NDT Method

TIR –Thermography and Infrared Rays

thermology

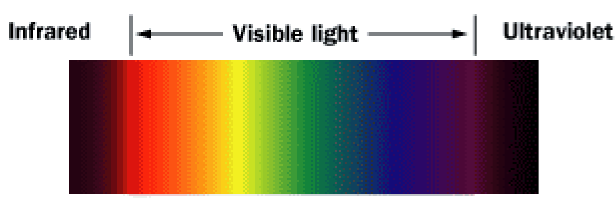
How does it work?

Infrared thermography is the technique of converting infrared energy (**radiant heat**) into an image that a person can see and understand. We ordinarily see in visible light. We can compare infrared to visible light - they are not the same, but they are analogous.

In a similar way, an infrared camera creates an image by converting radiant heat energy into a signal that can be displayed on a monitor (and later printed).

The infrared energy emitted from an object is directly proportional to its temperature. Therefore temperatures are accurately measured by the infrared camera.

Light Basics
In order to understand thermal imaging, it is important to understand something about light. The amount of energy in a light wave is related to its wavelength: Shorter wavelengths have higher energy. Of visible light, violet has the most energy, and red has the least. Just next to the visible light spectrum is the infrared spectrum.



Spectrum of light

Infrared light can be split into three categories:

1. **Near-infrared (near-IR)** - Closest to visible light, near-IR has wavelengths that range from 0.7 to 1.3 microns, or 700 billionths to 1,300 billionths of a meter.
2. **Mid-infrared (mid-IR)** - Mid-IR has wavelengths ranging from 1.3 to 3 microns. Both near-IR and mid-IR are used by a variety of electronic devices, including remote controls.
3. **Thermal-infrared (thermal-IR)** - Occupying the largest part of the infrared spectrum, thermal-IR has wavelengths ranging from 3 microns to over 30 microns.

The key difference between thermal-IR and the other two is that thermal-IR is emitted by an object instead of reflected off it. Infrared light is emitted by an object because of what is happening at the atomic level.

Thermal Imaging - Here's how it works:

A special lens focuses the infrared light emitted by all of the objects in view.

The focused light is scanned by a phased array of infrared-detector elements. The detector elements create a very detailed temperature pattern called a ***thermogram***. It only takes about one-thirtieth of a second for the detector array to obtain the temperature information to make the thermogram. This information is obtained from several thousand points in the field of view of the detector array.

The thermogram created by the detector elements is translated into electric impulses.

The impulses are sent to a signal-processing unit, a circuit board with a dedicated chip that translates the information from the elements into data for the display.

The signal-processing unit sends the information to the display, where it appears as various colors depending on the intensity of the infrared emission. The combination of all the impulses from all of the elements creates the image.

Types of Thermal Imaging Devices

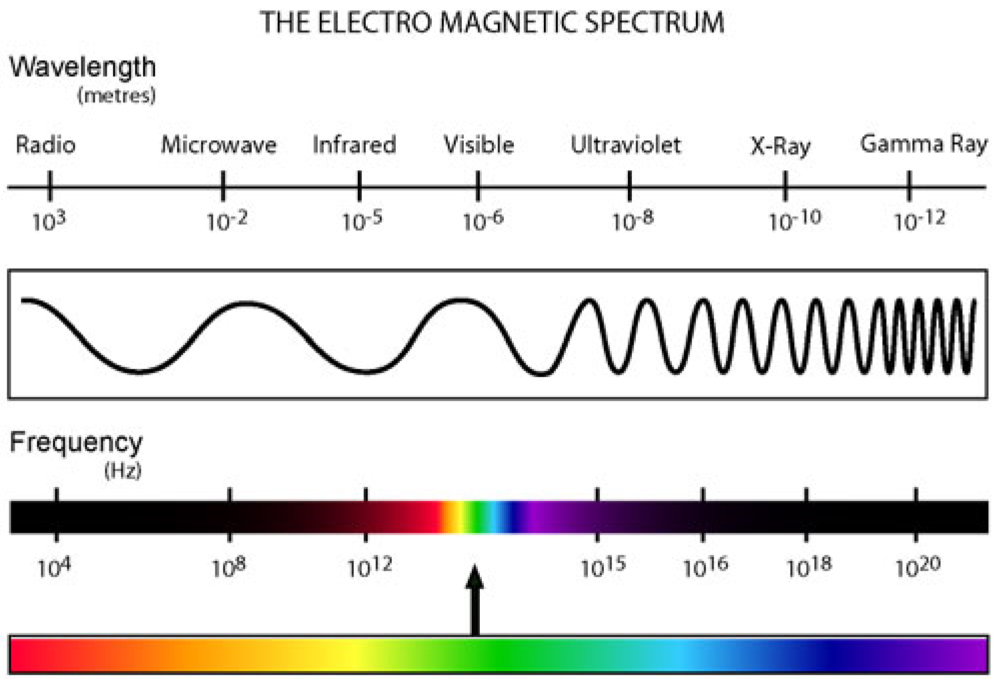
Most thermal-imaging devices scan at a rate of 30 times per second. They can sense temperatures ranging from -4 degrees Fahrenheit (-20 degrees Celsius) to 3,600 F (2,000 C), and can normally detect changes in temperature of about 0.4 F (0.2 C).

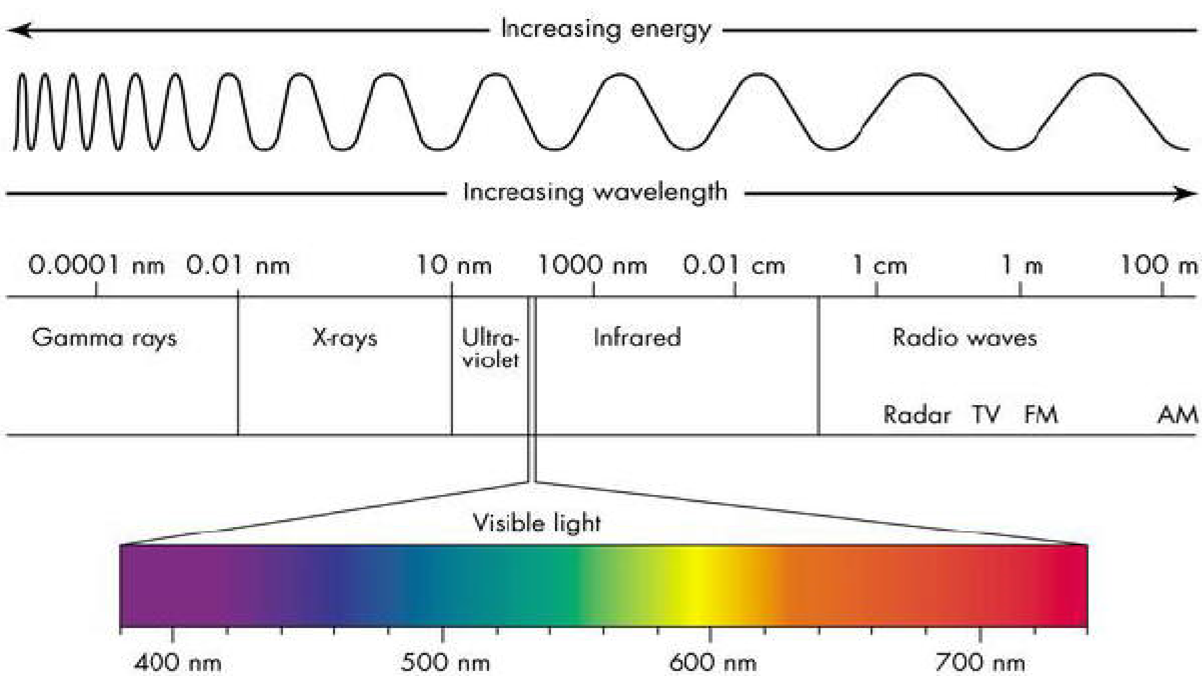
There are two common types of thermal-imaging devices:

Un-cooled - This is the most common type of thermal-imaging device. The infrared-detector elements are contained in a unit that operates at room temperature. This type of system is completely quiet, activates immediately and has the battery built right in.

Cryogenically cooled - More expensive and more susceptible to damage from rugged use, these systems have the elements sealed inside a container that cools them to below 32 F (zero C). The advantage of such a system is the incredible resolution and sensitivity that result from cooling the elements. Cryogenically-cooled systems can "see" a difference as small as 0.2 F (0.1 C) from more than 1,000 ft (300 m) away, which is enough to tell if a person is holding a gun at that distance!

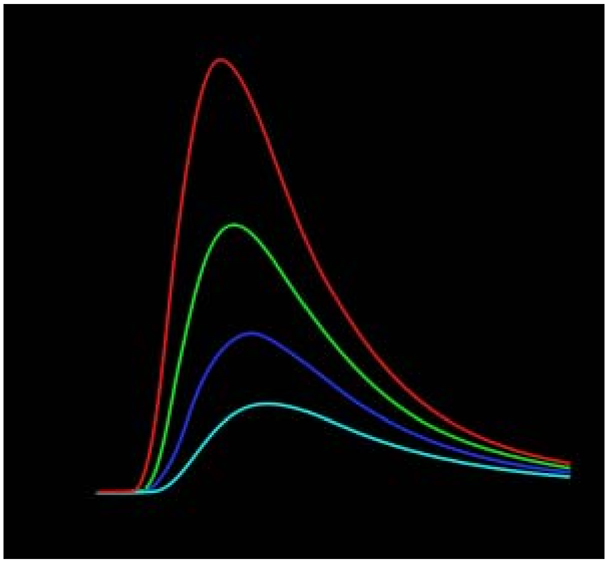
Unlike traditional most night-vision equipment which uses image-enhancement technology, thermal imaging is great for detecting people or working in near-absolute darkness with little or no ambient lighting (i.e. stars, moonlight, etc,)





The ability to measure temperature from an IR image is called **radiometry**. This requires sophisticated and expensive electronics. The ability to measure a temperature anywhere on the image is available only on the high-end cameras like the Flir PM280 used by *IRIS Associates*.

Peak wavelength



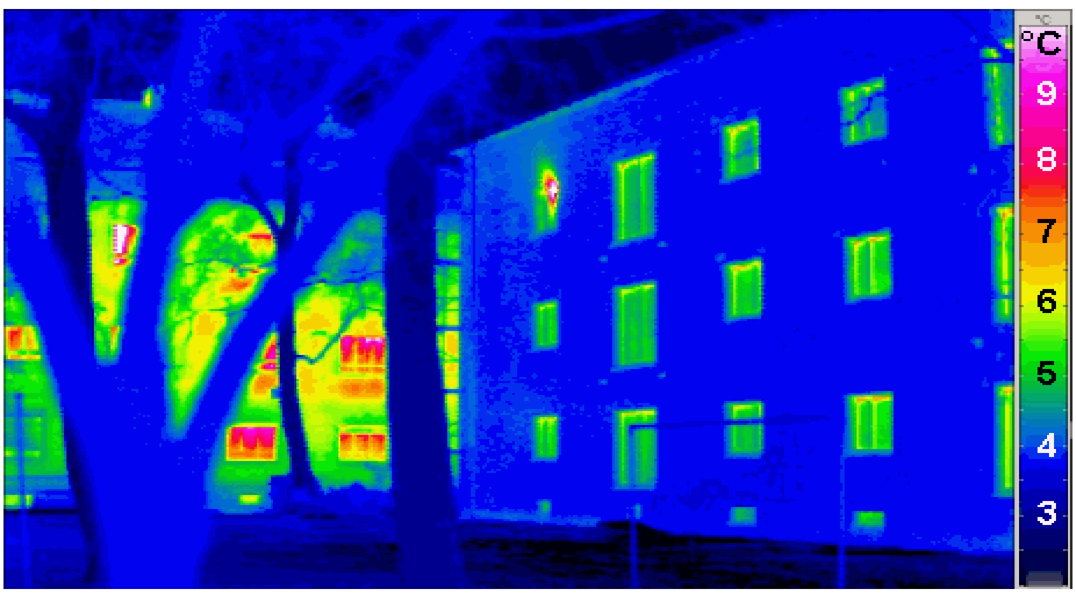
This diagram shows how the peak wavelength and total radiated amount vary with temperature. Although this plot shows relatively high temperatures, the same relationships hold true for any temperature down to absolute zero. Visible light is between 380 and 750 nm.

Thermal Imaging for Building Analysis

The establishment of a well-insulated building utilizes a large proportion of the worldwide energy consumption. Thus, the building sector has the largest potential for improving the total energy efficiency. A well insulated building being energy efficient can lead to minimal recurring expense & save a lot of the owner's money while also create an acceptable occupant environment.
The quickest & easiest method of establishing an energy efficient building is Infrared Thermography, that helps detect electrical problems, moisture & energy wastage in buildings.

An infrared camera is used for a quick & thorough diagnosis of the entire building whereby problem areas not visible through naked eye are detected. These cameras indicate the exact location of the problem area & aid in the proper diagnosis of the area with energy loss. Thus, for many building professionals, the IR Cameras serve as a practical & vital tool of diagnosis as they present a bigger picture of the area of problem.

The ***Building Diagnostic Service*** is extremely helpful in establishing the relation of building envelops, HVAC system & plumbing issues for maximum energy efficiency. The best part about this service is that, the source of the problem can be detected without any major impact on the building or people. It is for this reason that numerous building experts prefer Infrared Imaging as an accurate & reliable method of building diagnosis.



Thermal Imaging for Building Analysis

Infrared of Buildings to check moisture ingrates or water seepage

Infrared sensitivity in ANIMALS (SNAKE)

Infrared sensing in snakes

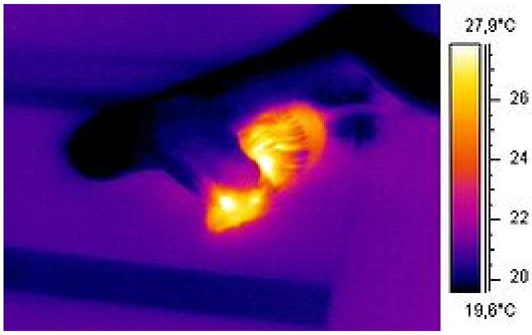
Pit vipers, pythons, and some boas have infrared-sensitive receptors in deep grooves between the nostril and eye, although some have labial pits on their upper lip just below the nostrils (common in pythons), which allow them to "see" the radiated heat of warm-blooded prey mammals(Mouse/Rat).

MOUSE

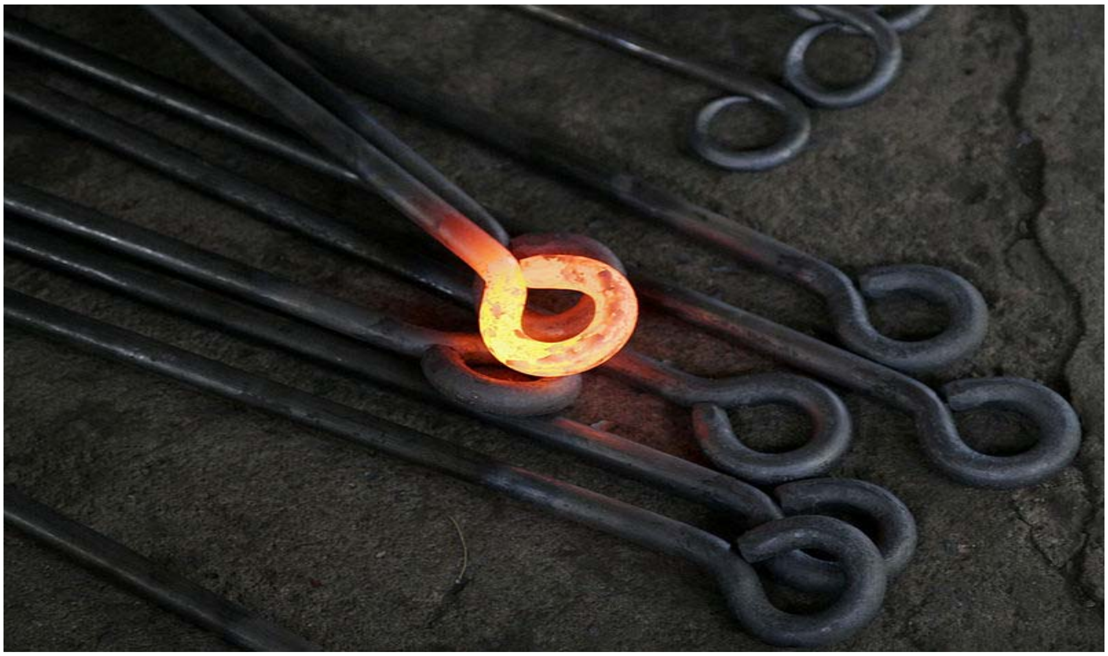
Mouse Have the hot blood and this can be detected by the Infrared Sensitivity of Snakes

Infrared sensitivity

Pit vipers, pythons, and some boas have **infrared-sensitive receptors** in deep grooves between the nostril and eye, although some have labial pits on their upper lip just below the nostrils (common in pythons), which allow them to "see" the radiated heat of warm-blooded prey mammals



Thermographic image of a snake eating a mouse



T1-T2 is applicabel if one end is heated then heat is transferred to other end, slowly and heated end looks, red hot and other end looks in metalic blue clour.

Pseudo Color

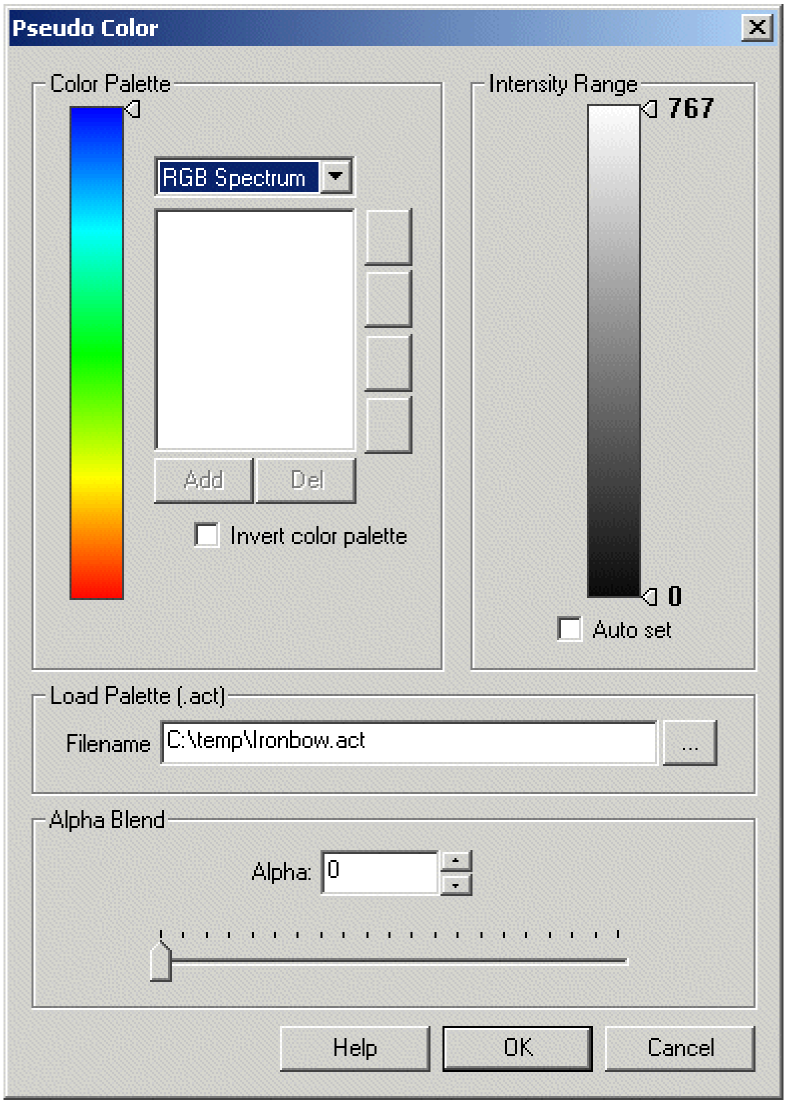
Pseudo Color (means what)

Artificially coloring an image can reveal textures and qualities within the image that may not have been apparent in the original coloring. You can use the pseudo coloring module to reveal an image's hidden texture.

The Pseudo Color module colonizes the image based on its grayscale value which maps to a full RGB color range. Pseudo Color images can help to reveal image qualities that would not be readily visible within the image's true color.

The false color of a pixel is created by determined by summing its RGB values and mapping them into a 768 row lookup table. This lookup table is created by oscillating through the RGB color table from Blue to Red to create 768 unique colors.

Interface



Instructions

1. Select the color palette that you would like to use. The default is the full RGB Spectrum. If you would like to create your own palette chose the "custom" (second last selection) setting which will enable the palette buttons for you to add, delete and reorder your own palette. If you wish to load your own 768 byte RGB order .act palette file select the "load palette" option (last selection) which will load in the file specified below as the palette.

2. If you want to reverse the high/low values of the palette (i.e. red to black instead of black to red) you can select the 'Invert color palette' checkbox

3. If you would like to shift the color palette grab the little palette knob seen on the right side of the color palette and drag it to the desired location. Shifting the color palette can be helpful in correlating surfaces with different lighting. For example, an image on a sunny day may have values shown in green using the RGB Spectrum palette. Taking the same image on a cloudy day would result in those values shown as red pixels. Shifting the color palette as a form of 'color correction factor' can help you better manually align those comparisons.

4. To have the module automatically set the minimum and maximum pixel intensity values used in coloring click on the 'Auto set' checkbox. When this is enabled the module with scale the color palette from the minimum value to the maximum value to ensure that the full palette colors are used.

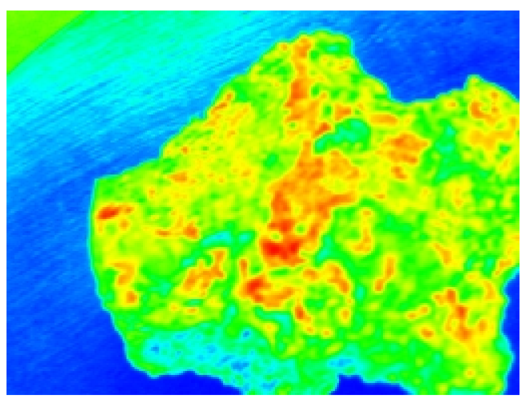
5. If the auto set checkbox is not enabled you will see the minimum and maximum values next to two knobs on the right side of the grayscale intensity palette. You can grab these knobs to change the respective values manually. Manually setting the minimum and maximum intensity values can be helpful in more closely analyzing specific intensity ranges within images.

6. The alpha blend allows you to view a combination of the original image and the pseudo colored image to gain a better understanding of the actual surface that is being colored. If you would like to blend the original color image with the specified palette select the appropriate alpha value. A zero alpha value replaces each image pixel with the palette value, a 100 value leaves the original image intact with the colored image being completely transparent, a 50 value combines 50% of the color palette with 50% of the original image.

Example

Source or OBJECT for Inspection

Pseudo Colored



Thermography Camer and Data aquisation Unit


IR is based on Thermo graphic Signal Reconstruction (TSR)

processing technique, which allows unmatched sensitivity that is comparable to full scale systems. Its flexible architecture let's you configure heat source, camera and signal processing to match the application.

Whether it's impact damage, trapped water, delamination in composites, or corrosion in Al structures, IR is ready to go wherever you need it! IR is extremely flexible, and can use alternative heat sources and IR cameras tailored to specific application requirements.

The system is ideally suited **for on-aircraft maintenance** applications, such as the detection of trapped water and impact damage in composite structures, and in field situations where inspection speed and setup time are critical. IR allows the inspector to set up the system and perform the complete inspection in minutes, compared to current solutions that are often too large, costly or complex for field applications.

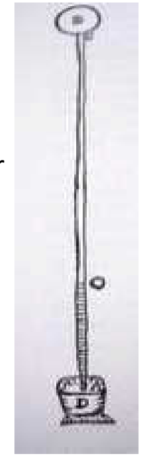
Thermal NDT methods involve the measurement or mapping of surface temperatures as heat flows to, from and/or through an object. The simplest thermal measurements involve making point measurements with a thermocouple. This type of measurement might be useful in locating hot spots, such as a bearing that is wearing out and starting to heat up due to an increase in friction.

In its more advanced form, the use of thermal imaging systems allow thermal information to be very rapidly collected over a wide area and in a non-contact mode. Thermal imaging systems are instruments that create pictures of heat flow rather than of light. Thermal imaging is a fast, cost effective way to perform detailed thermal analysis. The image above is a heat map of the space shuttle as it lands.

Thermal measurement methods have a wide range of uses. They are used by the police and military for night vision, surveillance, and navigation aid; by firemen and emergency rescue personnel for fire assessment, and for search and rescue; by the medical profession as a diagnostic tool; and by industry for energy audits, preventative maintenance, processes control and nondestructive testing. The basic premise of thermographic NDT is that the flow of heat from the surface of a solid is affected by internal flaws such as disbonds, voids or inclusions. The use of thermal imaging systems for industrial NDT applications will be the focus of this material.

Partial History of Thermal Testing

The detection of thermal energy is not a problem for the human body. Some sources say that the nerve endings in human skin respond to temperature changes as small as 0.009°C (0.0162°F). While humans have always had the ability to detect thermal energy, they have not had a way to quantify temperature until a few hundred years ago. A few of the more significant thermal measurement advances are discussed in the following paragraphs.



The Thermometer

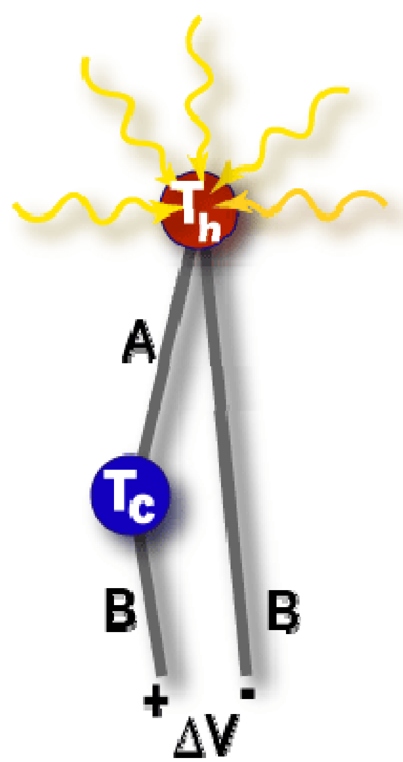
Ancient Greeks knew that air was expanded by heat. This knowledge was eventually used to develop the thermoscope, which traps air in a bulb so that the size of the bulb changes as the air expands or contracts in response to a temperature increase or decrease. The image on the right shows the first published sketch of a thermoscope, which was published by Italian inventor Santorio Santorii. The next step in making a thermometer was to apply a scale to measure the expansion and relate this to heat. Some references say that Galileo Galilei invented a rudimentary water thermometer in 1593 but there is no surviving documentation to support his work on this. Therefore, Santorii is regarded as the inventor of the thermometer, for he published the earliest account of it in 1612. Gabriel Fahrenheit invented the first mercury thermometer in 1714.

Infrared Energy

Sir William Herschel, an astronomer, is credited with the discovery of infrared energy in 1800. Knowing that sunlight was made up of all the colors of the spectrum, Herschel wanted to explore the colors and their relationship to heat. He devised an experiment using a prism to spread the light into the color spectrum and thermometers with blackened bulbs to measure the temperatures of the different colors. Herschel observed an increase in temperature from violet to red and observed that the hottest temperature was actually beyond red light. Herschel termed the radiation causing the heating beyond the visible red range "calorific rays." Today, it is called "infrared" energy.

The Seebeck Effect (Thermocouples)

In 1821, Thomas Johann Seebeck found that a circuit made from two dissimilar metals, with junctions at different temperatures, would deflect a compass needle. He initially believed this was due to magnetism induced by a temperature difference, but soon realized that it was an electrical current that was induced. More specifically, the temperature difference produces an electric potential (voltage) which can drive electric current in a closed circuit. Today, this is known as the Seebeck effect.



The voltage difference, DV, produced across the terminals of an open circuit made from a pair of dissimilar metals, A and B, whose two junctions are held at different temperatures, is directly proportional to the difference between the hot and cold junction temperatures, T_h - T_c. The Seebeck voltage does not depend on the distribution of temperature along the metals between the junctions. This is the physical basis for a thermocouple, which was invented by Nobili in 1829.

Noncontact Thermal Detectors

Melloni soon used the thermocouple technology to produce a device called the thermopile. A thermopile is made of thermocouple junction pairs connected electrically in series. The absorption of thermal radiation by one of the thermocouple junctions, called the active junction, increases its temperature. The differential temperature between the active junction and a reference junction kept at a fixed temperature produces an electromotive force directly proportional to the differential temperature created. This effect is called a thermoelectric effect. Melloni was able to show that a person 30 feet away could be detected by focusing his or her thermal energy on the thermopile. Thermopile detectors are used today for spectrometers, process temperature monitoring, fire and flame detection, presence monitor, and a number of other non-contact temperature measurement devices. A device similar to the thermopile measured a change in electrical resistance rather than a voltage change. This device was named the bolometer, and in 1880 it was shown that it could detect a cow over 1000 feet away.

During World War I, Case became the first to experiment with photoconducting detectors. These thallium sulfide detectors produced signals due to the direct interaction of infrared photons and were faster and much more sensitive than other thermal detectors that functioned from being heated. During World War II, photoconductive or quantum detectors were further refined and this resulted in a number of military applications, such as target locating, tracking, weapons guiding and intelligence gathering.

Imaging Systems

Application areas expanded to surveillance and intrusion during the Vietnam era. Shortly thereafter space-based applications for natural resource and pollution monitoring and astronomy were developed. IR imaging technology developed for the military spilled over into commercial markets in the 1960s. Initial applications were in laboratory level R&D, preventative maintenance applications, and surveillance. The first portable systems suitable for NDT applications were produced in the 1970s. These systems utilized a cooled scanned detector and the image quality was poor by today's standards. However, infrared imaging systems were soon being widely used for a variety of industrial and medical applications.

In the late 1980s, the US military released the focal plane array (FPA) technology into the commercial marketplace. The FPA uses a large array of tiny IR sensitive semiconductor detectors, similar to those used in charge couple device (CCD) cameras. This resulted in a dramatic increase in image quality. Concurrently, the advances in computer technology and image processing programs helped to simplify data collection and to improve data interpretation.

Current State

In 1992, the American Society for Nondestructive Testing officially adopted infrared testing as a standard test method. Today, a wide variety of thermal measurement equipment is commercially available and the technology is heavily used by industry. Researchers continue to improve systems and explore new applications.

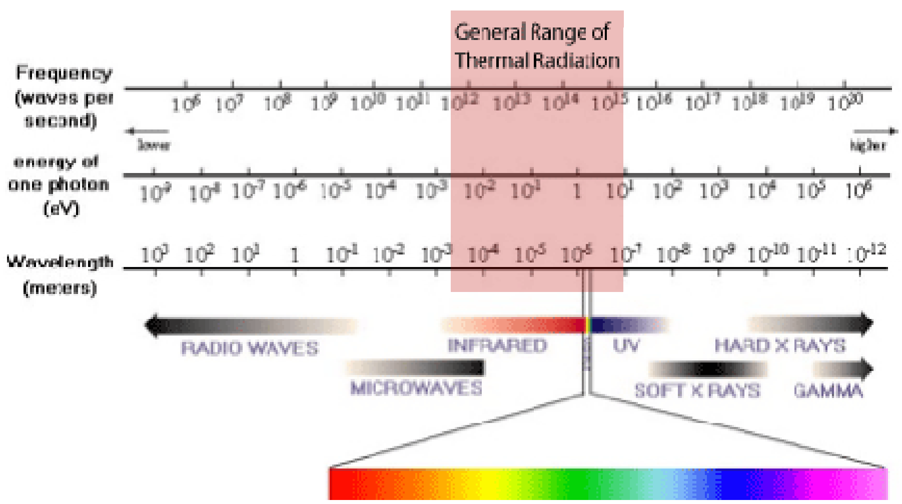
Scientific Principles of Thermal Testing

Thermal Energy
Energy can come in many forms, and it can change from one form to another but can never be lost. This is the First Law of Thermodynamics. A byproduct of nearly all energy conversion is heat, which is also known as thermal energy. When there is a temperature difference between two objects or two areas within the same object, heat transfer occurs. Heat energy transfers from the warmer areas to the cooler areas until thermal equilibrium is reached. This is the Second Law of Thermodynamics. When the temperature of an object is the same as the surrounding environment, it is said to be at ambient temperature.

Heat Transfer Mechanisms
Thermal energy transfer occurs through three mechanisms: conduction, convection, and/or radiation. Conduction occurs primarily in solids and to a lesser degree in fluids as warmer, more energetic molecules transfer their energy to cooler adjacent molecules. Convection occurs in liquids and gases, and involves the mass movement of molecules such as when stirring or mixing is involved.

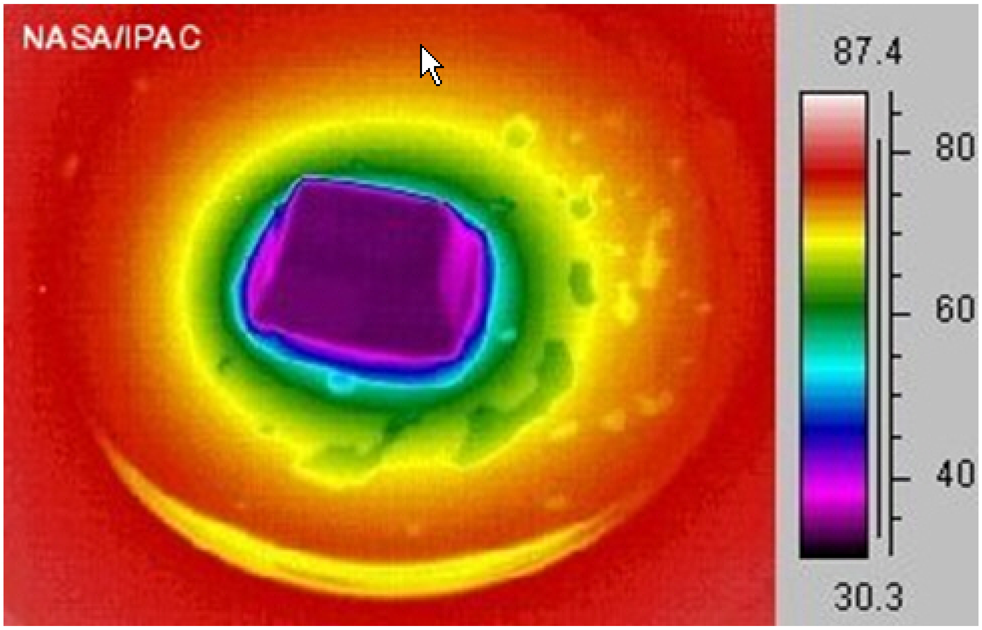
The third way that heat is transferred is through electromagnetic radiation of energy. Radiation needs no medium to flow through and, therefore, can occur even in a vacuum. Electromagnetic radiation is produced when electrons lose energy and fall to a lower energy state. Both the wavelength and intensity of the radiation is directly related to the temperature of the surface molecules or atoms.

Wavelength of Thermal Energy



The wavelength of thermal radiation extends from 0.1 microns to several hundred microns. As highlighted in the image, this means that not all of the heat radiated from an object will be visible to the human eye… but the heat is detectable. Consider the gradual heating of a piece of steel. With the application of a heat source, heat radiating from the part is felt long before a change in color is noticed. If the heat intensity is great enough and applied for long enough, the part will gradually change to a red color. The heat that is felt prior to the part changing color is the radiation that lies in the infrared frequency spectrum of electromagnetic radiation. Infrared (IR) radiation has a wavelength that is longer than visible light or, in other words, greater than 700 nanometers. As the wavelength of the radiation shortens, it reaches the point where it is short enough to enter the visible spectrum and can be detected with the human eye.

An infrared camera has the ability to detect and display infrared energy. Below is an infrared image of an ice cube melting. Note the temperature scale on side, which shows warm areas in red and cool areas in purple. It can be seen that the ice cube is colder than the surrounding air and it is absorbing heat at its surface. The basis for infrared imaging technology is that any object whose temperature is above 0°K radiates infrared energy. Even very cold objects radiate some infrared energy. Even though the object might be absorbing thermal energy to warm itself, it will still emit some infrared energy that is detectable by sensors. The amount of radiated energy is a function of the object's temperature and its relative efficiency of thermal radiation, known as emissivity.



(Photo courtesy of NASA/JPL-Caltech/IPAC)

Emissivity

A very important consideration in radiation heat transfer is the emissivity of the object being evaluated. Emissivity is a measure of a surface's efficiency in transferring infrared energy. It is the ratio of thermal energy emitted by a surface to the energy emitted by a perfect blackbody at the same temperature. A perfect blackbody only exists in theory and is an object that absorbs and reemits all of its energy. Human skin is nearly a perfect blackbody as it has an emissivity of 0.98, regardless of actual skin color.

If an object has low emissivity, IR instruments will indicate a lower temperature than the true surface temperature. For this reason, most systems and instruments provide the ability for the operator to adjust the emissivity of the object being measured. Sometimes, spray paints, powders, tape or "emissivity dots" are used to improve the emissivity of an object.

Equipment - Detectors

Thermal energy detection and measurement equipment comes in a large variety of forms and levels of sophistication. One way to categorize the equipment and materials is to separate thermal detectors from quantum (photon) detectors. The basic distinction between the two is that thermal detectors depend on a two-step process. The absorption of thermal energy in these detectors raises the temperature of the device, which in turn changes some temperature-dependent parameter, such as electrical conductivity. Quantum devices detect photons from infrared radiation. Quantum detectors are much more sensitive but require cooling to operate properly.

Thermal Detectors

Thermal detectors include heat sensitive coatings, thermoelectric devices and pryoelectric devices. Heat sensitive coatings range from simple wax-based substances that are blended to melt at certain temperatures to specially formulated paint and greases that change color as temperature changes. Heat sensitive coatings are relatively inexpensive but do not provide good quantitative data.

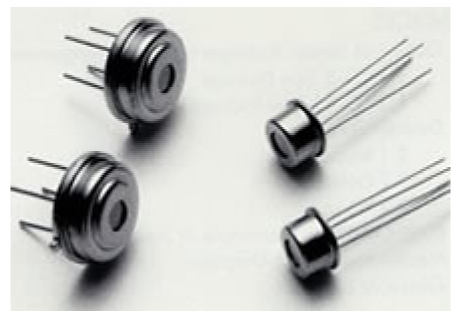
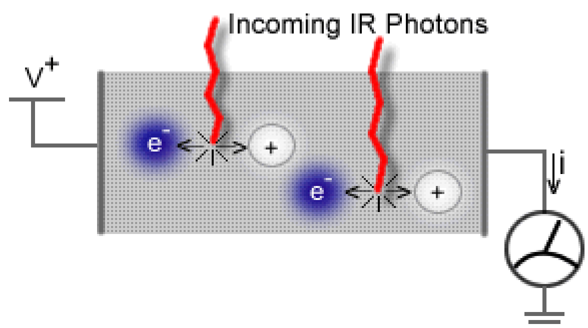


Image Courtesy of GE Thermometrics

Thermoelectric devices include thermocouples, thermopiles (shown right), thermistors and bolometers. These devices produce an electrical response based on a change in temperature of the sensor. They are often used for point or localized measurement in a contact or near contact mode. However, thermal sensors can be miniaturized. For example, mirobolometers are the active elements in some high-tech portable imaging systems, such as those used by fire departments. Benefits of thermal detectors are that the element does not need to be cooled and they are comparatively low in price. Thermal detectors are used to measure the temperature in everything from home appliances to fire and intruder detection systems to industrial furnaces to rockets.

Quantum (Photon) Detectors



Unlike thermal detectors, quantum detectors do not rely on the conversion of incoming radiation to heat, but convert incoming photons directly into an electrical signal. When photons in a particular range of wavelengths are absorbed by the detector, they create free electron-hole pairs, which can be detected as electrical current. The signal output of a quantum detector is very small and is overshadowed by noise generated internally to the device at room temperatures. Since this noise within a semiconductor is partly proportional to temperature, quantum detectors are operated at cryogenic temperatures [i. e. down to 77 K (liquid nitrogen) or 4 K (liquid helium)] to minimize noise. This cooling requirement is a significant disadvantage in the use of quantum detectors. However, their superior electronic performance still makes them the detector of choice for the bulk of thermal imaging applications. Some systems can detect temperature differences as small as 0.07°C.

Quantum detectors can be further subdivided into photoconductive and photovoltaic devices. The function of photoconductive detectors are based on the photogeneration of charge carriers (electrons, holes or electron-hole pairs). These charge carriers increase the conductivity of the device material. Possible materials used for photoconductive detectors include indium antimonide (InSb), quantum well infrared photodetector (QWIP), mercury cadmium telluride (mercad, MCT), lead sulfide (PbS), and lead selenide (PbSe).

Photovoltaic devices require an internal potential barrier with a built-in electric field in order to separate photo-generated electron-hole pairs. Such potential barriers can be created by the use of p-n junctions or Schottky barriers. Examples of photovoltaic infrared detector types are indium antimonide (InSb), mercury cadmium telluride (MCT), platinum silicide (PtSi), and silicon Schottky barriers.

Detector Cooling

There are several different ways of cooling the detector to the required temperature. In the early days of thermal imaging, liquid nitrogen was poured into imagers to cool the detector. Although satisfactory, the logistical and safety implications led to the development of other cooling methods. High pressure gas can be used to cool a detector to the required temperatures. The gas is allowed to rapidly expand in the cooling systems and this expansion results in the significant reduction in the temperature of a gas. Mechanical cooling systems are the standard for portable imaging systems. These have the logistical advantage of freeing the detection system from the requirements of carrying high pressure gases or liquid nitrogen.

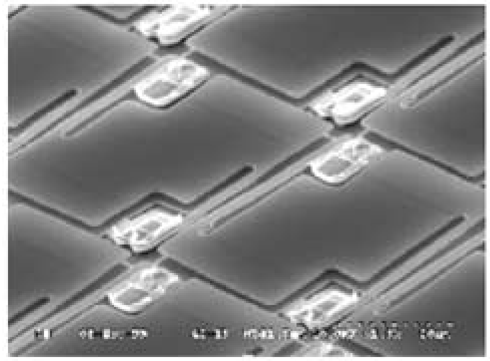
Equipment - Imaging Technology

Imaging Systems

Thermal imaging instruments measure radiated infrared energy and convert the data to corresponding maps of temperatures. A true thermal image is a gray scale image with hot items shown in white and cold items in black. Temperatures between the two extremes are shown as gradients of gray. Some thermal imagers have the ability to add color, which is artificially generated by the camera's video enhancement electronics, based upon the thermal attributes seen by the camera. Some instruments provide temperature data at each image pixel. Cursors can be positioned on each point, and the corresponding temperature is read out on the screen or display. Images may be digitized, stored, manipulated, processed and printed out. Industry-standard image formats, such as the tagged image file format (TIFF), permit files to work with a wide array of commercially available software packages.

Images are produced either by scanning a detector (or group of detectors) or by using with focal plane array. A scanning system in its simplest form could involve a single element detector scanning along each line in the frame (serial scanning). In practice, this would require very high scan speeds, so a series of elements are commonly scanned as a block, along each line. The use of multiple elements eases the scan speed requirement, but the scan speed and channel bandwidth requirements are still high. Multiple element scans do, however, result in a high degree of uniformity. The frame movement can be provided by frame scanning optics (using mirrors) or in the case of line scan type imagers, by the movement of the imager itself. Another method is to use a number of elements scanning in parallel (parallel scanning). These scanners have one element per line and scan several lines simultaneously. Scan speeds are lower but this method can give rise to poor image uniformity.

Another way thermal images are produced is with focal plane arrays (FPA), which are also known as staring arrays. A focal plane array is a group of sensor elements organized into a rectangular grid. A high magnification image of a portion of a mirobolometer focal plane array is shown to the right. The entire scene is focused on the array, each element cell then provides an output dependent upon the infrared radiation falling upon it. The spatial resolution of the image is determined by the number of pixels of the detector array. Common formats for commercial infrared detectors are 320 by 240 pixels (320 columns, 240 rows), and 640 by 480. The latter format is nearly the resolution obtained by a standard TV. Spatial resolution, the ability to measure temperatures on small areas, can be as fine as 15 microns. Temperature resolution, the ability to measure small temperature differences, can be as fine as 0.1° C.



The advantage of FPAs is that no moving mechanical parts are needed and that the detector sensitivity and speed can both be slower. The drawback is that the detector array is more complicated to fabricate and manufacturing costs are higher. However, improvements in semiconductor fabrication practices are driving the cost down and the general trend is that infrared camera systems will be based on FPAs, except for special applications. A microbolometer is the latest type of thermal imaging FPA, and consists of materials that measure heat by changing resistance at each pixel. The most common microbolometer material is vanadium oxide (VOX). Amorphous silicon is another relatively new microbolometer material. Applications extend from microelectronic levels to scanning wide areas of the earth from space. Airborne systems can be used to see through smoke in forest fires. Portable, hand-held units can be used for equipment monitoring in preventative maintenance and flaw detection in nondestructive testing programs.

Equipment for Establishing Heat Flow

In some inspection applications, such as corrosion or flaw detection, the components being inspected may be at ambient temperature and heat flow must be created. This can be accomplished by a variety of means. Heating can be accomplished by placing the part in a warm environment, such as a furnace, or directing heat on the surface with a heat gun or with flash lamps. Alternately, cooling can be accomplished by placing the component in a cold environment or cooling the surface with a spray of cold liquid or gas.

Image Capturing and Analysis

IR cameras alone or used with an external heat source can often detect large, near-surface flaws. However, repeatable, quantifiable detection of deeper, subtler features requires the additional sensitivity of a sophisticated computerized system. In these systems, a computer is used to capture a number of time sequence images which can be stepped through or viewed as a movie to evaluate the thermal changes in an object as a function of time. This technique is often referred to as thermal wave imaging.

The image to the right shows a pulsed thermography system. This system uses a closely controlled burst of thermal energy from a xenon flash lamp to heat the surface. The dissipation of heat is then tracked using a high speed thermal imaging camera. The camera sits on top of the gray box in the foreground. The gray box houses the xenon flash lamp and it is held against the surface being inspected. The equipment was designed to inspect the fuselage skins of aircraft for corrosion damage and can make quantitative measurements of material loss. It has also been shown to

detect areas of water incursion in composites and areas where bonded structure have separated.

Techniques and Select Industrial Applications of Thermal Imaging

Some thermal imaging techniques simply involve pointing a camera at a component and looking at areas of uneven heating or localized hot spots. The first two example applications discussed below fall into this category. For other applications, it may be necessary to generate heat flow within the component and/or evaluate heat flow as a function of time. A variety of thermal imaging techniques have been developed to provide the desired information. A few of these techniques are highlighted below.

Electrical and Mechanical System Inspection

Electrical and mechanical systems are the backbone of many manufacturing operations. An unexpected shutdown of even a minor piece of equipment could have a major impact on production. Since nearly everything gets hot before it fails, thermal inspection is a valuable and cost-effective diagnostic tool with many industrial applications.

With the infrared camera, an inspector can see the change in temperature from the surrounding area, identify whether or not it is abnormal and predict the possible failure. Applications for infrared testing include locating loose electrical connections, failing transformers, improper bushing and bearing lubrication, overloaded motors or pumps, coupling misalignment, and other applications where a change in temperature will indicate an undesirable condition. Since typical electrical failures occur when there is a temperature rise of over 50°C, problems can be detected well in advance of a failure.

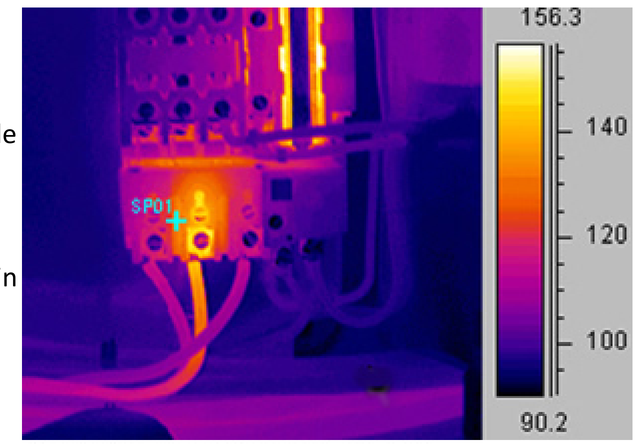


Image Courtesy of Sierra Pacific Corp.

The image on the right above shows three electrical connections. The middle connection is hotter than the others. Connections can become hot if they are loose or if corrosion causes an increase in the electrical resistance.

Electronic Component Inspection

In electronics design and manufacturing, a key reliability factor is semiconductor junction temperature. During operation, a semiconductor generates heat and this heat will flow from the component. The heat will flow from the component in all directions, but will flow particularly well along thermally conductive connectors. This leads to an increase in temperature at the junctions where the semiconductor attaches to the board. Components with high junction temperatures typically have shorter life spans. Thermal imaging can be used to evaluate the dissipation of heat and measure the temperature at the junctions.

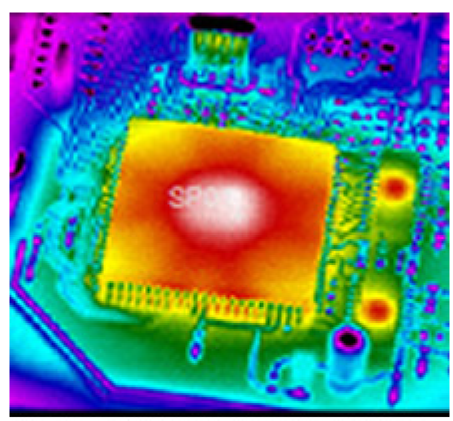


Image Courtesy of Sierra Pacific Corp.

Corrosion Damage (Metal Thinning)

IR techniques can be used to detect material thinning of relatively thin structures since areas with different thermal masses with absorb and radiate heat at different rates. In relatively thin, thermally conductive materials, heat will be conducted away from the surface faster by thicker regions. By heating the surface and monitoring its cooling characteristics, a thickness map can be produced. Thin areas may be the result of corrosion damage on the backside of a structure which is normally not visible. The image to the right shows corrosion damage and **disbonding** of a tear strap/stringer on the inside surface of an aircraft skin. This type of damage is costly to detect visually because a great deal of the interior of the aircraft must be disassembled. With IR techniques, the damage can be detected from the outside of the aircraft.

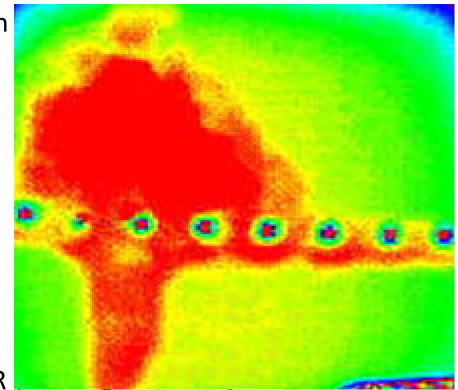


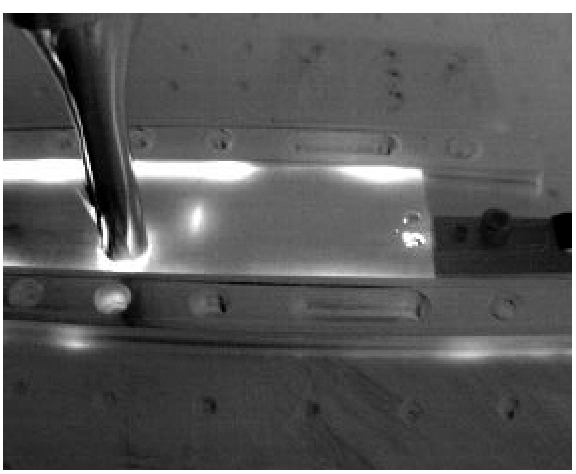
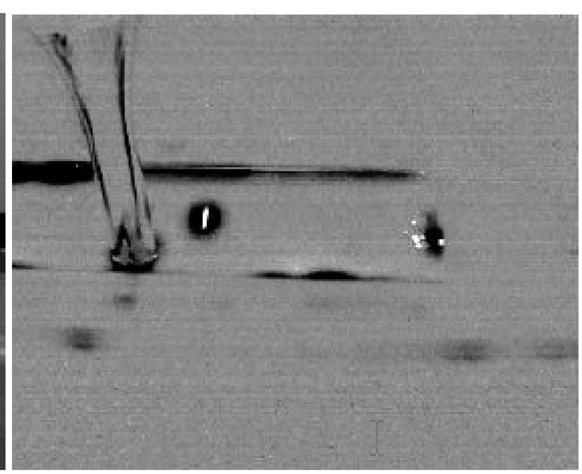
Image Courtesy of Wayne State University

Flaw Detection

Infrared techniques can be used to detect flaws in materials or structures. The inspection technique monitors the flow of heat from the surface of a solid and this flow is affected by internal flaws such as disbonds, voids or inclusions. Sound material, a good weld, or a solid bond will see heat dissipate rapidly through the material, whereas a defect will retain the heat for longer.

A new technique call vibrothermograph or thermosonic testing was recently introduced by researchers at Wayne State University for the detection of cracks. A solid sample is excited with bursts of high-energy, low-frequency acoustic energy. This causes frictional heating at the faces of any cracks present and hotspots are detected by an infrared camera.
Despite the apparent simplicity of the scheme, there are a number of experimental considerations that can complicate the implementation of the technique. Factors including acoustic horn location, horn-crack proximity, horn-sample coupling, and effective detection range all significantly affect the degree of excitation that occurs at a crack site for a given energy input.

Below are two images from an IR camera showing a 0.050" thick 7075 aluminum plate sample with a prefabricated crack being inspected using a commercial vibrothermography system. The image on the left is the IR image with a pre-excitation image subtracted. A crack can be seen in the middle of the sample and just to the right of the ultrasonic horn. Also seen is heating due to the horn tip, friction at various clamping sites, and reflection from the hole at the right edge of the sample. The image on the right is the same data with image processing performed to make the crack indication easier to distinguish.

Advantages of TIR

- Single test station for multiple applications
- Non-contact inspection
- Increased speed, accuracy and reliability
- Complements other NDE test procedures

Note this article under construction, if you have any suggestion please write us.

SUNIL B.GAVADE
Mumbai Mobile No:+091-9768700717
E-mail: sbgavade@gmail.com