A PRIMER ON INFRARED THERMOGRAPHY

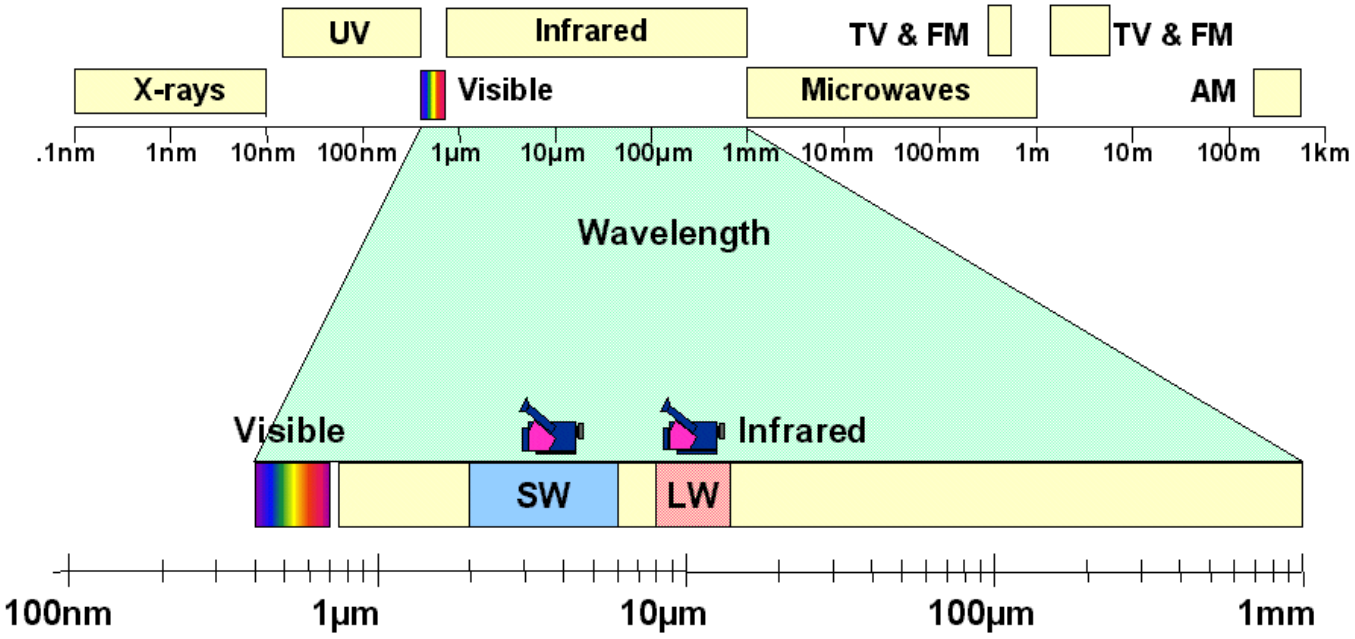
(ANSWERS TO THE TOP 10 QUESTIONS PEOPLE ASK ABOUT INFRARED THERMOGRAPHY

BY GARY L. ORLOVE, P.E., ASNT NDT LEVEL III T/IR

WHAT IS INFRARED?

Infrared energy is part of the electromagnetic spectrum and behaves similarly to visible light. It travels through space at the speed of light and can be reflected, refracted, absorbed, and emitted. The wavelength of IR energy is about an order of magnitude longer than visible light, between 0.7 and 1000 μm (millionths of a meter). Other common forms of electromagnetic radiation include radio, ultraviolet, and x-ray.

See http://www.ipac.caltech.edu/Outreach/Edu/infrared.html for more information.



The Electromagnetic Spectrum

WHAT IS THE ELECTROMAGNETIC SPECTRUM?

We know that infrared radiation is a form of electromagnetic radiation, which is longer in wavelength than visible light. Other types of electromagnetic radiation include x-

"Electromagnetic radiation is categorized by wavelength or frequency."

rays, ultraviolet rays, radio waves, etc. Electromagnetic radiation is categorized by wavelength or frequency. Broadcast radio stations are identified by their frequency, usually in kilohertz (kHz) or megahertz (MHz). Infrared detectors or systems are categorized by their wavelength. The unit of measurement used is the micrometer, or micron, (m) which is one millionth of a meter. A system that can detect radiation in the 8 to 12 micrometer band we usually call "longwave." One that detects radiation between 3 to 5 micrometers is termed "shortwave." (A 3 to 5 system can also be classified as "midband," because there are systems, which can detect radiation shorter than 3 micrometers.) The visible part of the electromagnetic spectrum falls between .4 and .75 micrometers. We can see colors because we can discriminate between different wavelengths. If you have a laser pointer you may have noticed that the radiation is specified in nanometers; usually about 650nm. If you examine a chart of the electromagnetic spectrum at 650nm (.65 micrometers) you will see that it is the radiation of red light.

WHERE DOES INFRARED ENERGY COME FROM?

"Infrared cameras do not see temperatures, they detect thermal radiation"

All objects emit infrared radiation as a function of their temperature. This means all objects emit infrared radiation. Infrared energy is generated by the vibration and rotation of atoms and molecules. The higher the temperature of an object, the more the motion and hence the more infrared energy is emitted. This is the energy detected by infrared cameras. The cameras do not see temperatures, they detect thermal radiation.

At absolute zero (-273.16°C, -459.72°F), material is at its lowest energy state so infrared radiation is minimized.

ARE THERE LINKS FOR IR THERMOGRAPHY ON THE WEB?

Try these:

www.electro-optical.com/bb_rad/bb_rad.htm

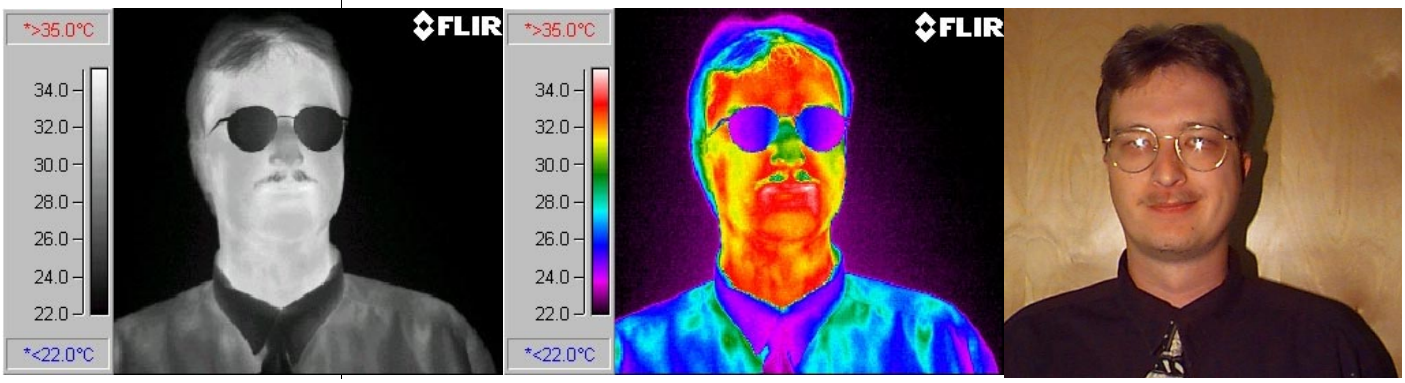
www.infraredtraining.com

www.inframation.org

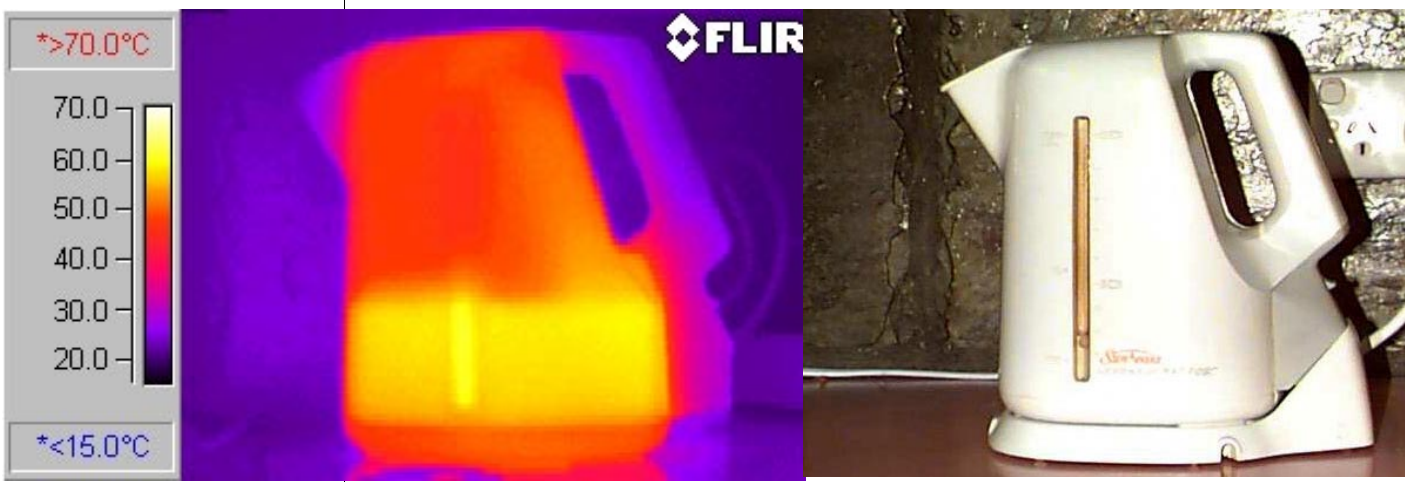
www.ipac.caltech.edu/Outreach/Edu/infrared.html

WHAT IS INFRARED THERMOGRAPHY?

Infrared Thermography is the technique for producing a visible image of invisible (to our eyes) infrared light emitted by objects due to their thermal condition. The most typical type of thermography camera resembles a typical camcorder and produces a live TV picture of heat radiation. More sophisticated cameras can actually measure the temperatures of any object or surface in the image and produce false color images that make interpretation of thermal patterns easier. An image produced by an infrared camera is called a thermogram or sometimes a thermograph.



Black and white and color thermograms of a person; and a visible light photograph. Note the glasses appear cool because they are cooler than the skin and longwave infrared energy will not pass through glass. You can see the temperature patterns on the face, reds are warmer, yellows and greens are cooler. Thermal patterns on the skin surface can be indicative of disease and are sometimes used to aid medical diagnoses.



A thermogram and visual image of a plastic kettle after heating water. Notice that you can see the heat from the water conducting through the walls. Liquid levels in industrial tanks can be measured in the same manner.

"Infrared Thermography is the technique for producing a visible image of invisible (to our eyes) infrared light emitted by objects due to their thermal condition."

WHY CAN'T INFRARED FILM BE USED FOR THERMAL IMAGING APPLICATIONS?

This is a question that people have been asking for over twenty years. Let's take a brief look at the differences between film and electronic thermal imaging.

Infrared photography involves the production of photographs by means of recording the ***reflection*** of infrared radiation from very hot sources such as the sun. Radiation that lies in a range approximately between 0.7 and 0.9 micrometers can be recorded on specially sensitized photographic emulsions. Such film is also usually sensitive to visible light as well; so special filters must be used to block the visible light. Special detectors along with specialized electronic equipment are required to record heat waves of longer wavelengths (infrared thermography).

Infrared-sensitive photographic emulsions can be used to study the distribution of objects that are just below red heat levels such as stoves, engine parts, high-pressure boilers, etc. The range of temperature that can be recorded is from approximately 250 to 500°C (482 to 932°F). Electronic thermography can be used on objects with temperatures ranging from -40 °C to more than 1500 °C (-40 °F to > 2730 °F). So if you wanted to see heat loss from your house with infrared film, it would have to be on fire!

A more detailed discussion of infrared photography and thermal photography can be found in KODAK Publications No. M-28, Applied Infrared Photography and No. P-570, Thermal Recording and Infrared Photography of Hot Objects available from Eastman Kodak.

For more information go to http://www.kodak.com/cluster/global/en/service/education/scienceFair/infraredPhotography.shtml

"... there are at least a couple of films with real thermal infrared footage: Predator and Predator 2"

I HAVE SEEN MOVIES WHERE THERMAL IMAGING IS USED TO "SEE THROUGH" WALLS. CAN THIS REALLY BE DONE?

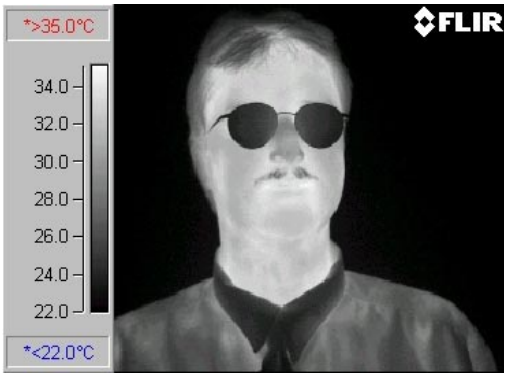
Unfortunately this is pure Hollywood fiction. However there are at least a couple of films with real thermal infrared footage: Predator and Predator 2. These were made using a single detector scanning system with a liquid nitrogen cooled detector. Today we use room temperature focal plane arrays.

HOW IS THERMAL IMAGING DIFFERENT FROM "NIGHT VISION" GOGGLES?

Night vision goggles amplify small amounts of visible light (and sometimes near infrared light) thousands of times so objects can be seen at night. These only work if some light is present i.e. moonlight or starlight. Thermal imaging works by detecting the heat energy being radiated by objects and requires absolutely no light. One advantage of thermography over night vision technologies is that night vision goggles can be easily blinded just by shining a flashlight at them. Since thermal imagers only look at the heat they are totally unaffected by light sources.

Visible light

Near infrared "Night Vision"



Thermal infrared

WHERE CAN INFRARED THERMOGRAPHY BE USED?

"Thermography can be applied in any situation where a problem or condition can display itself by means of a thermal difference."

Infrared thermography is such a valuable and versatile tool that we cannot possibly list all the applications. New and innovative ways of using the technology are being developed everyday.

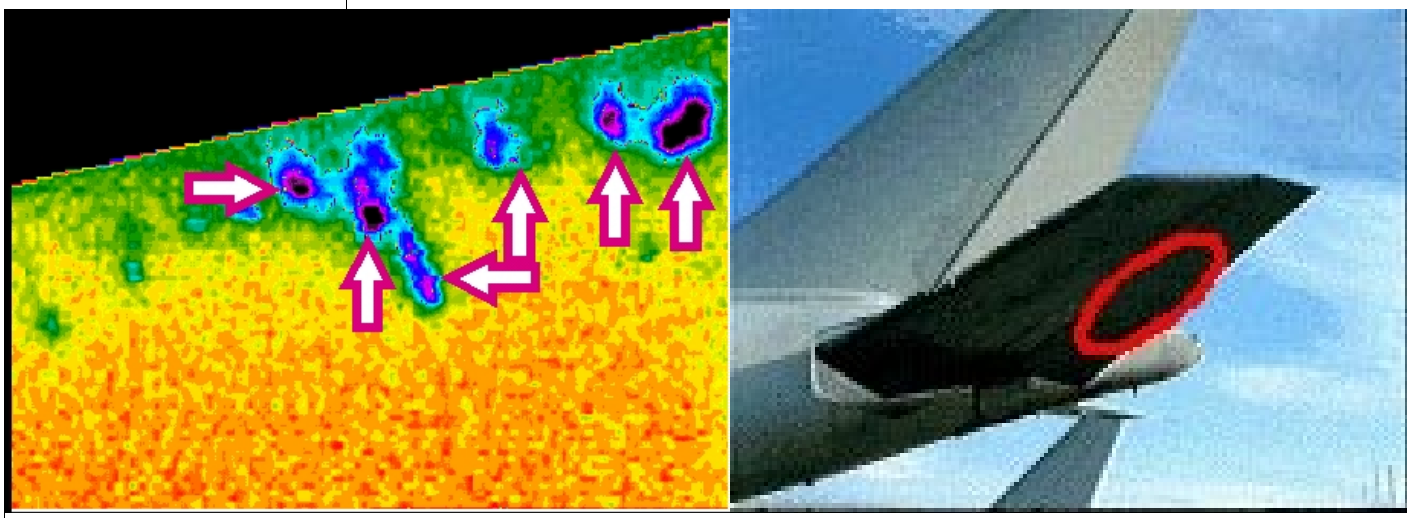
Thermography can be applied in any situation where a problem or condition can display itself by means of a thermal difference. For many situations, this is quite easy to apply; a thermal condition can be seen because the process involves release of thermal energy. An example of this is inspecting the condition of electrical distribution equipment. When electrical current passes through a conductor, a byproduct is heat. We can see that heat with an infrared camera. When there is a problem, usually more heat is generated and the camera can quickly pick it up.

Another example is the inspection of concrete bridges. As many of us know, concrete can develop delaminations, which can lead to potholes. When a pothole develops, it is quite easy to detect; usually your tire and wheel "find" the hole and you end up

with an unpleasant repair bill. Wouldn't it be great if we could find these before they cause problems? By cleverly using the sun's energy as a heating medium, and viewing with an infrared camera; we find that subsurface delaminations have a different heating effect than the sound parts of the deck structure, so the camera can see it. This example shows that even though the bridge deck doesn't generate heat it can still be analyzed with thermography if we are clever.

Here is another example of an application where we can use passive heating or cooling. Recently developed composite aircraft materials are extremely sturdy and lightweight. These materials are vital to aircraft performance and airworthiness.

It has been discovered that certain aircraft control surfaces tend to absorb water in the honeycomb structure.



Thermogram showing water ingress (dark areas) on illustrated section of aircraft

However, the honeycomb structure of this material presents a potentially dangerous problem: water ingress.

It has been discovered that certain control surfaces tend to absorb water in the honeycomb structure, for reasons that are not fully understood. The problem is aggravated by the effects of lightning and hail, which cause barely visible impact damage. The water enters the honeycomb and freezes when the aircraft is at high altitude. As the ice expands the cells in the structure breakdown. This condition grows like a cancer and eventually jeopardizes the entire structural integrity of the component.

Until recently, the only effective method of diagnosing the problem was through radiography. While this is still the most accurate way, it has several disadvantages; it is expensive in time, equipment, and manpower, and can expose maintenance personnel to hazardous ionizing radiation.

Thermography can be an indispensable tool for inspecting planes for this problem. After the plane has landed, the ice re-

mains at 0 C while it is melting. The rest of the plane has warmed to ambient temperatures on the approach. This provides an ideal opportunity to search for the ice pockets with a thermal imaging system while the plane is being serviced.

An entire aircraft can be surveyed in 20 minutes with no downtime. Images are recorded digitally for later analysis at an image processing workstation.

There are many more instances when thermography can be utilized. Here are a few:

BENEFITS OF INFRARED THERMOGRAPHY

- Virtually eliminate unscheduled power outages
- Detect problems quickly, without interrupting service
- Assess priorities for corrective action
- Minimize preventative maintenance and troubleshooting time
- Comply with insurance company requirements
- Check for defective equipment while still under manufacturer warranty

Electrical Distribution Systems

- Power generation generator inspections.
- Substation Electrical inspections, transformers and capacitor evaluation,
- Over head urban and rural distribution electrical inspections
- Electrical motor inspections

Building Envelopes and Structures

- Thermal heat loss inspections for buildings, plants, facilities, refineries.
- Moisture contamination evaluations in buildings, condo's, plants facilities
- Concrete integrity inspections
- Concrete water heated floor inspections for leaks and temperature distribution
- Locate missing or damaged insulation
- Identify air leakage energy losses
- Evaluate the thermal performance of retrofits
- Locate radiant heating wires or pipes
- Detect delaminations in concrete bridge deck

Roofing Systems

- Flat roof leak detection for buildings, plants, facilities
- Identify water damaged portions of a roof quickly and accurately
- Eliminate unnecessary replacement of good roofing
- Plan accurate budgets based on facts
- Document problems before the warranty/bond expires

Mechanical Systems

- Boilers
  - *Inspect burners for flame impingement and burner management*
  - *Look at combustion patterns of fuel*
  - *Detect thermal patterns on boiler tubes and measure tube skin temperature during normal operation or when boiler is on standby*
  - *Scan and record temperatures in areas of boiler not monitored*
  - *Scan the exterior of boiler for refectory damage or locate warmer areas where potential refectory damage may occur*
- Detect coke buildup in crude furnaces
- Power Plant boiler flue gas leak detection
- Mechanical bearing inspections
- Heat ventilation air conditioning equipment evaluation
- Cold Storage cooling losses.
- Detect insulation leaks in refrigeration equipment

Petrochemical Applications

- Refinery process line insulation loss or leak detection
- Refinery process evaluation
- Heat exchanger Quality and efficiency evaluation
- Furnace refractory (insulation) inspections
- Furnace Internal flame evaluation and tube inspections
- Flame propagation explosion analysis.

Electronic Equipment

- Printed circuit board evaluation and troubleshooting.
- Thermal mapping of semiconductor device services

Infrared Training Center

16 Esquire Rd.
N. Billerica, MA 01862

Phone: 978-901-8405
Fax: 978-901-8832

We're on the Web!
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"Hands On" Thermography Training, Certification, and Support

- Circuit board component evaluation
- Production-type inspection of bonded structures
- Inspection of hybrid microcircuits
- Inspection of solder joints

Environmental Applications

- Locate old waste disposal sites
- Locate old buried tanks on industrial sites
- Locate and monitor oil spills

Research and development applications

- Design proto typing evaluation

Automotive Applications

- Motor racing suspension and tire contact diagnostics
- Brake and engine systems evaluation for performance and cooling efficiencies
- Finding faulty fuel injection nozzles

Aerospace Applications

- Water ingress in airplane control surfaces and radomes
- Tire and brake system diagnosis
- Windshield and wing surface deicing system diagnosis
- Stress crack and corrosion identification and location
- Jet and rocket engine analysis
- Composite materials delamination and disbanding location
- Target signature analysis

Medical / Veterinary Applications

- Medical injury examinations for whiplash, back injuries, Carpal Tunnel syndrome
- Disease evaluation - breast cancer, arthritis and many more
- Dentistry, tempomandibular jaw dysfunction and more
- Sports injuries evaluation, and therapy progress
- Equine (horse) injury examination, stress fractures, lameness
- Laser dosimetry determination

Airborne applications

- Pipeline inspection, leak detection, stress corrosion cracking areas
- Environmental inspections, pollution dumping, thermal dumping of waste water
- Fire Mapping, hold over fires, fire line and mop-up inspections
- High Voltage Aerial Electrical inspections for transmission lines
- Search and rescue
- Covert surveillance

Pulp and Paper

- Detect uneven heat distribution in Fourdrinier steam boxes
- Identify wet streaks, non-uniformity, that can have adverse effects on paper quality
- Identify basis weight variations
- Monitor size press performance
- Analyze dryer temperatures to look for non-uniformity in dryers
- Monitor coating to see that it is being applied uniformly to surface of the paper
- Analyze reel to find anomalies that may be induced by pieces of process equipment connected to the paper machine
- Inspect chip piles for hot spots

Steam Turbine and Hydroelectric Generators

- Locate inter-laminar faults in stator cores
- Monitor the effectiveness of repairs to the damaged areas
- Help maintain quality control during a stator core repair
- Obtain a thermal image of the stator core that serves as a permanent record of the condition of the stator core following repairs

Miscellaneous Applications

- Detect RF heating in antennas, wave guides, guy wires and frame structures
- Locate low-intensity sleeper fires on forest lands
- Locate lost people
- Remote sensing applications
- Firefighting – Locate people in burning buildings and navigate through smoke

HOW DO I FIND OUT MORE ABOUT THERMOGRAPHY AND ITS APPLICATIONS?

Come to an **itc** training course and get hands on experience with a thermal camera!