A SunCam online continuing education course

Introduction to Thermal Imaging

by

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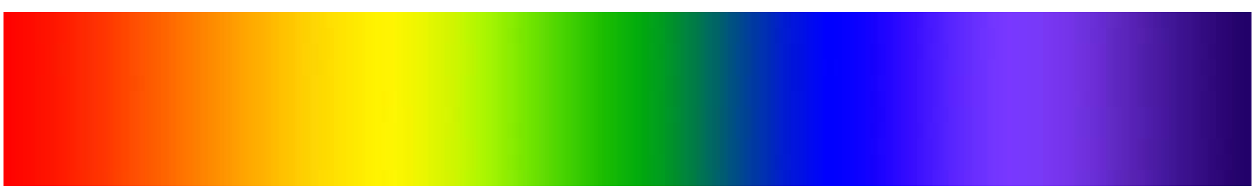
Thermal imaging is the technology to identify and record images using specialized equipment. These images represent the infrared radiation emitted by the object. This course will provide a background on the discovery of infrared energy and an overview of the electromagnetic spectrum. It will define key terms and concepts related to thermal imaging. It will explain the types of thermal imaging equipment and night vision technologies. Additionally, examples will be provided for the application of thermal imaging in the manufacturing and healthcare industries as well as building inspection. Finally, this course will distinguish between the levels of professional certifications for thermographers.

Discovery

Sir Isaac Newton, renowned physicist, mathematician and astronomer, may be best known for his discovery of the Laws of Gravity. The popular story describes Newton sitting under an apple tree when inspiration literally hits him as an apple falls onto his head. Newton was also responsible for the initial development of the Electromagnetic Spectrum.

In the late 1600's, Newton performed an experiment with light. Using a triangular piece of glass, or prism, Newton was able to create a spectrum of sunlight. When the light passed through the glass, the light separated into a spectrum of unique colors. The spectrum retained the same colors in the same order each time the experiment was re-performed. This phenomenon is defined as visible light; the light that is able to be seen.

Visible Light Spectrum

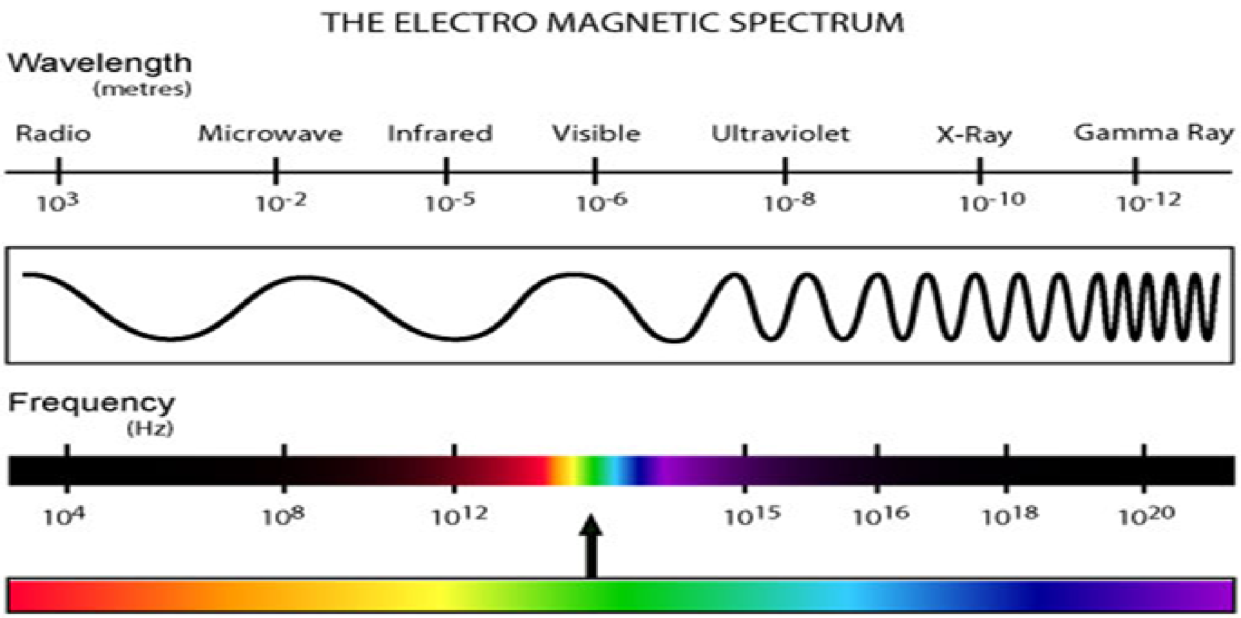


Scientists continued to build on Newton's discovery. Sir William Herschel, a famous astronomer, also conducted experiments utilizing prisms to create the spectrum of visible light. Around 1800, Herschel measured the temperature of each color of the spectrum. He determined that there was a temperature difference when taking measurements of each color. As the thermometer moved from violet to red along the visible light spectrum, the temperature increased. Additionally, temperature readings continued to increase as the thermometer moved past red. Herschel concluded that there was invisible light beyond visible light spectrum. This invisible light was named Infrared Light; or meaning below red.

Scientists have established that light travels in waves. Each color of visible light has its own wavelength and vibrates at different rates (or frequencies). There is an inverse relationship between wavelength and frequency. Red light has the longest wavelength and the slowest frequency. On the other end of the visible light spectrum, violet has the shortest wavelength and fastest frequency. The calculation for the Speed of Light (c) is equal to wavelength multiplied by frequency.

$$c = \lambda f$$

The Electromagnetic spectrum is a group of electromagnetic waves. In addition to visible light, there are light waves that exist but cannot be seen by the human eye. Each light wave and the amount of energy that it emits is defined by its wavelength and frequency. Gamma rays have the highest frequency, shortest wavelengths and emit the highest amount of energy.



Infrared waves are below visible light on the electromagnetic spectrum. Their wavelengths are longer and their frequencies are slower as compared to visible light. Infrared light cannot be seen by the human eye. However, infrared light can be felt in the form of heat. Infrared waves are commonly referred to as heat waves.

Thermal Imaging Concepts

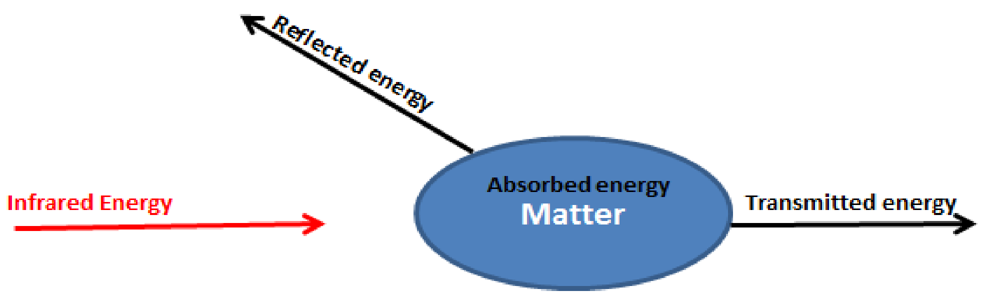
Thermal imaging technology is measuring the infrared energy emitted from an object. Specifically, heat or infrared radiation is being measured. The principle of heat transfer between objects states that heat will flow in the direction from the hot object towards the cold object. Heat transfer will continue until equilibrium is achieved and both objects are at the same temperature.

There are three methods for heat to transfer from one place to another. They are conduction, convection and radiation. For conduction to take place, heat is transferred between substances that are in direct contact with each other. An example of two solids touching each other would be when a pot is placed on a stove top burner. As the burner is heated, the heat is transferred and increases the temperature of the pot. For convection to occur, heat is transferred through the air or a liquid. The heated air or liquid moves away from the heat source, creating a circular current. As a fire warms the air, the hot air rises. Colder air drops and is heated by the fire. Conduction and convection require matter (solid, liquid or gas) to transfer heat. Alternatively, radiation transfers heat in a vacuum. Radiation is energy that is transmitted in waves or particles. Thermal imaging technology measures heat transferred by radiation.

The rate at which heat transfers is dependent on temperature, distance and emissivity. The greater the difference in temperature between the two objects, the faster the rate of heat transfer. In contrast, the distance between the objects is inversely related to the rate of heat transfer. As the distance between the objects is reduced, the speed of heat transfer is increased. Emissivity is the effectiveness of the object in emitting infrared energy. The rate of heat transfer will increase the more emissive the object is. In other words, emissivity is a measure of how well the surface of an object radiates infrared energy.

When infrared energy is in contact with matter (solid, liquid or gas), the matter will absorb, transmit and reflect the infrared energy. The amount of energy absorbed is equal to the amount of energy that is radiated back from the object into the environment. Objects that are good absorbers of infrared energy are good emitters of infrared energy. Thermal imaging technology measures emitted infrared energy.

Emissivity is a ratio of energy being emitted by an object as compared to the energy emitted by a theoretical black body. A theoretical black body is a material that is a perfect emitter of heat energy. It emits all of the infrared energy that it absorbs. A theoretical black body does not exist in the real world.



Absorbed energy = Emitted energy

Emitted energy = Emissivity

Emitted energy + Reflected energy + Transmitted energy = 1

The emissivity of a material is expressed as a value between 0 and 1. A theoretical black body has an emissivity value of 1. A material with an emissivity value of 0 would be deemed a perfect thermal mirror. It does not absorb any infrared energy that is directed at it; therefore, it does not emit any infrared energy. As an example, an object that has the potential to emit 100 units of energy, but only emits 90 units in the real world, would have an emissivity value of 0.90.

Transmitted energy is energy that passes through a material. Most materials, or solids, report low, or close to zero, transmitted energy values. As a result, emissivity is reduced as reflected energy is increased.

Infrared energy is not radiated equally by objects and materials. Emissivity tables, comprehensive listing of materials and their emissivity values, are important as they are used to calibrate thermal imaging equipment.

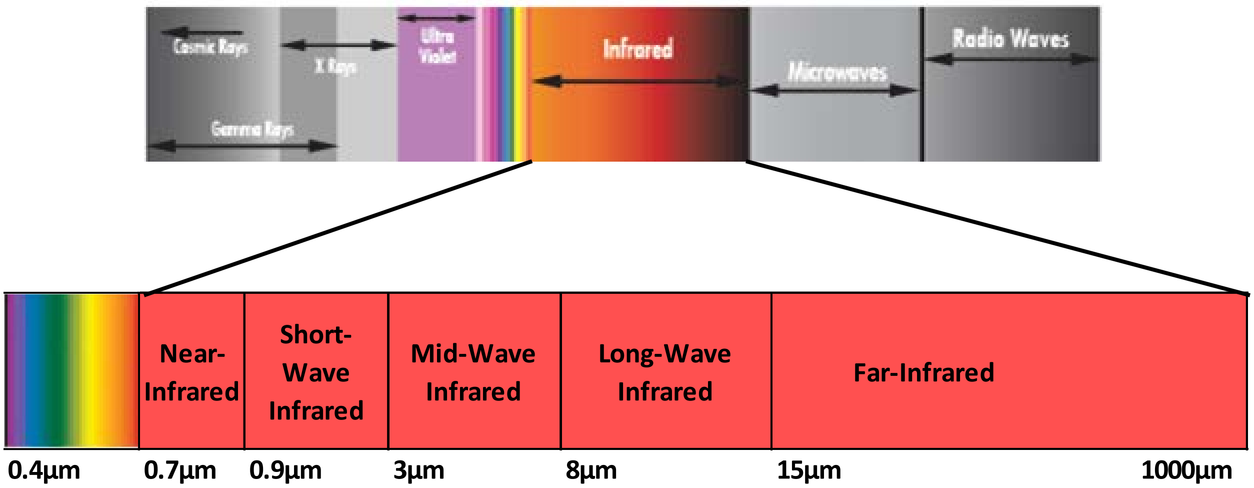
Examples of emissivity values of various materials include:

Material	**Emissivity**
Brass, highly polished	0.03
Cement	0.54
Brick	0.86
Wood	0.87
Glass	0.92
Water	0.95
Charcoal	0.96

Emissivity of an object is affected by its geometric shape, its temperature, its surface condition and wavelength dependence. Objects that are convex (rounded or spherical) report lower emissivity values. Emitted energy is dispersed across the surface of the rounded object in various directions thereby decreasing emissivity. Examples of convex objects would be cables, pipes and tubing. Objects that have concave shapes report higher emissivity values. Emitted energy is concentrated in the cavity of the object thereby increasing emissivity.

The object's temperature affects emissivity. Increasing an object's temperature will increase its emissivity. By painting an object's surface, its surface temperature will increase, resulting in an increased emissivity measure. Additionally, surface condition influences emissivity. A surface that is highly polished will be more reflective. Increased reflectivity decreases emissivity. Aluminum can report significantly different emissivity values as a result of its surface condition. Polished aluminum has an emissivity value of 0.10 as compared to anodized aluminum that has an emissivity value of 0.77. One final point to note, emissivity is a spectral parameter. This means that a material will radiate infrared energy stronger at one wavelength on the infrared radiation spectrum as compared to another wavelength. Different thermal imagers operate at different ranges on the Infrared Radiation spectrum.

As mentioned, all objects radiate energy. Radiation is heat transfer without a medium; it does not require matter (solid, liquid, gas) to move heat from one place to another. Radiation travels like light in waves. Infrared radiation is defined by wavelengths ranging from 0.750 -1000µm (µm is a micrometer). Infrared wavelengths are longer and slower than visible light wavelengths.



Infrared Radiation (IR)

Infrared light on the electromagnetic spectrum is separated into ranges based on wavelength. The infrared radiation (IR) spectrum is made up of Near-Infrared, Short-Wave Infrared, Mid-Wave Infrared, Long-Wave Infrared and Far-Infrared. Near-Infrared and Short-Wave Infrared includes wavelengths between 0.78–3 µm. Mid-Wave Infrared includes wavelengths between 3–8 µm. Long-Wave Infrared includes wavelengths between 8–15 µm. Far-Infrared includes wavelengths between 15- 1,000 µm. The smallest portion of the IR spectrum is Near-Infrared which is the closest to Visible light. Far-Infrared is the largest portion of the IR spectrum.

Thermal imagers function in discrete ranges of the IR spectrum. They can operate in a small portion of the Mid-Infrared (3-5 µm) or Long-Wave Infrared (8-14 µm) range. In this range, thermal energy is emitted from the object. Atmospheric absorption of infrared energy prevents thermal imagers from functioning properly between 5-8 µm wavelength ranges. In the Near-Infrared range, infrared light is reflected from the object. IR illuminators, or low light imagers, operate in the Near-Infrared range (an example would be night vision goggles). Overall, thermal imaging technology operates in a small portion of the IR spectrum.

Thermal Imaging Technology

Thermal imaging, or infrared thermography, uses specialized equipment or methods to detect the infrared energy that is radiated by an object. The infrared energy is captured to create an image. As a result, an image of an object can be produced that would otherwise be invisible to the human eye.

The first thermal image was taken in 1840 by John Herschel, the son of Sir William Herschel. In 1880, Samuel Langley, astronomer, invented the bolometer. The bolometer is a very sensitive thermometer which allows scientists to measure infrared radiation. It was designed to measure the energy of the sun and stars.

In the 1930s during WWII, governments funded thermal imaging equipment research for military purposes. This research was considered highly sensitive at the time. In the 1950s and 1960s, single element detectors were developed by Texas Instruments, Honeywell and Hughes Aircraft. Single element detectors could scan scenes and create a line image. In the 1970s and 1980s, three methods; the pyroelectric vidicon tube, ferroelectric infrared detectors and the microbolometer; were developed which laid the foundation for present-day thermal imaging technology.

Thermal Imaging Equipment

Thermal imaging equipment detects and converts infrared wavelengths into visible images. They produce thermograms and corresponding temperature measurements. Thermograms are graphic records of temperature variations. Thermograms may be displayed in black and white or color.

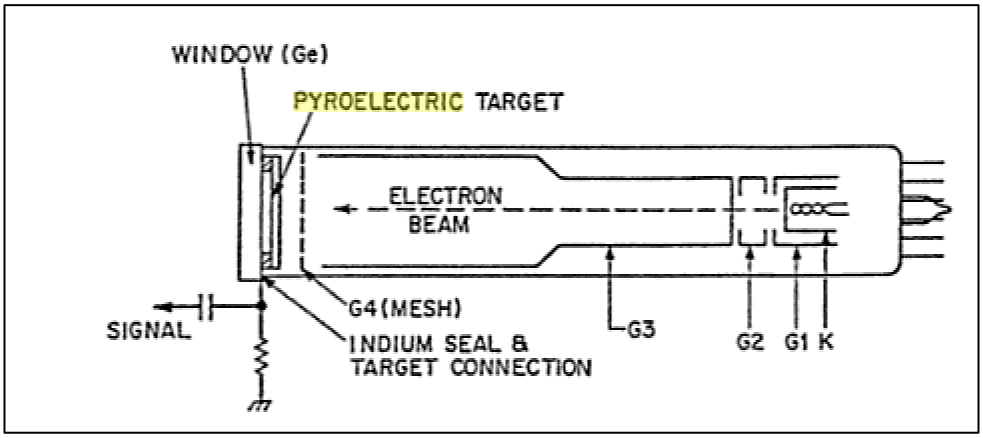
The information provided by thermograms can be qualitative and quantitative. Qualitative data can be observed but not measured. This is non-numerical data. The color variations in the thermogram represent changes in temperature. Thermograms can graphically report temperature abnormalities by displaying hotter temperatures in brighter or darker colors. Quantitative data is numerical. Thermal imagers can report the surface temperatures of an object.

Thermal imaging equipment includes at least three components; a lens, a detector and a display. The lens is the optic component that is focused on the IR energy. Optic lens are generally made up of germanium, silicon, glass or zinc selenide. The detector is a sensor to measure the IR energy. The display is the screen to reveal the image. Displays include computer monitors and camera screens.

There are four types of detectors that have been developed for thermal imaging equipment – mechanical scanning systems, pyroelectric vidicon (PEV), cooled focal plane array (FPA) and microbolometer.

Mechanical scanning systems were installed in earlier generations of thermal imaging cameras. Detectors would scan the object in order to generate an image. The mechanical scanners required cooling agents to operate. Cooling agents also referred to as cryogenic refrigeration units, added cost and weight to the thermal imaging camera. Mechanical scanning systems provide fair or poor resolution images.

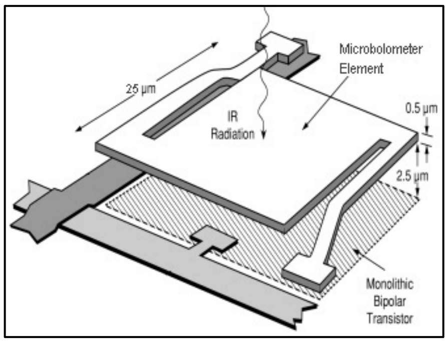
The pyroelectric vidicon (PEV) detector is a tube assembly, similar to a television tube. The pyroelectric vidicon tube includes a germanium (Ge) lens. Unlike glass, germanium (Ge) is a material that is transparent to infrared radiation. PEV detectors also include a unique pyroelectric target which is a material that will exhibit a spontaneous polarization of positive and negative electric charges in response to temperature changes. This phenomenon is a pyroelectric effect. A PEV tube does not require cooling. A PEV detector provides fair to poor resolution images.



Pyroelectric vidicon (PEV) tube

A cooled focal plane array (FPA) detector is an array of light sensor pixels that are arranged in a lattice like pattern on the focal plane of a lens. It is highly sensitive to temperature changes. As a result, it can provide high resolution images. The cooled FPA detector requires cooling by a cooling agent. A Stirling Cycle cooler is a mechanical cooler that uses helium to lower temperature. A cooled FPA detector operates in the Mid-Wave Infrared range, wavelengths between 3–5 µm.

A microbolometer detector is an array of heat detecting sensors that are sensitive to infrared radiation. As infrared energy strikes the individual bolometer elements, the elements increase in temperature. This causes a change in electrical resistance. The electrical resistance change is measured and converted into temperature values. The temperature values are displayed graphically in an infrared image. A microbolometer is an uncooled thermal sensor, and does not require a cooling agent. A microbolometer operates in the Long-Wave Infrared range, wavelengths between 8–12 µm. A microbolometer detector provides high resolution images.



Microbolometer detector

There is not a single thermal camera that is commercially available that can operate in all ranges of the IR spectrum. Thermal cameras that operate in the Mid-Wave Infrared portion of the IR spectrum produce high resolution images and accurate temperature readings. These cameras are primarily used for high temperature readings (e.g. manufacturing applications). Thermal cameras that operate in the Long-Wave Infrared portion of the IR spectrum also produce high resolution images and accurate temperature readings. Images are detailed because atmospheric absorption of IR is minimal in the wavelength range between 8–15 µm

Night Vision Technologies

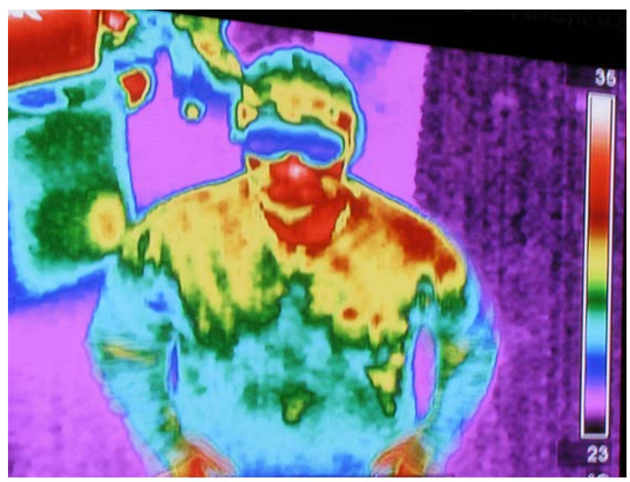
Night vision is the ability to see objects and improve visibility in a dark environment. Night vision is generally associated with military and surveillance applications. Thermal imaging and image enhancement, or low light imaging, are common night vision technologies. The different technologies operate by different principles and have advantages and disadvantages.

Thermal imaging uses the thermal radiation emitted from an object to create an image. The heat from the object is captured by the thermal imager. The thermal imager operates in the Far-Infrared portion of the IR spectrum. Thermal imaging camera does not require a light source, and its performance will not be disrupted by fog, smoke, dust, rain or snow. The thermal image can detect an object, but cannot identify details (e.g. record the characters of a license plate, photograph a person's facial features). Overall, thermal imaging can be used in a completely dark environment, but cannot recognize identifying details of an object.

Image enhancement, or low light imaging, uses a small amount of natural light to illuminate a dark environment. Natural or ambient light is provided by sources that are available, e.g. sun, moon, stars, lightening. Image enhancers are referred to as night vision devices (NVD). NVDs collect both visible light and infrared light. They operate in the Near-Infrared portion of the IR spectrum.

NVDs are highly sensitive, and are able to identify people. NVD equipment is available as night vision googles, scopes and cameras. They are commonly used in the military, law enforcement and security as well as environmental observation, hunting and entertainment. Since a small amount of light is needed, low light imagers are not functional in a completely dark environment.

Image enhancement technology

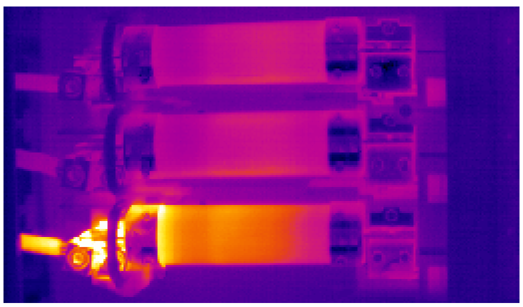


Thermal image technology

Application in Manufacturing

There are many innovative uses for thermal imaging in the manufacturing process. Thermal imaging technology can be applied to evaluate product development, product quality, equipment validation, equipment throughput, preventative maintenance and troubleshooting inefficiencies in electrical and mechanical systems. Thermal imaging technologies can be employed in the operations of various industries, for example pharmaceutical, electronics, commercial equipment and consumer goods.

Thermal imaging was initially introduced to monitor electrical systems. Thermal imaging cameras could detect the "hot spots" in electrical wiring and circuit boards. Potential electrical issues could be corrected before they lead to damaged equipment and safety issues.



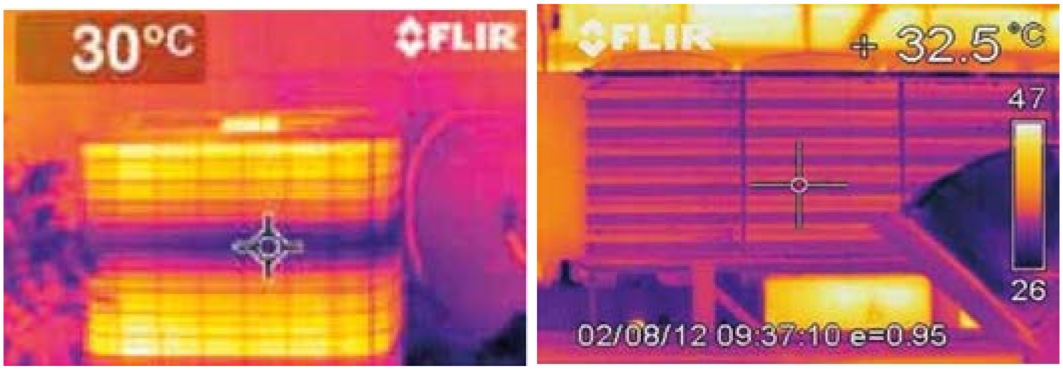
The image is an electrical panel. An overloaded circuit is detected by the bright color.

In this condition, the circuit is a fire hazard.

Thermal imaging technology is being widely used in manufacturing as part of a preventive and predictive maintenance program. A sound Quality Program supports routinely maintaining equipment to avoid a failure. A scheduled maintenance of a machine is less costly and time consuming than the unplanned maintenance of a machine. In addition, unplanned equipment failures could result in defected products, extended damage to the machine, prolonged production downtime, and compromised safety of the operator.

The International Organization for Standardization (ISO) is an independent, non-governmental standard setting group. Membership is international and represents almost every commercial industry. ISO's mission is to provide standards to ensure that products and services are safe, reliable and of good quality. Companies that are ISO members can leverage the standards to increase efficiencies and productivity.

ISO has issued guidance on the use of infrared thermography as a part of a preventive maintenance program. ISO 18434 recognizes that thermal imaging is a useful tool to monitor the condition of machinery. The operation of machinery produces heat, or thermal energy. It is important to establish a baseline temperature of the machinery under normal operations. Routine monitoring of the equipment will detect temperature abnormalities. Temperature abnormalities could be indications of machinery overload, equipment misalignment, improper lubrication or worn components.



The image is of a blocked HVAC unit as compared to an unblocked unit. The bright color reports the higher temperature of the blocked unit. The equipment is overheating and operating above the normal temperature. By detecting the blockage early, the equipment can be repaired before it fails and is damaged.

Thermal imaging is ideal for preventive maintenance applications. Sophisticated thermal imaging equipment can produce images and make temperature measurements available immediately. Thermal imaging technology is highly sensitive. Thermal imaging equipment is able to detect even subtle differences in an object's temperature. Additionally, thermal imaging is a non-invasive technique. Thermal imaging equipment does not contact or interpret the machinery that is being evaluated.

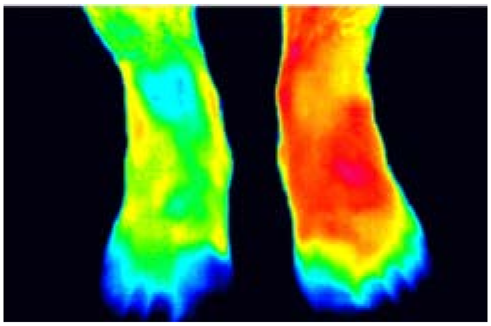
The American Society for Nondestructive Testing (ASNT) is a non-profit, technical society for nondestructive professionals. Membership includes professionals in a variety of industries including manufacturing, construction, research and education. ASNT promotes technologies that facilitate nondestructive testing and provides a forum for members to exchange technical information. Nondestructive testing is the process to inspect, test or evaluate materials, components and/or assemblies without destroying them. A benefit is that products that are tested using nondestructive techniques can still be used. ASNT has recognized Thermal/Infrared Testing as an acceptable method for nondestructive testing.

Application in Health Care

The relationship between the human body temperature and disease has been recognized for centuries. A healthy body will maintain a normal temperature of 37C (98.6F). Slight variations in body temperature may be due to the person's age, time of day, where the temperature is taken and the person's activities prior to taking a temperature reading. A significant increase in body temperature, or fever, is the body's normal responses to fighting off an infection.

Medical thermography is the use of thermal imaging cameras to measure the thermal energy emitted from the body. Thermal imaging cameras can report patterns in blood flow and temperature near the surface of the body. Thermal imaging is a non-invasive procedure. Images from the camera can be applied as a diagnostic tool.

Medical thermography has been used to evaluate the presence of inflammation that may be caused by cardiovascular disease, arthritis, fibromyalgia and injury. Inflammation is the body's natural response to the injury or infection. When a part of the body is inflamed (e.g. joint or muscle), common symptoms include pain, redness, swelling, immobility and heat. The blood flow is increasing to the inflamed area, causing body temperature to increase as well. If the inflammation is subtle and does not display visible symptoms, a thermal imaging camera could detect the temperature change.

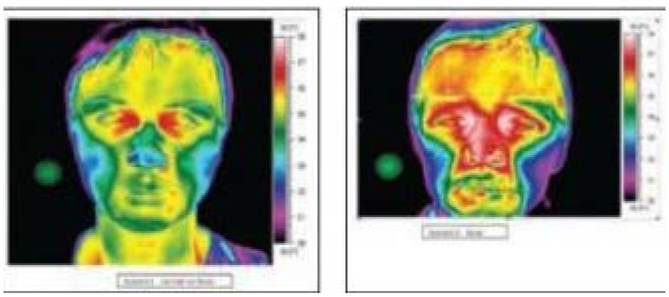


The image is of a foot that has suffered an injury. In the image of the right foot, inflammation is indicated by the red color.

Medical thermography has been studied as a potential diagnostic tool for breast cancer. There have been many experiments undertaken to determine whether thermal imaging can effectively detect pre-cancerous abnormalities during breast cancer screenings. The theory is that the cancerous cells increase body temperature and can be identified using a thermal imaging camera. In 2011, the FDA issued a warning that thermal imaging alone should not be used as a diagnostic tool for early detection of breast cancer. Currently, there is no scientific data to support using thermal imaging as a primary diagnostic tool. A mammography is the most effective tool to screen for breast cancer.

As mentioned, medical thermal imaging measures body temperature changes. In response to containing the spread of infectious diseases globally, medical thermography is currently being used in international airports as a standard practice for fever screening. Health screenings of travelers is always in place. During times of an increased threat of a global epidemic (e.g. 2003 severe acute respiratory syndrome (SARS) outbreak, 2009 influenza A pandemic (H1N1), 2014 Ebola crisis), the Centers for Disease Control and Prevention (CDC) has provided guidelines that require the measurement of a traveler's temperature.

Temperature screenings can be done by using a thermal imaging camera or a non-contact infrared thermometer. Thermal cameras are set up to examine people as they pass through an airport. Temperature measurements are taken on the surface of the face, specifically at the inner corner of the eye. The inner corner of the eye, or the inner canthus of the eye, is supplied by the internal carotid artery. These measurements are the most effective to detect fever.



The image on the left is of a healthy person. The image on the right is of a person with a fever. The high body temperatures are indicated by the red color around the eyes and nose.

A non-contact infrared thermometer (NCIT) uses infrared technology. NCIT is used to measure skin temperature. It is a hand held device that focuses a laser on a specific target. The NCIT is able to measure the temperature of the target. They are easy to use, accurate and a low cost alternative to a thermal imaging camera for temperature screening.

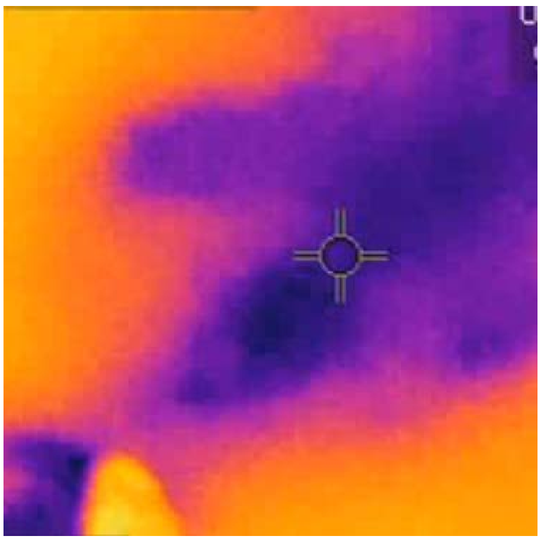
Application in Building Inspections

A thermal imaging camera is a valuable tool for a building inspector's toolkit. The thermal imaging camera can detect changes in temperature, indicating loss of energy and/or moisture issues. At the start of the inspection, the building inspector must orient himself with the location of the room in relation to the entire building. The inspector's report will describe the structure or system, document observations and provide a conclusion.

The following is an example of an inspection of a one story building adjacent to a two story commercial building. The inspector has examined the roof, noting that it is a flat roof. The north wall of the structure meets the south wall of the two story building structure. There were faint stains on the roof surface in the north east corner.

Inside the one story building, the inspector examined the ceiling. The inspector scanned the surface of the ceiling with the thermal imaging camera. The thermal imaging camera allowed the inspector to examine a large area relatively quickly. The image from the thermal camera indicated a temperature change on the ceiling's surface.

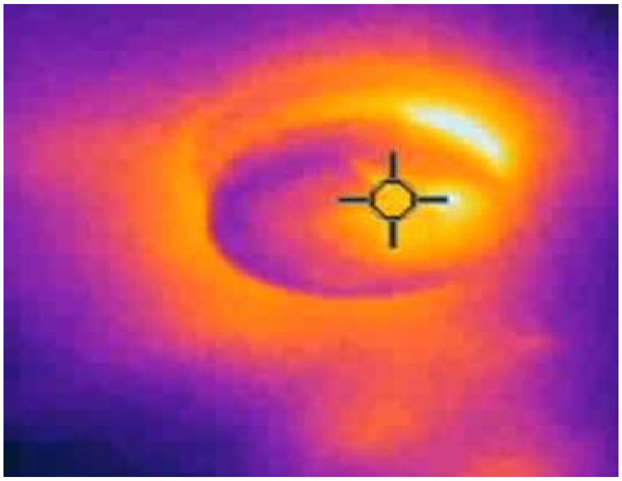
Upon closer inspection, water stains were visible in this area of the ceiling. The inspector was aware that the water stains on the ceiling are located in the north east corner of the building. The inspector applied a moisture meter to this area of the ceiling. The moisture meter readings indicated elevated levels of moisture in the ceiling. In addition to the physical stains on the roof and on the ceiling, the results of the thermal camera and moisture meter confirmed the existence of a water damage originating on the roof and penetrating into the ceiling of the structure.



A change in temperature of the ceiling surface is indicated by the dark image in the photograph. The thermal camera was used to perform an initial assessment of the ceiling. The suspicious image was examined with a moisture meter which confirmed the presence of water damage caused by a low spot on the roof.

The following is an example of an inspection of a residential building. The inspector has entered the bathroom, noting a ventilation fan installed in the ceiling. The ventilation fan created a penetration between the bathroom ceiling and attic. The inspector used a thermal imaging camera to inspect the ceiling, specifically focusing on the ventilation fan and looking for hot spots.

The thermal image reports a change in temperature around the ventilation fan. This is indicated by the bright image. Upon further inspection in the attic, the inspector discovered that insulation has been removed around the fan. The removal of insulation around the ventilation fan in the attic is causing heat to leak out of the bathroom and into the attic.



A change in temperature of the ceiling surface is indicated by the bright image in the photograph. The thermal camera was used in to examine the ceiling penetration. The image indicates a loss of energy through the ceiling, which was confirmed by seeing missing insulation in the attic.

Professional Certifications

A preventive maintenance program in a manufacturing environment that utilizes thermal imaging technology can realize cost benefits in terms of increased productivity and cost savings by avoiding equipment failures. In order to realize these benefits, the operator of the thermal imaging equipment must be able to properly interpret the results. The operator must have the capability to accurately and consistently analyze the data. A person who is certified to operate thermal imaging equipment is called a Certified Thermographer.

A certified Thermographer has demonstrated the skills required to perform infrared inspections. In the US, certification is issued in compliance with the standards of the American Society for Nondestructive Testing (ASNT). Certification can be issued by an approved vendor or by the applicant's employer. Outside of the US, a central certifying body in each country that conforms to the standards of the International Organization for Standardization (ISO) issues the certification. ISO 18436 specifies the requirements for certifying personnel who utilize infrared thermography to monitor machinery. Certification requires successful completion of coursework, including passing an examination. A period of qualifying field experience is also necessary.

There are three levels of Thermographer certification; Level 1, Level 2 and Level 3.

Level 1 thermographers are trained to follow written test procedures to evaluate specific types of equipment and systems (e.g. electrical, mechanical, structural). They can operate infrared cameras, collect data, and identify thermal patterns. They can report on qualitative data measured by the infrared technology.

Level 2 thermographers are qualified to calibrate equipment, analyze data, and issue reports. They can determine the root cause of a problem and recommend remediation. Level 2 thermographers provide technical direction to Level I certified personnel. They can report on quantitative data measured by the infrared technology.

Level 3 thermographers are experienced thermography program managers. They oversee a company's use of infrared technology in a predictive maintenance program. They write inspection procedures of systems, processes and equipment. They supervise testing, and provide training to staff.

Summary

The existence of infrared radiation was discovered over 200 years ago. All objects radiate infrared energy, or heat. Inventions in the 20th Century enabled scientists to detect an object's infrared radiation and convert that energy into a visible image. In simpler terms, thermal imaging technology could enable an object to be seen when visible light is not present.

While advances in thermal imaging technology progressed, they were not widely publicized. Thermal imaging research and development was primarily funded by governments for military applications. These scientific discoveries were deemed highly confidential. Furthermore, thermal imaging equipment was very expensive.

In the 1990's, new generations of thermal imaging technology were developed, resulting in higher resolution images and lighter and portable equipment. The commercialization of thermal imaging equipment evolved. Thermal imaging cameras became more affordable. Innovative uses for the technology were identified. Although thermal imaging cameras continue to be important tools for the military, new applications have been uncovered in a variety of industries.

The non-destructive quality of thermal imaging cameras make them ideal for use in preventative maintenance programs. To ensure proper use of thermal imaging technologies, standards have been issued by ISO and ASNT. Professional certifications are available for users to obtain and improve their skills in operating thermal imaging technologies.