs
- Online computerized data collection and report generation, either as a stand-alone system or integrated into an existing system

There are many third-party services available, and most of the sources of information listed below provide third-party thermography services, many of which also include support software. In addition, Global Risk Consultants, Hartford Steam Boiler, CHUBB, CNA and Zurich all offer infrared inspection within an insurance framework.

A word of caution: Any service will only be as good as the program specifications and the training, certification, experience and responsibilities of the technicians involved, and then only to the extent that the technology utilized will allow.

CONCLUSIONS

All predictive maintenance programs must justify their existence by adding to the bottom line in one way or another. From systems that measure increased up-time to those that focus on avoided costs, quantifying the results of infrared thermography can be a complex, often difficult, job. Without a solid framework in which to communicate the results, the best system in the world is of little value.

Whether an in-house thermographer or a third-party service is used in the thermographic inspection, training and certification are key to the success of any program. Certification facilitates movement of personnel from one site to another while retaining continuity and superior results within the guidelines of the American Society for Nondestructive Testing.

If a third-party service is used, the thermographer responsible for the program should be a permanent, full time employee of the service provider whose sole responsibilities are thermographic applications and who is Level III certified. Thermography itself is an interpretive skill, and should be performed by someone who is qualified and experienced. Owning a thermographic camera does not make one a thermographer any more than owning a stethoscope makes one as a doctor.

Starting a new maintenance program is not always easy, and when a new program also incorporates a new technology, such as infrared thermography, success can seem elusive. The difference between success and failure is simply getting the equipment into use. As easy as that sounds, it can't happen without an organized approach that will integrate infrared thermography into an existing predictive maintenance program.

SOURCES OF INFORMATION

Academy of Infrared Training, Inc.
(http://www.INFRAREDTRAINING.net/)

FLinfrared Systems Inc. (http://FLIRTHERMOGRAPHY.com/)

FM Global Resource Collection (CD/DVD format only)

Global Risk Consultants Corp.
(http://www.GLOBALRISKCONSULTANTS.com/)

Hartford Steam Boiler Inspection and Insurance Company
(http://HSB.com/)

Infraspection Institute (http://www.INFRASPECTION.com/)

Oregon Infrared LLC (http://www.OREGONINFRARED.com/)

Snell Infrared (http://www.SNELLINFRARED.com/)

United Power Services Incorporated
(http://UNITED-POWER.com/)

Weidmann ACTI Inc. (http://www.weidmaNN-ACTI.com/)

Holst, Gerald C., "Common Sense Approach to Thermal Imaging," SPIE Volume PM 86 (http://www.spie.org)

PRINCIPAL PROFESSIONAL SOCIETIES

- The American Society for Nondestructive Testing (www.ASNT.org) exists to create a safer world by promoting the profession and technologies of nondestructive testing.
- The Non-Destructive Testing Management Association (www.NDTMA.org) was formed to provide a forum for the open exchange of managerial, technical and regulatory information critical to the successful management of NDT personnel and activities.
- The International Society for Optical Engineering (www.SPIE.org) is a not-for-profit society that has become the largest international force for the exchange, collection and dissemination of knowledge in optics, photonics and imaging.
- ThermoSense (www.THERMOSENSE.org) is the largest and oldest international technical meeting focused on the scientific,

industrial and general uses of infrared imaging and infrared temperature measurement. Its regular printed proceedings are found in most scientific and engineering libraries, providing an unequaled depth and breadth of technical information and reference data.

OTHER THERMOGRAPHIC ASSOCIATIONS

- American National Standards Institute (www.ANSI.org)
- American Society for Testing and Materials (www.ASTM.org)
- International Organization for Standardization (www.ISO.org)
- Association for Facilities Engineering – Region 2 (www.AFE2.org)
- Association for Facilities Engineering – St. Louis (www.AFESTLOUIS.org)

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