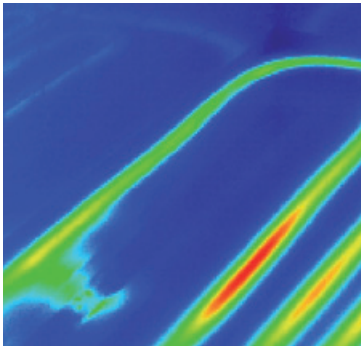






THERMAL IMAGING GUIDEBOOK FOR BUILDING AND RENEWABLE ENERGY APPLICATIONS

An informative guide for the use of thermal imaging cameras for inspecting buildings, solar panels and windmills.



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This booklet is produced in close cooperation with the Infrared Training Center (ITC).
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Introduction

The first commercial thermal imaging camera was sold in 1965 for high voltage power line inspections, by what would later become FLIR Systems.

Since then thermal imaging technology has evolved. Thermal imaging cameras have become compact systems that look just like a digital video camera or digital photo camera. They are easy to use and generate crisp real-time high-resolution images.

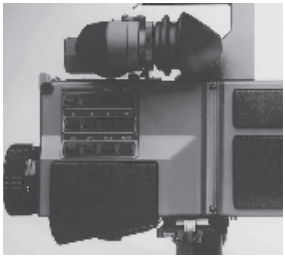
One of the sectors that rapidly discovered that thermal imaging can provide valuable information that is practically impossible to capture with any other tool is the building industry. From an exotic technology, thermal imaging cameras have evolved to a widespread tool that is used by numerous building inspectors worldwide.

A thermal imaging camera is a unique tool to map the energy loss from a building. This method is quick and the thermal images which the camera produces provide a precise and convincing argumentation.

The use of a thermal imaging camera – either as a standalone tool or in combination with other methods such as 'BlowerDoor' systems – speeds up the work considerably. Thermal imaging pinpoints exactly where the energy losses are without the use of any destructive testing methods.







Thermal imaging cameras have strongly evolved over the last 50 years. FLIR Systems has always been a thermal imaging pioneer that brings the most advanced thermal imaging cameras to the market.

A thermal imaging camera is a reliable non contact instrument which is able to scan and visualize the temperature distribution of entire surfaces quickly and accurately. Thermography programs have contributed to substantial cost savings around the world.

Thermal imaging for the building industry
Since the 1970s we have become increasingly conscious that energy resources are precious and limited.

The building sector accounts for 40% of the EU's energy requirements and offers the largest single potential for energy efficiency. Due to the huge potential the European Commission has formed a directive for energy performance regulation of buildings on which many national laws are already based. Thousands of European businesses are already affected while the Energy Performance Certificates (EPCs) have become mandatory in many countries in the EU for new buildings and building refurbishments.

This, together with recent economic stimulus packages in many countries, is likely to drive up the demand for air tightness testing and other methods for energy efficiency investigation.

In a longer perspective we are likely to see harsher EU directives for energy savings in buildings. This will have great impact on many professionals working in the building sector.



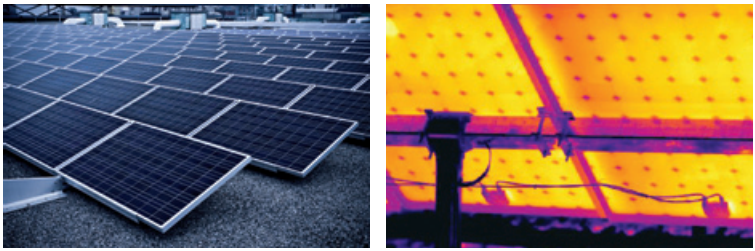
Modern thermal imaging cameras are small, lightweight and easy to use.

Renewable energies

The fact that traditional energy sources like coal, gas and oil are scarce has also led to rising prices. Furthermore, awareness has risen that we cannot keep polluting our planet using these fossil fuels.

Solar

Solar panels can convert the sun's energy into electricity. And into hard cash. To receive maximum returns and high yields for decades however, high quality is key. The solar module, the most important part of a solar system, must be reliable and able to continue producing electricity for years at an end. To ensure good quality during the full lifetime cycle of a solar module, thermal imaging cameras can play an important role.



The use of thermal imaging cameras for solar panel evaluation offers several advantages. Anomalies can clearly be seen on a crisp thermal image and - unlike most other methods - thermal cameras can be used to scan installed solar panels during normal operation.

As fossil fuel reserves dwindle, the prices for coal and gas rise to new heights and many people look to the sun for a renewable power source. But solar panels are susceptible to wear. Building professionals all over the world therefore use thermal imaging cameras to inspect solar panels installed on rooftops or in solar parks.

Wind

Another renewable energy source is wind. All over the world, windmills are becoming increasingly popular for generating electricity. Entire wind parks are being installed both on land and off shore.

A windmill contains a lot of mechanical and electrical components that can easily be checked with a thermal imaging camera. Correct maintenance inspections of all parts of a windmill ensure that they will keep generating electricity for many years to come.



A thermal image of a wind turbine taken from ground level

This booklet is an in-depth guide for building, solar panel and windmill inspections using a thermal imaging camera. There are many details to pay attention to when carrying out a thermal inspection. As well as knowing how the thermal camera works and how to take images, it is important to know the physics behind the thermal patterns of a building, solar panel or windmill, and how they are constructed. All of this has to be taken into consideration to understand, interpret and judge thermal images correctly.

It is impossible, however, to cover all principles, concepts and use of systems for analysis of these types of applications in this guidebook. That is why FLIR Systems offers training courses in cooperation with the Infrared Training Center (ITC) specifically designed for building applications.

This guidebook will present

- Thermal imaging applications
- How the thermal imaging camera works and what to consider when purchasing a camera
- Comprehensive advice on how to conduct thermographic surveys

1 The thermal imaging camera and how it works

A thermal imaging camera records the intensity of radiation in the infrared part of the electromagnetic spectrum and converts it to a visible image.



Sir William Herschel discovered infrared radiation in 1800.

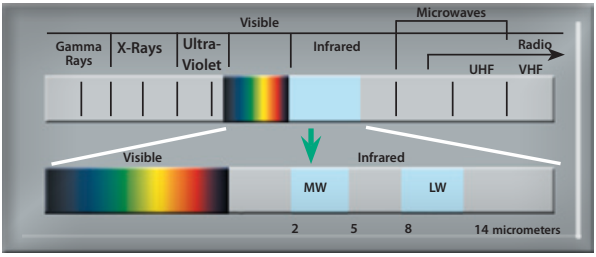
What is infrared?

Our eyes are detectors that are designed to detect electromagnetic radiation in the visible light spectrum. All other forms of electromagnetic radiation, such as infrared, are invisible to the human eye.

The existence of infrared was discovered in 1800 by astronomer Sir Frederick William Herschel. Curious to the thermal difference between different light colors, he directed sunlight through a glass prism to create a spectrum and then measured the temperature of each color. He found that the temperatures of the colors increased from the violet to the red part of the spectrum.

After noticing this pattern Herschel decided to measure the temperature just beyond the red portion of the spectrum in a region where no sunlight was visible. To his surprise, he found that this region had the highest temperature of all.

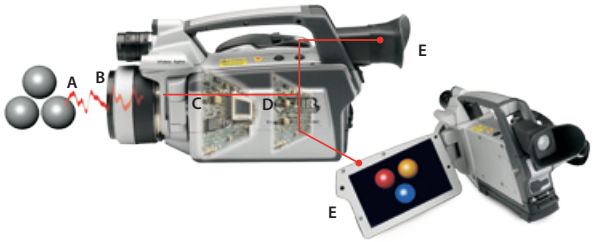
Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum. The primary source of infrared radiation is heat or thermal radiation. Any object that has a temperature above absolute zero (-273.15 degrees Celsius or 0 Kelvin) emits radiation in the infrared region. Even objects that we think of as being very cold, such as ice cubes, emit infrared radiation.



We experience infrared radiation every day. The heat that we feel from sunlight, a fire or a radiator is all infrared. Although our eyes cannot see it, the nerves in our skin can feel it as heat. The warmer the object, the more infrared radiation it emits.

The thermal imaging camera

Infrared energy (A) coming from an object is focused by the optics (B) onto an infrared detector (C). The detector sends the information to sensor electronics (D) for image processing. The electronics translate the data coming from the detector into an image (E) that can be viewed in the viewfinder or on a standard video monitor or LCD screen.



Infrared thermography is the art of transforming an infrared image into a radiometric one, which allows temperature values to be read from the image. So every pixel in the radiometric image is in fact a temperature measurement. In order to do this, complex algorithms are incorporated into the thermal imaging camera.

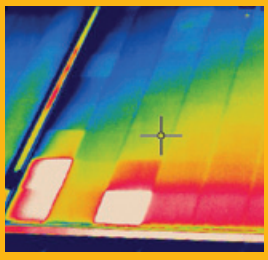
2

Why use thermal imaging?

Thermal imaging cameras for building applications are powerful and non invasive tools for monitoring and diagnosing the condition of buildings, solar panels and windmills. With a thermal imaging camera you can identify problems early, allowing them to be documented and corrected before becoming more serious and more costly to repair.

FLIR thermal imaging cameras:

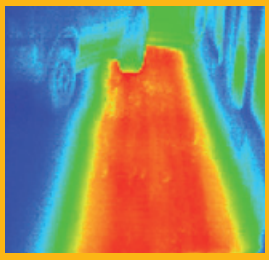
- Are as easy to use as a camcorder or a digital camera
- Give you a full image of the situation
- Identify and locate the problem
- Measure temperatures
- Store information
- Tell you exactly what needs to be fixed
- Help you find faults before real problems occur
- Save you valuable time and money



Defects in photovoltaic cells.



Thermal inspection of a window installation.



Heated pavement, but only a part of it is working.

FLIR Systems offers a wide range of thermal imaging cameras. Whether you use thermal imaging for an inspection of large buildings or for a domestic residence, FLIR will have just the right thermal imaging camera for you.



Why use thermal imaging cameras?
Why would you choose a FLIR thermal imaging camera? There are other technologies available to help you measure temperatures in a non-contact mode. Infrared thermometers for example.

Infrared thermometers - thermal imaging cameras
Infrared (IR) thermometers are reliable and very useful for single-spot temperature readings, but when scanning large areas, it's easy to miss critical parts like air leakages, areas with insufficient insulation or water intrusion. A FLIR thermal imaging camera can scan entire buildings, heating and HVAC installations. It never misses a potential problem area no matter how small this might be.



IR thermometer, temperature measurement in one spot



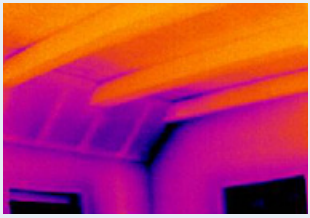
FLIR i3, temperature in 3,600 spots

Find problems faster and easier with extreme accuracy
It is easy to miss a critical building problem if you are only using a spot IR thermometer. A FLIR thermal imaging camera will give you a total view of the situation and instant diagnostic insights. It not only locates a construction problem in a building but shows the full extent of problems.

Use thousands of infrared thermometers at the same time
With an infrared thermometer you are able to measure the temperature at one single spot. FLIR thermal imaging cameras can measure temperatures on the entire image. The FLIR i3 has an image resolution of 60 x 60 pixels. This means that it is equal to using 3,600 IR thermometers at the same time. If we look at the FLIR P660, our top model, which has an image resolution of 640 x 480 pixels, this means 307,200 pixels or using 307,200 infrared thermometers at the same time.



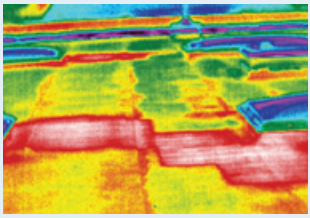
What an IR Thermometer sees.



What a thermal imaging camera sees.



What an IR Thermometer sees.



What a thermal imaging camera sees.



What an IR Thermometer sees.



What a thermal imaging camera sees.



3 Using thermal imaging for building applications

Inspecting buildings using a thermal imaging camera is a powerful and non invasive means of monitoring and diagnosing the condition of buildings. Thermal imaging technology has become one of the most valuable diagnostic tools for building inspections. A thermal imaging camera can identify problems early, allowing them to be documented and corrected before becoming more serious and more costly to repair.

A building diagnostics inspection with a thermal imaging camera can help:

- Visualize energy losses
- Detect missing or defective insulation
- Source air leaks
- Find moisture in insulation, in roofs and walls, both in the internal and the external structure
- Detect mold and badly insulated areas
- Locate thermal bridges
- Locate water infiltration in flat roofs
- Detect breaches in hot-water pipes
- Detect construction failures
- Monitor the drying of buildings
- Find faults in supply lines and district heating
- Detect electrical faults

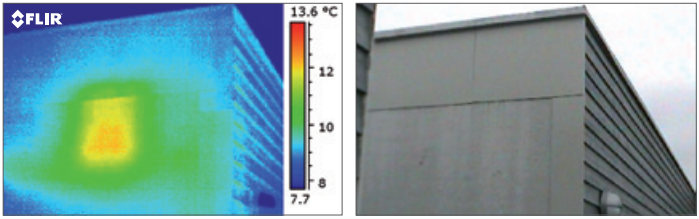
Thermal imaging cameras are the perfect tool for locating and identifying building failures because they make the invisible visible. On a thermal image problems seem to jump right out at you. A thermal imaging camera is the one tool that really lets you SEE it all.

A thermal image that includes accurate temperature data provides building experts with important information about the insulation conditions, moisture ingress, mold development, electrical faults, the presence of thermal bridges and the conditions of HVAC systems.

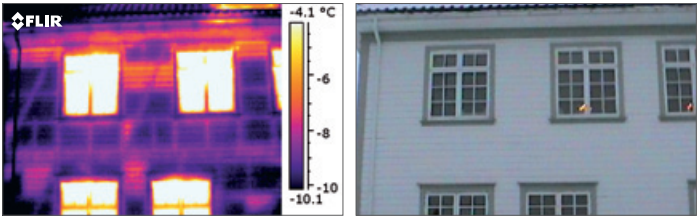
Thermal imaging cameras are such a valuable and versatile tool that it is not possible to list all the applications. New and innovative ways of using the technology are being developed every day. Some of the many ways in which thermal imaging cameras can be used within the range of building related applications are explained in this section of the guide.

Insulation defects and air leaks

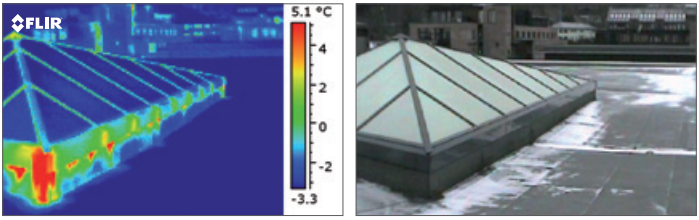
Thermal imaging is an outstanding tool to locate building defects such as missing insulation, delaminating render and condensation problems.



This building is warmer on the inside. It is a sandwich construction, concrete - insulation - concrete. One section of insulation is missing which is not possible to see visually either from the inside or the outside. Here thermal imaging can see what the human eye can't.

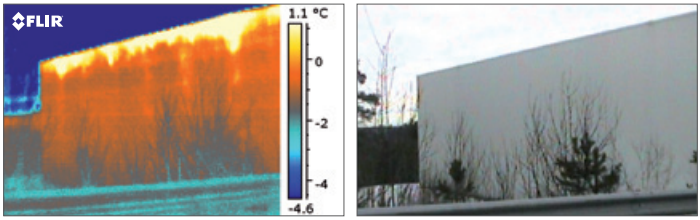


Framework construction. Many of the sections are missing insulation as indicated by the warmer colors.



Glass roof above an atrium. It is watertight, but not air tight. Warm air escapes because of the over pressure.The solution is to air tighten the glass roof.

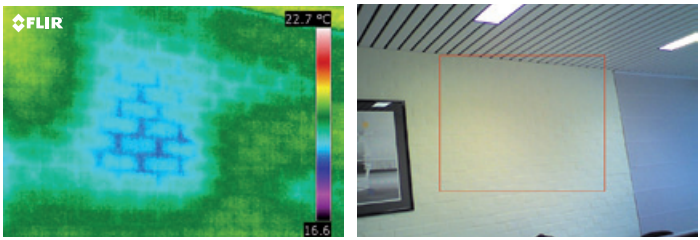
Warehouses with well insulated prefabricated walls and roof can experience energy loss from the joints between these parts.



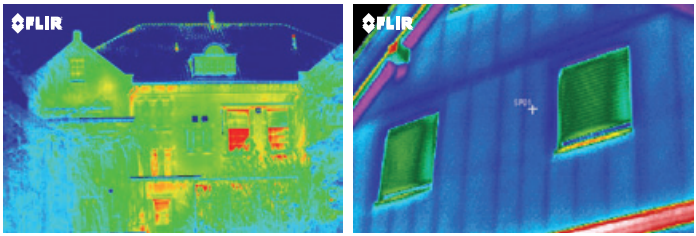
A warehouse with a lot of warm air escaping between the wall and the roof. These joints should be tightened to stop the energy loss.

When using a thermal imaging camera to find missing insulation or energy losses, the difference in temperature between the inside of the building and the outside should be preferably at least 10 °C. When using a thermal imaging camera with a high image resolution and high thermal sensitivity the temperature difference can be less.

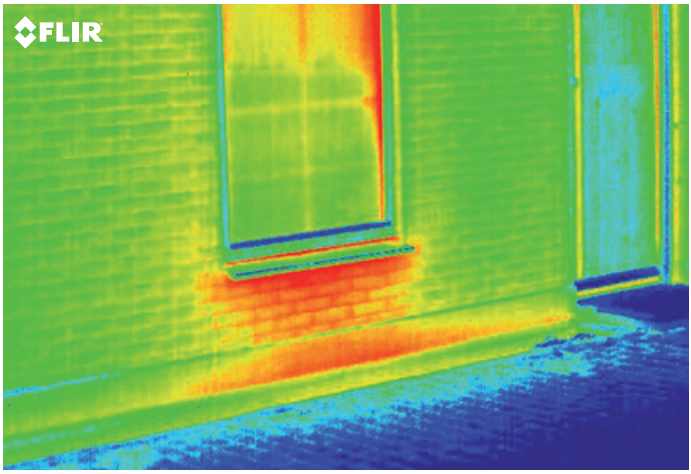
In cold climates, buildings are often inspected during winter time. In hotter climates, where it is important to see that the building is well insulated in order to keep the cool air that is generated by HVAC systems inside, the summer months can be ideal for this type of thermal inspections.



Missing insulation in parts of the wall.



Thermal survey from outside, the thermal images clearly indicate poor or missing insulation.



The thermal image clearly shows insufficient insulation in the wall below the window.

Detection of air leaks

Air leaks lead to higher energy consumption and often cause problems with the ventilation system. Air leaks can also lead to condensation in the construction which in its turn can cause a poor indoor climate.

To detect air leaks with a thermal imaging camera a temperature difference and a pressure difference is needed.

With a thermal imaging camera you detect the characteristic patterns that occur when cold air is coming through a leak in the construction, goes along a surface and cools the surface down. The thermal inspection should always take place on the side of the construction with negative pressure. Air leaks are often detected with the help of the pressurization method, often referred to as the "BlowerDoor" test. More information about "BlowerDoor" tests can be found further on in this booklet.

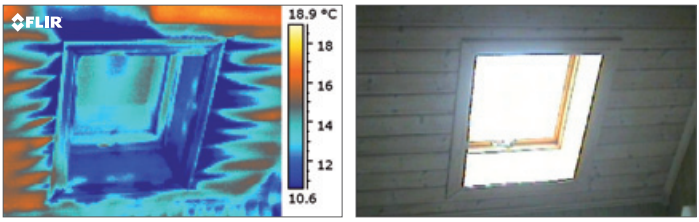
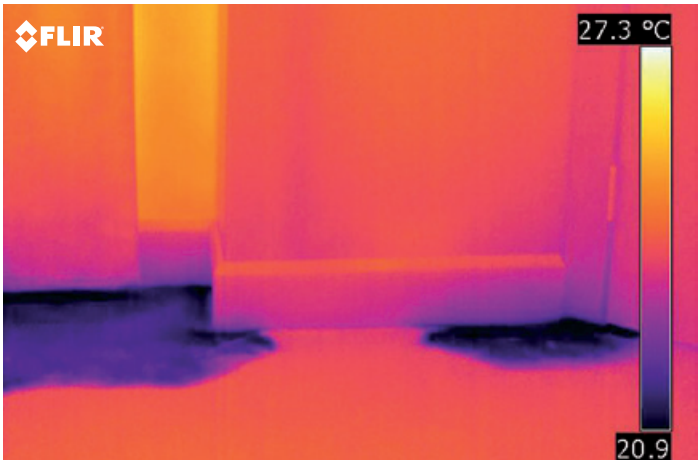


Image shows air leaks between the ceiling and the window.

Moisture Detection

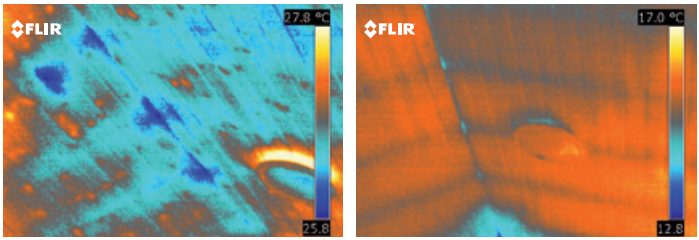
Moisture damage is the most common form of deterioration for a building. Air leakage can cause condensation to form within walls, floors, or ceilings. Wet insulation takes a long time to dry and becomes a prime location for mold and fungi.

Scanning with a thermal imaging camera can locate moisture that creates an environment conductive to mold. One might smell its presence, but not know where it is forming. A thermal survey will determine where moist areas are located that can lead to serious mold which can lead to health issues.



Moisture intrusion in floor, impossible to see with the human eye, but clearly visible on the thermal image.

Moisture can be difficult to spot and the trick is to make the construction change temperature. Materials with moisture will then be clearly visible as they change temperature much slower than dry materials. Where other methods only measure the temperature in one spot, thermal imaging cameras can scan an entire area rapidly.



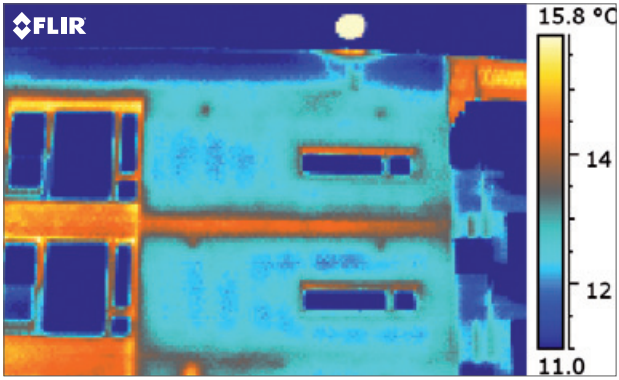
Thermal images taken of the same ceiling. In the left image the room temperature has been changed quickly by heating the room which makes the moisture clearly visible on the thermal image.

Thermal Bridges
Other applications include the location of thermal bridges, which indicate spots in a building where energy is being wasted.

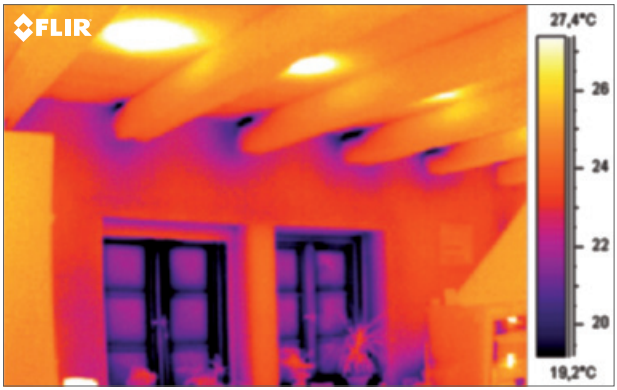
A thermal bridge is an area where the building envelope has a lower thermal resistance. It is caused by construction constraints. Heat will follow the easiest path from the heated space to the outside - the path with the least resistance.

Typical effects of thermal bridges are:

- Decreased interior surface temperatures; in the worst cases this can result in condensation problems, particularly at corners.
- Significantly increased heat losses.
- Cold areas in buildings.



The image shows a thermal bridge at one of the floors.

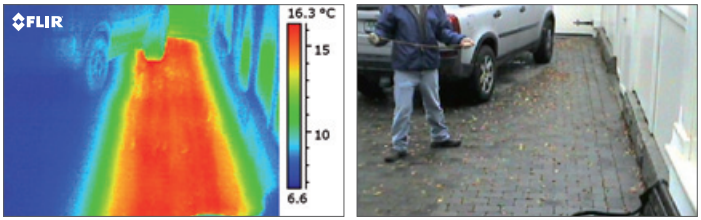


The thermal image shows thermal bridges between the roof beams and adjacent walls.

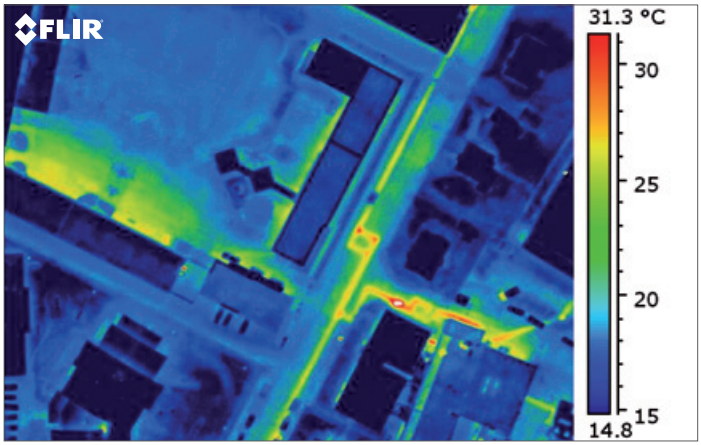
Supply lines and district heating
In cold climates, pavements and parking areas are sometimes heated.

District heating systems distribute heat, often steam, that is generated in a centralized location for residential and commercial heating requirements.

A thermographic survey can easily detect defects in pipes or tubes of any underground heating system. A thermal imaging camera can help to identify the exact location of the defect so that repair works can be minimized.



Defects in district heating systems can be easily located with a thermal imaging camera.

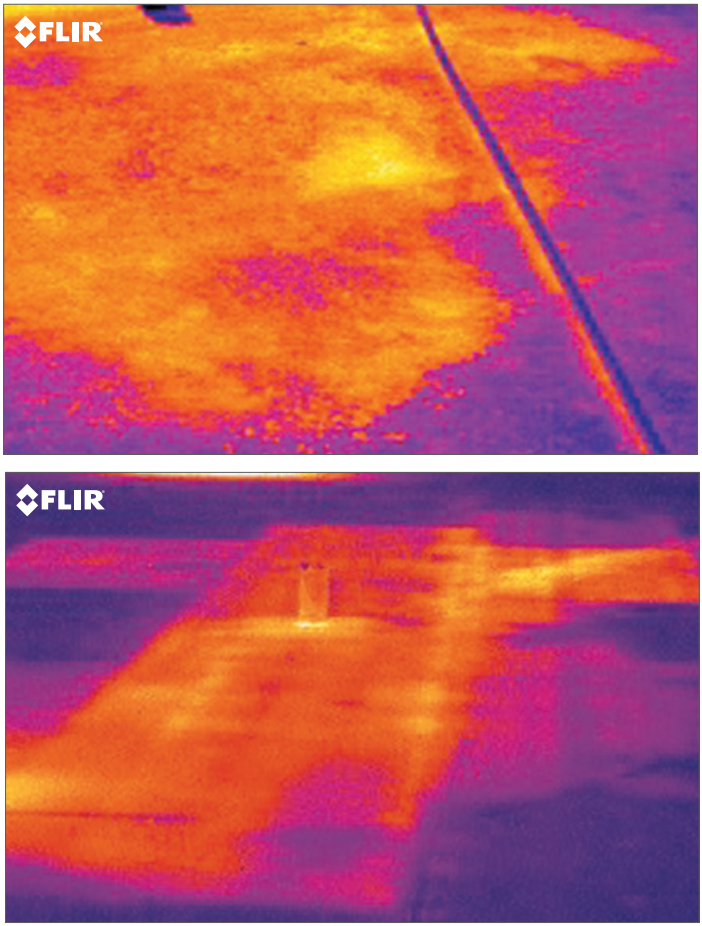


A thermal image, taken from the air, identifies leaks or insulation failure in the district heating system

Finding water infiltration in flat roofs
Thermal imaging is also used to detect water infiltration in flat roofs.

Water retains heat longer than the rest of the roofing material and can easily be detected with a thermal imaging camera very late in the evening or at night after the rest of the roof has cooled down.

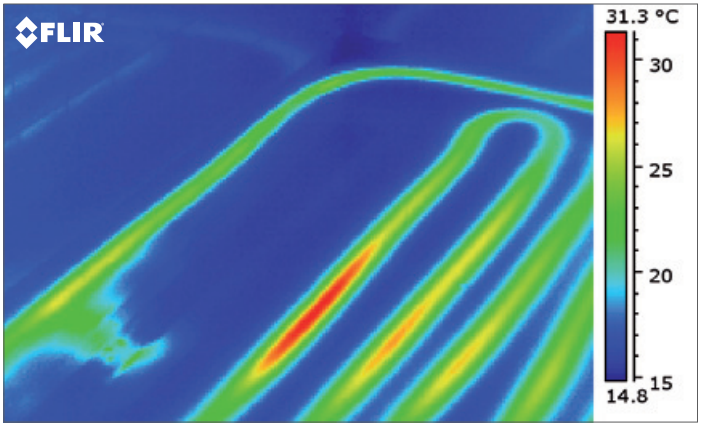
Tremendous savings can be made by repairing wet areas rather than replacing the entire roof.



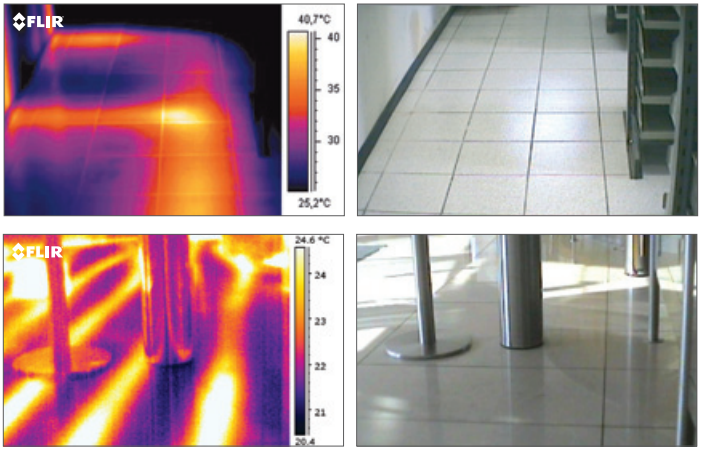
Water infiltration in flat roofs.

Locating leaks in floor heating

Thermal imaging is an easy-to-use tool to find and check pipes and tubes for leaks, even when the water pipes are laid in the floor or under plaster. The heat of the pipes radiates through the surface and the pattern can be easily detected with a thermal imaging camera.



The thermal image shows a leak in an underfloor heating system.



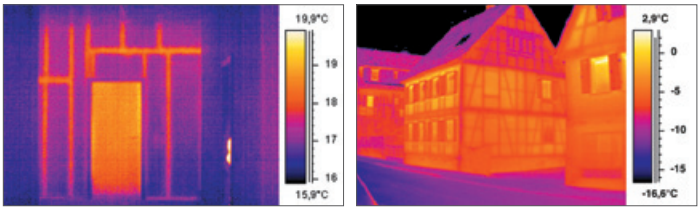
Underfloor heating problems can easily be detected with a thermal imaging camera.

Quality assurance
Thermal imaging technology is also used for quality assurance and the inspection of new buildings.

During construction-drying, thermal images make it possible to determine the progress of the drying procedures so that necessary measures can be taken to speed up the drying process.

If this process can be accelerated and it can be proven, with the help of a thermal imaging camera, that the construction is totally dry, the building can be surrendered faster to the client.

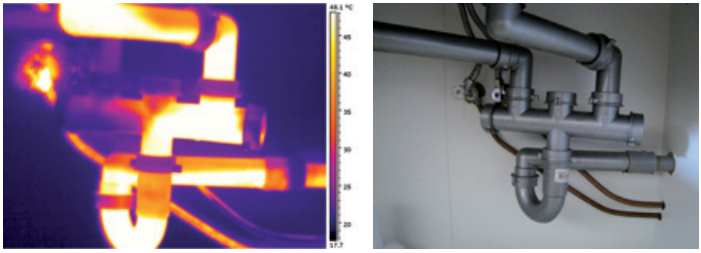
Building renovations
Thermal imaging provides valuable information during the renovation of buildings and monuments. Framework constructions hidden by mineral plaster can become clearly visible in a thermal image. It can then be decided whether exposure of these structures is useful. The detachment of plaster from walls can also be located in a very early stage so that preservation measures can be taken.



Thermal imaging makes underlying structures clearly visible.

Plumbing

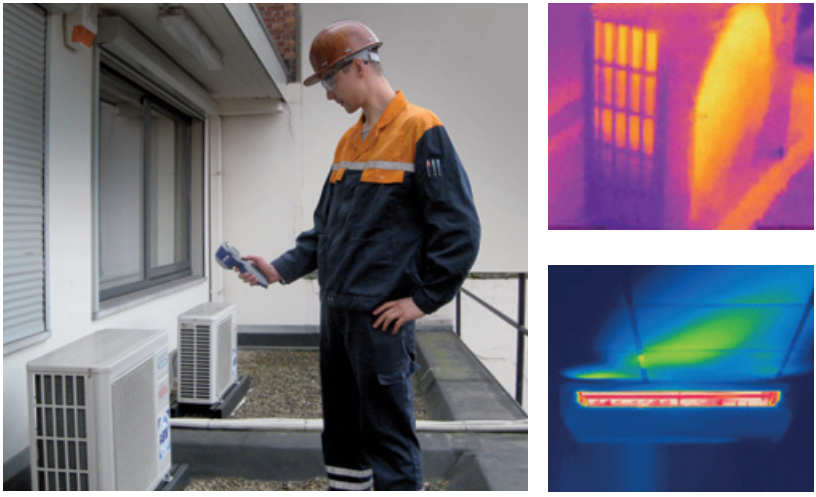
Thermal imaging is a perfect tool to detect blocked or broken pipes and other plumbing relates issues. Even if the pipes are laid under the floor or inside a wall it can be possible to determine the exact location of the problem by having hot water flowing through the pipes. The heat will radiate and the problem area will become clearly visible on a thermal image.



Detect plumbing problems with thermal imaging.

HVAC installations

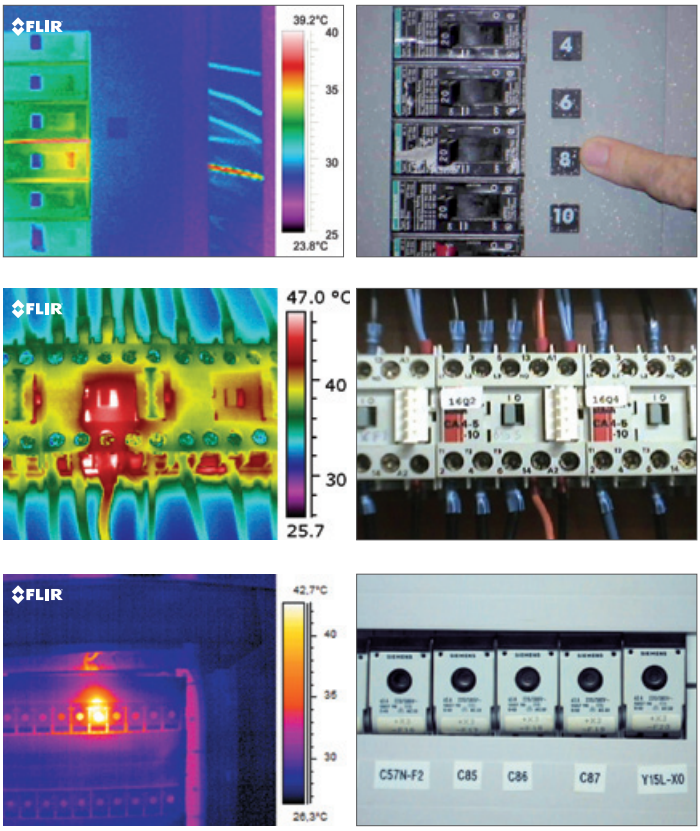
Heating, Ventilation and Air-Conditioning (HVAC) systems need to be well maintained. They need to deliver air at the correct humidity and temperature and filter any indoor pollutants. Thermal imaging can help to determine whether HVAC systems are operating properly. When working incorrectly they can cause poor indoor air quality.



Electrical faults
Every building also contains a lot of electrical installations. Thermal imaging can also be used to scan electrical cabinets, fuses, connections, etc.

By detecting problems that are invisible to the naked eye the problem can be repaired. If left unchecked, electrical problems can cause high temperatures. Furthermore, sparks can fly which might set the surroundings on fire.

For more information about checking electrical systems with a thermal imaging camera, please read the "Thermal imaging guidebook for industrial applications".



One of the fuses is overheated, a potential fire risk.

4

Thermal physics for building applications

In order to interpret the thermal images correctly the operator needs to know how different materials and circumstances influence the temperature readings from the thermal imaging camera. Some of the most important factors influencing the temperature readings are:

1. Thermal conductivity
Different materials have different thermal properties. Insulation tends to warm up slowly, while metals tend to warm up quickly. This is called thermal conductivity. Difference in thermal properties in two different materials can lead to large temperature differences in certain situations.

2. Emissivity
To read correct temperatures, one important thing needs to be taken into account, and that is a factor known as emissivity. Emissivity is the efficiency with which an object emits infrared radiation. This is highly dependent on material properties.



If you look at the thermal image you might think that the gold paint is colder than the mug surface. In reality they have exactly the same temperature, the difference in intensity of infrared radiation is caused by a difference in emissivity.

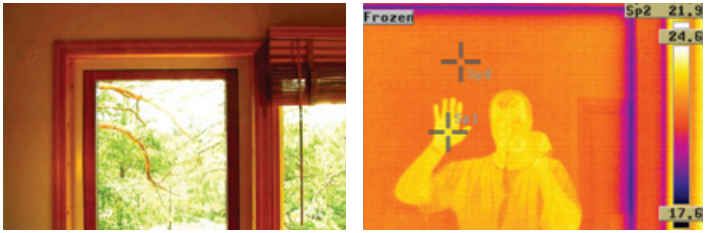
It is extremely important to set the right emissivity in the camera or the temperature measurements will be incorrect. FLIR Systems thermal imaging cameras have predefined emissivity settings for lots of materials, and the rest can be found in an emissivity table.



The thermal image on the left has the right emissivity settings for human skin (0.97) and the temperature reading shows the correct temperature (36.7 °C). For the thermal image on the right, the wrong emissivity was entered (0.15), leading to a false temperature reading (98.3 °C).

3. Reflection

Some materials, such as most metals, reflect thermal radiation much like a mirror reflects visible light. Reflections can lead to misinterpretation of the thermal image; the reflection of thermal radiation from the operator's own body or from a light bulb might lead to a false temperature reading. The operator should therefore choose the angle at which the thermal imaging camera is pointed at the object carefully, to avoid such reflections.



The window reflects thermal radiation, so to a thermal imaging camera the window acts as a mirror.

If the object's surface material has a low emissivity and there is a large difference in temperature between the object and the ambient temperature, the reflection of incident radiation will influence the temperature readings from the thermal imaging camera. To solve this problem FLIR has included the option in its thermal imaging cameras to set the apparent reflected temperature.

4. Indoor and outside temperatures
To detect missing or ill performing insulation using thermal imaging cameras there needs to be a difference between the temperature indoors and the temperature outside. It is often possible to do work with smaller temperature differences, but usually a temperature difference of at least 10 °C between the two sides of the wall is advisable.

Such inspections are typically done from both the inside and the outside. Missing, damaged or non-performing insulation will stand out clearly if the temperature difference is sufficient.

The user should know the indoor- and outdoor temperature and also needs to know if there have been big temperature changes during the last 24 hours.

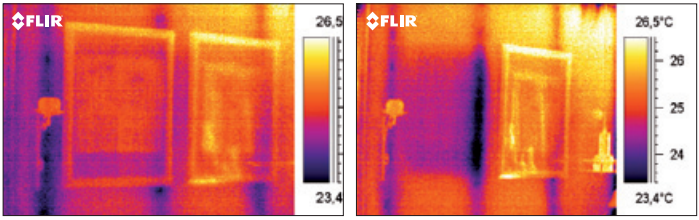
5. Influences on the outside of a building
It probably goes without saying that direct sunlight can influence thermal readings, but sunlight can have long lasting effects as well. Direct sunlight and shadows might even influence the thermal pattern on a surface many hours after the exposure to sunlight has ended. Differences in thermal conductivity can also cause differences in thermal patterns. Brick changes temperature much slower than wood, for example. Wind can also influence the thermal data. Airflows cool down the surface material, lowering the temperature differences between hot and cold areas.

Another obvious factor that can render thermal imaging inspection useless is rain, since it lowers the surface temperatures. Even after the rain has stopped the evaporation of the water cools down the material's surface. Obviously this can lead to misleading thermal patterns.

6. Heating and ventilation systems
External influences on surface temperatures can also be found indoors. Ambient temperature can influence the object surface temperature, but there's another factor as well: climate control. Heating systems create temperature differences that can cause misleading thermal patterns. Cool air flowing from ventilators or air conditioning systems can have the opposite effect, cooling down the surface.

7. Influences on the inside of the building

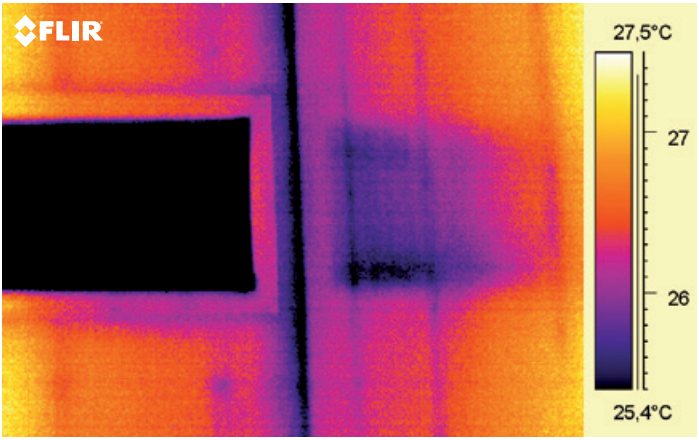
Bookshelves, cabinets and pictures hanging on the wall can also change the thermal pattern. These examples of furniture and wall decorations have an insulating effect. If these things are taken away from the wall, that area of the wall will show up in the thermal image as being colder. This might be confused for missing insulation. For that reason it is advisable to remove items from the wall at least 6 hours before inspection.



These two thermal images are taken of the same wall. The temperature outside is colder than inside. The image to the right shows what can happen when you take away a picture from the wall. The cold area behind the picture has the same size as the area between two studs in the wall, it looks like some insulation is missing in the wall.

8. Reflections from the surroundings

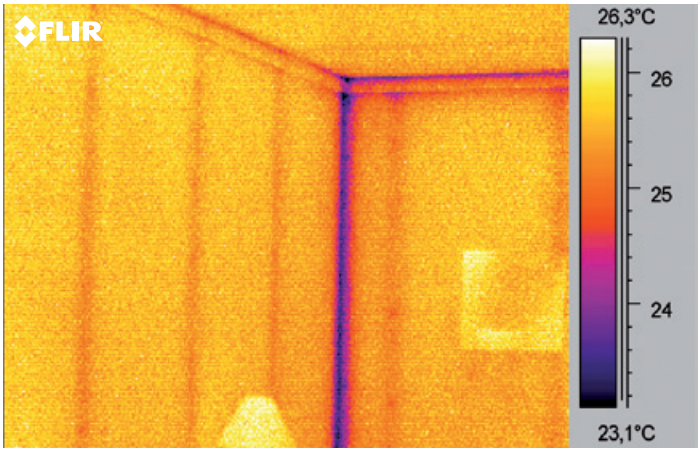
When scanning reflective targets, be sure to change your angle to minimize the reflections on the image. The reflection could be from your body heat, or some other heat source in the area, a piece of machinery, light bulb or a transformer. Reflections will give you incorrect data in the thermal image, and if not understood, it is a data error.



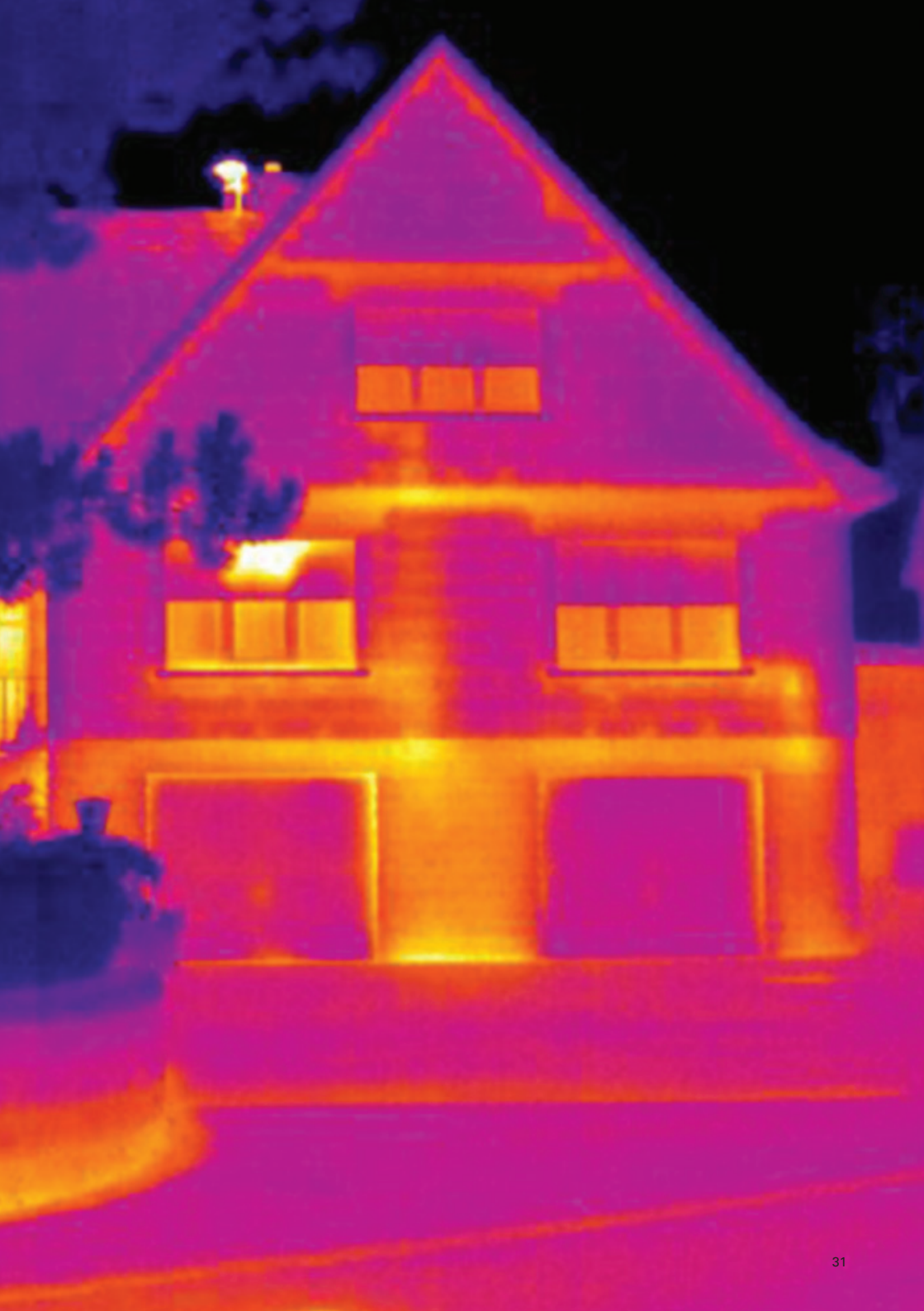
The image shows reflections on an inner wall (to the right) caused by the window to the left.

9. Type of materials used in the construction
Some materials, for example concrete, are thermally slow which mean they change temperature very slowly. Other materials, like most metals, change temperature quickly. In order to interpret the results correctly, the thermographer has to know if there has been any big temperature change outside or inside before the inspection takes place – as this can affect the temperature readings.

10. How the construction is built
An outer wall can be built with an air gap between the outer skin and the rest of the construction. Such type of construction is not suitable for control from the outside. Any framework in the wall construction becomes colder seen from the inside (provided it's warmer inside). From the cold side it is the opposite situation. These are expected characteristic patterns and there is nothing wrong.



Thermal image taken from the inside. The framework is visible, and so are the screws fitting the sheet covering to the framework. The corner is clearly colder, called a corner-effect, but there is nothing wrong here.



5

Thermal imaging cameras for inspecting solar panels.

Renewable energies
The fact that traditional energy sources like coal, gas and oil are scarce has led to high prices. Furthermore, awareness has risen that we cannot keep polluting our planet using these fossil fuels.

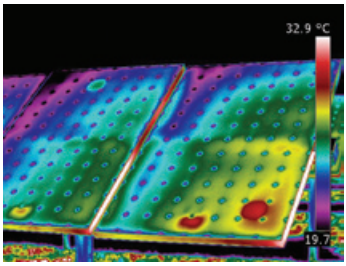
With solar panels on your roof you can convert the sun's energy into electricity and into hard cash. Solar power can be a lucrative investment. To receive maximum return and high yields for decades however, high quality is key. The solar module is the most important part of a solar system. It must be reliable and able to continue producing electricity for years at an end. To ensure reliable operation during the full lifetime cycle of a solar module, thermal imaging cameras can play an important role.

As fossil fuel reserves dwindle, the prices for coal and gas rise to new heights and many people look to the sun for a renewable power source. But solar panels are susceptible to wear. Building professionals all over the world therefore use thermal imaging cameras to inspect solar panels installed on rooftops or in solar parks.

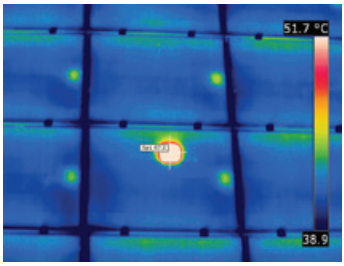
Inspecting solar panels
The use of thermal imaging cameras for solar panel evaluation offers several advantages. Anomalies can clearly be seen on a crisp thermal image and - unlike most other methods – thermal imaging cameras can be used to scan installed solar panels during normal operation. Finally, thermal imaging cameras also allow to scan large areas within a short time frame.



With a thermal imaging camera, potential problem areas can be detected and repaired before actual problems or failures occur. But not every thermal imaging camera is suited for solar cell inspection, and there are some rules and guidelines that need to be followed in order to perform efficient inspections and to ensure that you draw correct conclusions.



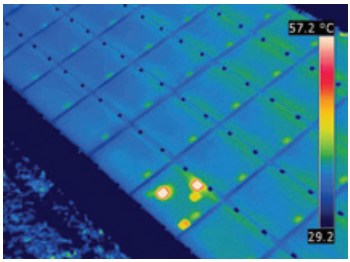
These red spots indicate modules that are consistently hotter than the rest, indicating faulty connections.



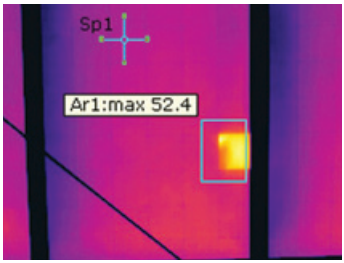
This hot spot within one solar cell indicates physical damage within the cell.

Procedures for inspecting solar panels with thermal imaging cameras

To achieve sufficient thermal contrast when inspecting solar cells in the field, a solar irradiance of 500 W/m² or higher is needed. For the maximum result a solar irradiance of 700 W/m² is advisable. The solar irradiance describes the instantaneous power incident on a surface in units of kW/m², which can be measured with either a pyranometer (for global solar irradiance) or a pyrheliometer (for direct solar irradiance). It strongly depends on location and local weather. Low outside temperatures may also increase thermal contrast.

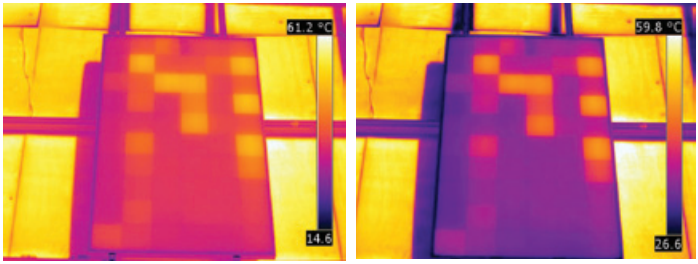


This thermal image shows an example of the so-called 'patchwork pattern', which indicates that this panel has a defective bypass diode.



This thermal image shows a hot spot due to cell breakage in a standard 60 cell module.

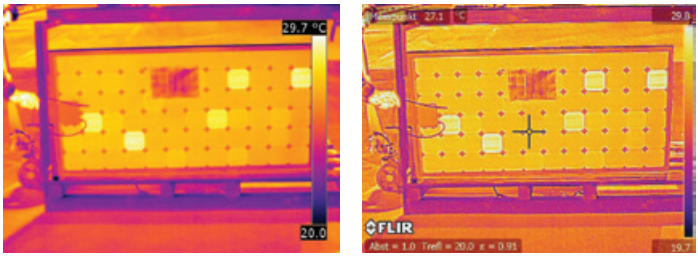
What type of camera do you need?
Handheld thermal imaging cameras for building inspections typically have an uncooled microbolometer detector sensitive in the 8 – 14 µm waveband. However, glass is not transparent in this region. When solar cells are inspected from the front, a thermal imaging camera sees the heat distribution on the glass surface but only indirectly the heat distribution in the underlying cells. Therefore, the temperature differences that can be measured and seen on the solar panel's glass surface are small. In order for these differences to be visible, the thermal imaging camera used for these inspections needs a thermal sensitivity ≤0.08 ºC. To clearly visualize small temperature differences in the thermal image, the camera should also allow manual adjustment of the level and span.



Thermal image with level and span in automatic mode (left) and manual mode (right).

Photovoltaic modules are generally mounted on highly reflective aluminum framework, which shows up as a cold area on the thermal image, because it reflects the thermal radiation emitted by the sky. In practice that means that the thermal imaging camera will display the framework temperature as being well below 0 °C. Because the thermal imaging camera's display algorithm automatically adapts to the maximum and minimum measured temperatures, many small thermal anomalies will not immediately be visible. To achieve a high contrast thermal image continuous manual correction of level and span would be needed.

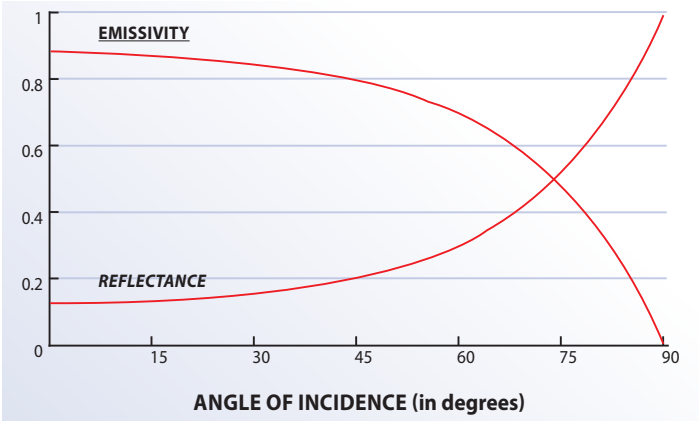
The so-called DDE (Digital Detail Enhancement) functionality provides the solution. DDE automatically optimizes image contrast in high dynamic range scenes, and the thermal image no longer needs to be adjusted manually. A thermal imaging camera that has DDE is therefore well suited for fast and accurate solar panel inspections.



Thermal image without DDE (left) and with DDE (right)

Positioning the camera: take into account reflections and emissivity

Even though glass has an emissivity of 0.85 – 0.90 in the 8 – 14 µm waveband, thermal measurements on glass surfaces are not easy to do. Glass reflections are specular, which means that surrounding objects with different temperatures can be seen clearly in the thermal image. In the worst case, this results in misinterpretations (false "hotspots") and measurement errors.



Angle dependence of the emissivity of glass

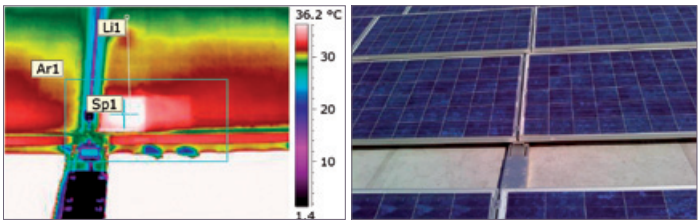


Viewing angle recommended (green) and to be avoided (red) during thermographic inspections.

In order to avoid reflection of the thermal imaging camera and the operator in the glass, it should not be positioned perpendicularly to the module being inspected. However, emissivity is at its highest when the camera is perpendicular, and decreases with an increasing angle. A viewing angle of 5 – 60° is a good compromise (where 0° is perpendicular).

Long distance observations

It is not always easy to achieve a suitable viewing angle during the measurement set-up. Using a tripod can provide a solution in most cases. In more difficult conditions it might be necessary to use mobile working platforms or even to fly over the solar cells with a helicopter. In these cases, the longer distance from the target can be advantageous, since a larger area can be seen in one pass. To ensure the quality of the thermal image, a thermal imaging camera with an image resolution of at least 320 × 240 pixels, preferably 640 × 480 pixels, should be used for these longer distances.

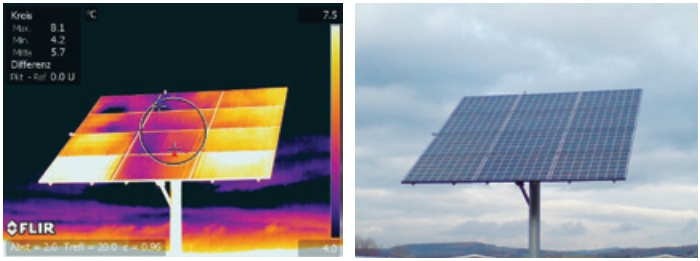


Faulty solar cells produce an excess of heat, making them easy to spot with thermal imaging technology.

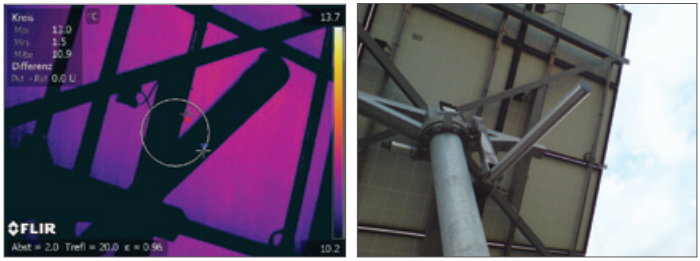
The camera should also have an interchangeable lens, so the operator can switch to a telephoto lens for long distance observations, such as from a helicopter. It is advisable, however, to only use telephoto lenses with thermal imaging cameras that have a high image resolution. Low resolution thermal imaging cameras will be unable to pick up the small thermal details that indicate solar panel faults in long distance measurements using a telephoto lens.

Looking at it from a different perspective

In most cases installed photovoltaic modules can also be inspected with a thermal imaging camera from the rear of a module. This method minimizes interfering reflections from the sun and the clouds. In addition, the temperatures obtained at the back may be higher, as the cell is being measured directly and not through the glass surface.



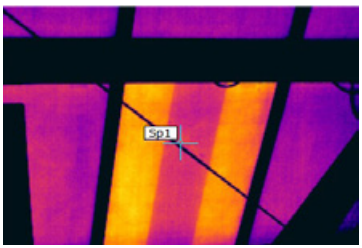
The hot spots on this thermal image taken from the front of the solar panel might seem to indicate that a multitude of cells are working inefficiently.



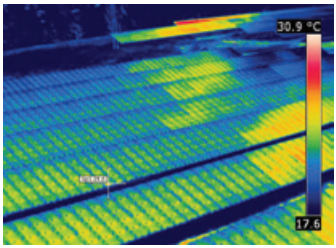
Inspection from the back shows no hot spots, the hot spots in the previous thermal image taken from the front were caused by cloud reflection.

Ambient and measurement conditions

When undertaking thermographic inspections, the sky should be clear since clouds reduce solar irradiance and also produce interference through reflections. Informative images can, however, be obtained even with an overcast sky, provided that the thermal imaging camera used is sufficiently sensitive. Calm conditions are desirable, since any airflow on the surface of the solar module will cause convective cooling and thus will reduce the thermal gradient. The cooler the air temperature, the higher the potential thermal contrast. Performing thermographic inspections in the early morning is an option.



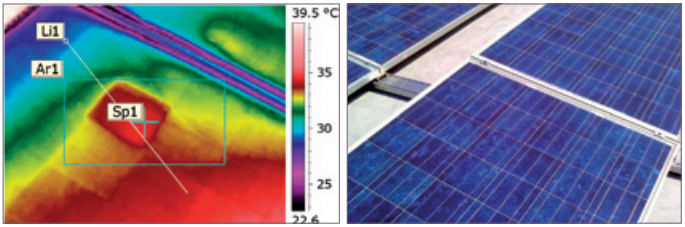
Two strings of cells show up hot in the thermal image, which indicates broken bypass diodes.



This thermal image shows large areas with elevated temperatures. Without more information, it is not obvious whether these are thermal anomalies or shadowing/reflections.

Another way to enhance thermal contrast is to disconnect the cells from the load, to prevent the flow of current, which allows heating to occur through solar irradiance alone. The load is then connected, and the cells are observed in the heating phase.

Under normal circumstances, however, the system should be inspected under standard operating conditions, namely under load. Depending on the type of cell and the kind of fault or failure, measurements under no-load or short-circuit conditions can provide additional information.

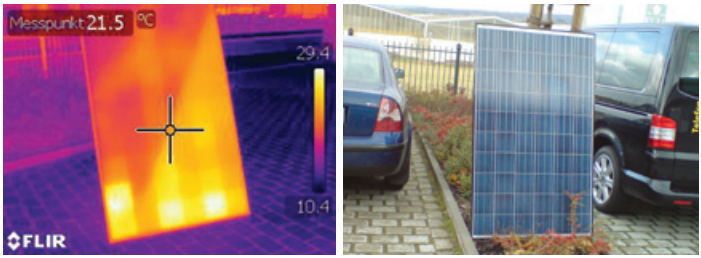


With a thermal imaging camera you can quickly locate issues such as this damaged cell, so the problem can be solved promptly.

Measurement errors
Measurement errors arise primarily due to poor camera positioning and suboptimal ambient and measurement conditions. Typical measurement errors are caused by:

- too shallow viewing angle
- change in solar irradiance over time (due to changes in sky cover, for example)
- reflections (e.g., sun, clouds, surrounding buildings of greater height, measurement set-ups)
- partial shadowing (e.g., due to surrounding buildings or other structures).

What can you see in the thermal image
If parts of the solar panel are hotter than others, the warm areas will show up clearly in the thermal image. Depending on the shape and location, these hot spots and areas can indicate several different faults. If an entire module is warmer than usual that might indicate interconnection problems. If individual cells or strings of cells are showing up as a hot spot or a warmer 'patchwork pattern', the cause can usually be found either in defective bypass diodes, in internal short-circuits, or in a cell mismatch.



A test with a solar panel shows that the hot spots can quite easily be seen on the thermal image, even from the front.

Shadowing and cracks in cells show up as hot spots or polygonal patches in the thermal image. The temperature rise of a cell or of part of a cell indicates a defective cell or shadowing. Thermal images obtained under load, no-load, and short-circuit conditions should be compared. A comparison of thermal images of the front and rear faces of the module can also give valuable information. Of course, for correct identification of the failure, modules showing anomalies must also be tested electrically and inspected visually.

Conclusions

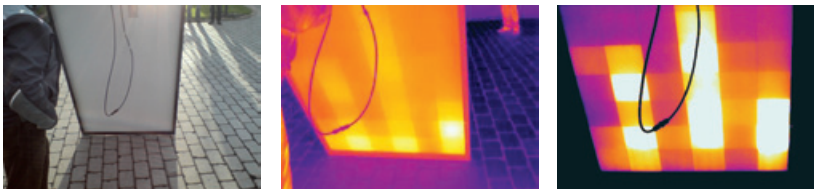
The thermographic inspection of photovoltaic systems allows the fast localization of potential defects at the cell and module level as well as the detection of possible electrical interconnection problems. The inspections are carried out under normal operating conditions and do not require a system shut down.

For correct and informative thermal images, certain conditions and measurement procedures should be observed:

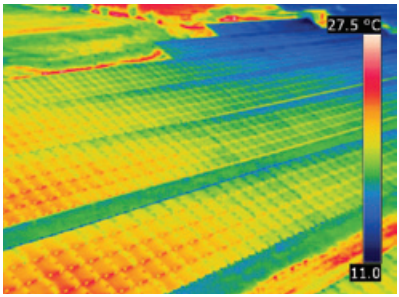
- a suitable thermal imaging camera with the right accessories should be used;
- sufficient solar irradiance is required (at least 500 W/m^2 – above 700 W/m^2 preferred);
- the viewing angle must be within the safe margins (between 5° and 60°);
- shadowing and reflections must be prevented.

Thermal imaging cameras are primarily used to locate defects. Classification and assessment of the anomalies detected require a sound understanding of solar technology, knowledge of the system inspected, and additional electrical measurements. Proper documentation is, of course, a must, and should contain all inspection conditions, additional measurements, and other relevant information.

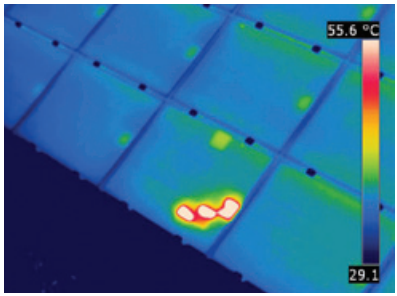
Inspections with a thermal imaging camera - starting with the quality control in the installation phase, followed by regular checkups - facilitate complete and simple system condition monitoring. This will help to maintain the solar panels' functionality and to extend their lifetime. Using thermal imaging cameras for solar panel inspections will therefore drastically improve the operating company’s return on investment.



Images taken from the back of a solar panel show much less reflection than the front, making the temperature measurements much more accurate.



In order not to draw false conclusions you need to hold the thermal imaging camera under a correct angle when inspecting solar panels.



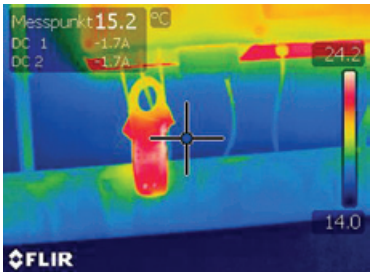
Thermal image made using a FLIR P660 camera on a flight over a solar farm. (Thermogram courtesy of Evi Müllers, IMM)

Error type	Example	Appears in the thermal image as
Manufacturing defect	Impurities and gas pockets	A 'hot spot' or 'cold spot'
	Cracks in cells	Cell heating, form mainly elongated
Damage	Cracks	Cell heating, form mainly elongated
	Cracks in cells	A portion of a cell appears hotter
Temporary shadowing	Pollution	Hot spots
	Bird droppings	
	Humidity	
Defective bypass diode (causes short circuits and reduces circuit protection)	N.a.	A 'patchwork pattern'
Faulty interconnections	Module or string of modules not connected	A module or a string of modules is consistently hotter

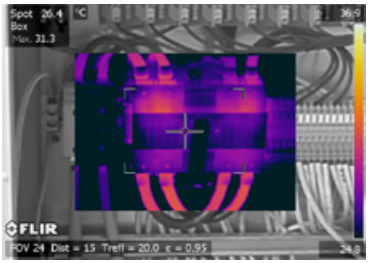
Table 1: List of typical module errors (Source: ZAE Bayern e.V, "Überprüfung der Qualität von Photovoltaik-Modulen mittels Infrarot-Aufnahmen" ["Quality testing in photovoltaic modules using infrared imaging"], 2007)

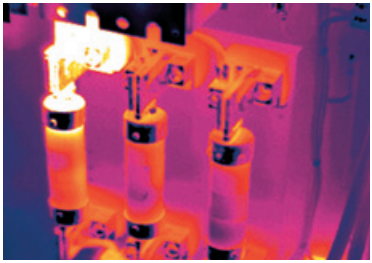
But thermal imaging cameras can do much more than solar panel inspections alone. They are also very usefull for the maintenance of the entire electrical circuit, including connectors, cables, inverters, etc.





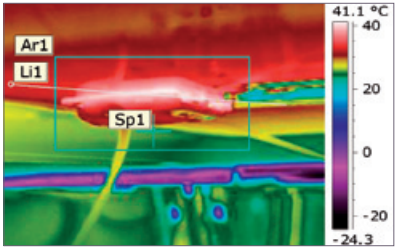
This inverter converts the direct current from the solar panels to alternating current. Thermal imaging cameras can be used to inspect this equipment. An external Extech clamp meter can provide additional information.





FLIR thermal imaging cameras are used to inspect the entire solar installation, including cables, connectors, fuse boxes and inverters, in other words: the entire system.





FLIR thermal imaging cameras can also be used to scan the other components of the solar installation, such as this faulty connector.



6

Inspecting wind turbines with thermal imaging cameras

Energy harvested from the wind through wind turbines is one of the most common forms of renewable energy. To that end new wind turbines are installed every year all over Europe and all over the world. All of these wind turbines have to be monitored and maintained. FLIR thermal imaging cameras can play an important role in the wind turbine predictive maintenance programs.



Thermal imaging cameras from FLIR systems are used to inspect electrical and mechanical installations all over the world. The thermal data gathered help to prevent dangerous accidents and costly downtime. All critical components of a wind turbine can be monitored using a thermal imaging camera from FLIR Systems.

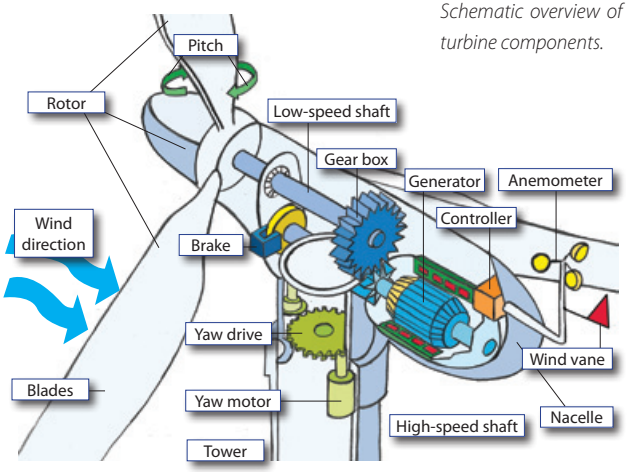


A thermal image of a wind turbine taken from ground level

Accidents

Wind turbines incorporate many different electrical and mechanical components. Like all other equipment these components are susceptible to wear and can break down. This can cause not only costly downtime, but dangerous accidents as well.

A common cause for these accidents is a failure in either the brake mechanism or in the gearbox. The gearbox and the brakes prevent the blades from turning too quickly. If either of these components fail then the turbine is allowed to revolve at many times its normal speed, which imposes loads on the blades well in excess of what they were designed for.



Schematic overview of wind turbine components.

Life-threatening

In such a case the tips of a rotor blade could be travelling at hundreds kilometers an hour, and when a blade or a piece of a blade suddenly detaches from the rotor it can have an enormous amount of kinetic energy and momentum as it is hurled away. This can lead to life-threatening accidents. There are many instances where large sections of broken blade have been found hundreds of meters or even farther from the turbine they had broken off from.

Inspections with thermal imaging cameras can help prevent such accidents. Both for electrical and mechanical components the general rule is that a component will become hot before it fails. Thermal imaging cameras can be used to spot this rise in temperature before a failure occurs. These hot spots will show up clearly in the thermal image.

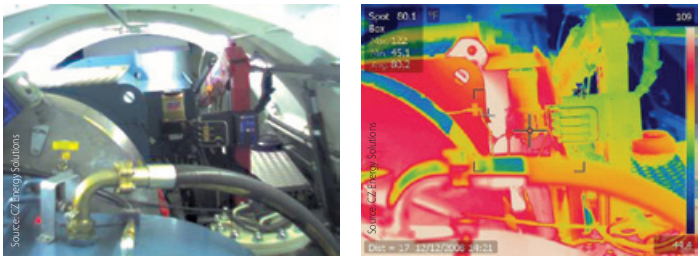
Thermal imaging helps you 'see' the problem.
Where other technologies tell you whether there is a problem with the entire machine, thermal imaging cameras will show you exactly which component is causing the problem. Reliable, quick and efficient: thermal imaging can be used to spot signs of wear on bearings, shafts, gears and brakes, allowing you to repair or replace components before failures occur.

Check the entire system
Thermal imaging cameras can be used to inspect the electrical components such as transformers, connectors, controllers yaw motors and such. Thermal imaging is the only technology that allows you to inspect all electrical and mechanical components of the wind turbine and of the surrounding electrical system.

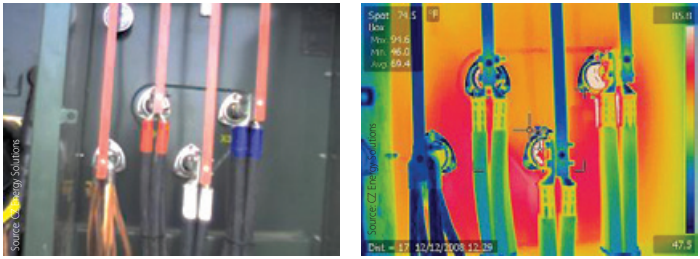
FLIR thermal imaging camera: the perfect tool
Wind turbine maintenance crews all over the world rely on thermal imaging cameras. An important factor in usability in the field is the camera design. All FLIR cameras are as compact as possible, ergonomically designed and easy to use, which is very important if you have to climb tens of meters to get to the wind turbine you are to inspect.



This huge 12 ton gearbox and disk brake assembly is lifted with a crane to a height of 60 meters to be mounted in this wind turbine nacelle.



A thermal imaging wind turbine transmission survey. This survey was performed at a height of around 50 meters.



Thermal imaging cameras can be used to scan the entire system surrounding the wind turbines as well. One of these three phase connectors, the rightmost one, is much warmer than the rest. This defect was spotted and was repaired before a failure occurred.

Another important factor is the lens. FLIR Systems offers optional 45° and 90° wide angle lenses. This allows you to capture large pieces of equipment in one go, even when you're up close. The fact that you can't take a step back when you're up high inspecting a wind turbine makes this a very important feature.

FLIR Systems offers a full range of thermal imaging cameras for building inspections. From the compact entrance model i3, through the practical Ebx- and B-Series to the advanced B660, FLIR Systems has exactly the right type of camera for each application.

7 Choosing the right thermal imaging camera supplier

Buying a thermal imaging camera is a long term investment. You therefore not only need to select the thermal imaging camera that best fits your needs but also a reliable supplier that can support you over a longer period of time.

A well established brand should be able to offer you:

- **Hardware**
  Different users have different needs. It is therefore very important that the manufacturer can offer you a full range of thermal imaging cameras, from affordable entry models to advanced high end models, so that you can choose the one that best fits your needs.
- **Software**
  Whatever your application, you will need software to analyze the thermal images and to report your finding to customers or management. Choose a thermal imaging camera that can be combined with the correct software for your application.
- **Accessories**
  Once you start using a thermal imaging camera and discover all the advantages it has to offer, your needs might change. Make sure you have a system that can grow with your needs. The manufacturer should be able to offer you different types of lenses, displays, etc.
- **Service**
  Although most thermal imaging cameras that are used for building applications are as good as maintenance free, you want to be sure that you have a service center close by in case anything should happen with the camera. Thermal imaging cameras also need to be recalibrated once in a while. In both cases you do not want to send your camera to the other end of the world but to a local repair center to ensure that you have the camera back in the shortest possible timeframe.
- **Training**
  There is more to the world of thermal imaging than just knowing how to handle the camera. Select a supplier that can give you good training and application support when needed.



8 Finding the best solution

Basically six key requirements are important to evaluate when investigating a suitable combination of thermal imaging camera, software and training:

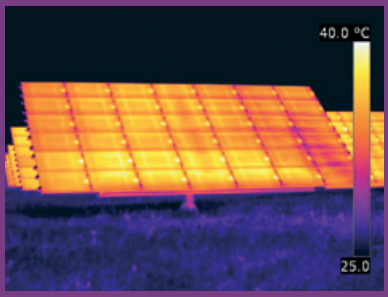
1. Image quality
2. Thermal sensitivity
3. Accuracy
4. Camera functions
5. Software
6. Training demands

1. Image quality
Image quality or camera resolution is an important factor. The most affordable entry models have a resolution of 60 x 60 pixels, while the advanced high end models have a resolution of 640 x 480 pixels.

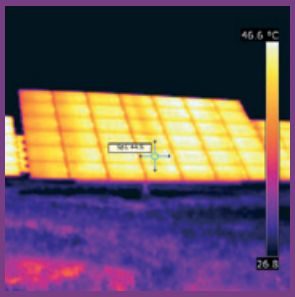
The thermal imaging cameras with a 320 x 240 or 640 x 480 pixels resolution deliver superior image quality. For more advanced inspections the 640 x 480 pixels resolution is becoming the standard for professional thermographers.

A camera with 640 x 480 pixels has 307,200 measurement points in one image which is four times more than a camera with 320 x 240 pixels and 76,800 measurement points. Not only will the measurement accuracy be better, but there is also a huge difference in the image quality.

High resolution helps to see, measure and understand more accurately.



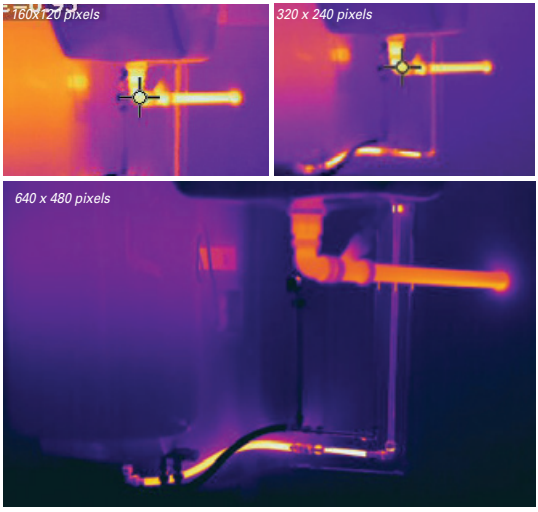
Thermal image: 640 x 480 pixels

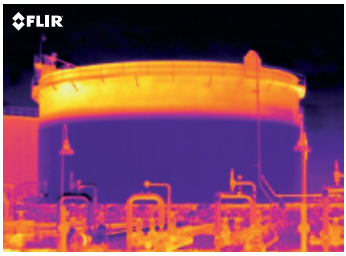


Thermal image: 180 x 180 pixels

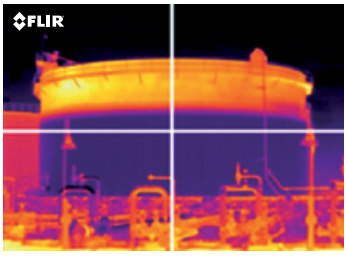
High resolution cameras also resolve small details during long distance observations. Compared to a camera with lower image quality you can view a larger area at once without loosing thermal information.

With a 640 x 480 pixels camera equipped with at 45 degree lens, an area of about 4 m x 3 m can be inspected at 5 meters distance with only one image. To inspect the same installation with a 320 x 240 pixels camera, also with a 45 degree lens, four images on half the distance are required. Not only does this increase the efficiency in the field, a lower amount of images taken in the field also saves time in the documentation phase.





640 x 480 pixels
One thermal image needed

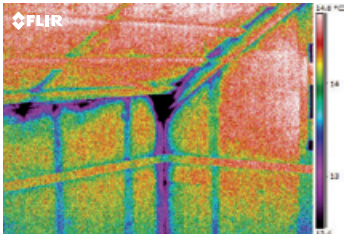


320 x 240 pixels
Four thermal images needed at half the distance

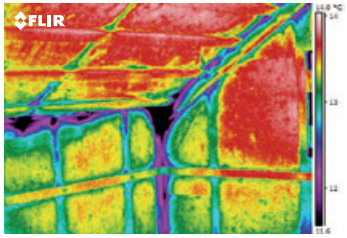
2. Thermal sensitivity



Thermal sensitivity describes how small a temperature difference the camera can detect. The better the thermal sensitivity, the smaller the minimum temperature difference the thermal imaging camera can pick up and visualize. Usually the thermal sensitivity is described in °C or mK. The most advanced thermal imaging cameras for building applications will have a thermal sensitivity of 0.03 °C (30 mK).



65 mK sensitivity



45 mK sensitivity

Being able to detect these minute temperature differences is important in most thermal imaging applications. High camera sensitivity is particularly important for building applications where temperature differences are typically lower. Higher sensitivity is needed to capture more detailed images and thus better diagnoses for further actions. The higher the sensitivity the better the camera is able to capture the finest image details even at low temperature differences.

3. Accuracy

All measurements are susceptible to error, and unfortunately thermal imaging temperature measurements are no exception. This is where the thermal imaging accuracy comes into play.

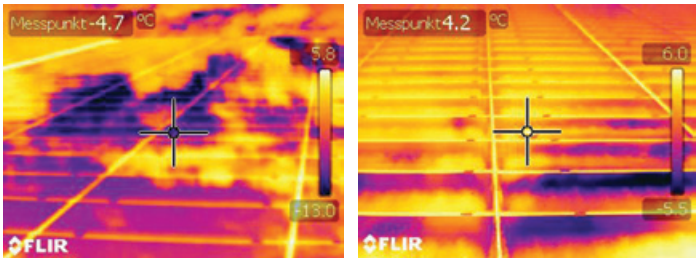
In thermal imaging camera specification sheets the accuracy is expressed both in percentages and degrees Celsius. This is the margin of error within which the camera will operate. The measured temperature might vary from the actual temperature with either the mentioned percentage or absolute temperature, whichever is bigger.

The current industry standard for accuracy is ±2 % / ±2 °C. The more advanced thermal imaging cameras from FLIR Systems score even better: ±1 % / ±1 °C.

4. Camera functions

Emissivity and reflected apparent temperature

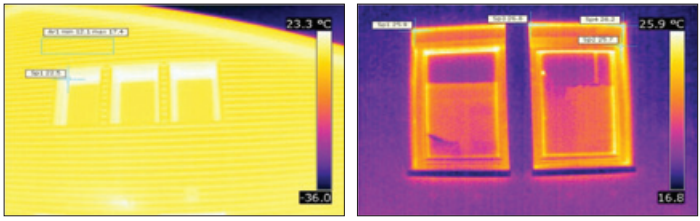
The emissivity of the object is a very important parameter that has to be taken into account. All FLIR thermal imaging cameras for building applications allow the operator to set the emissivity and reflected apparent temperature. Being able to set the parameters emissivity and reflected apparent temperature makes a huge difference. When buying a thermal imaging camera you should make sure that these functions are included.



This thermal image quite clearly shows that reflection can pose a problem. The thermal camera displays the thermal image including the reflections caused by the cloud. When measuring on the reflection the temperature will read as a mixture of the panel temperature and the apparent reflected temperature of the cloud.

Manual level and span correction

Another important camera feature is the option to manually set the span and level of the displayed thermal images. Without this feature, the camera will automatically display all temperatures between the minimum and maximum temperature of the scene. But sometimes the operator is only interested in a small part of that temperature scale.



The span of auto-adjusted thermal image on the left is too wide. The manually tuned thermal image on the right clearly shows heat leakage that was almost invisible in the auto-adjusted thermal image.

Dewpoint, relative humidity and insulation alarm

- Dewpoint alarm:

The dewpoint can be regarded as the temperature at which the humidity in a certain volume of air will condense as liquid water. At this point the relative humidity is 100%. By setting a number of parameters inside the camera the dewpoint alarm will automatically detect areas where this can happen due to deficiencies in the building structure.

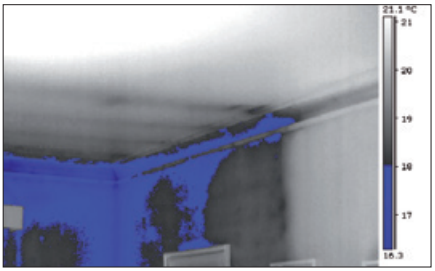
- Relative humidity alarm:

In some situations mold will grow on areas where the relative humidity is less than 100%. To detect those areas, the dewpoint alarm can not be used since it only detects areas where the relative humidity is 100%.

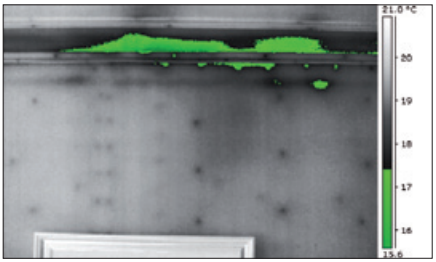
To detect areas where the relative humidity is less than 100% the relative humidity alarm can be used. You can set the relative humidity above which the alarm will trigger.

- Insulation alarm:

The insulation alarm detects areas where there may be an insulation deficiency in the building. It triggers when the insulation level falls below a preset value of the energy leakage through the wall.



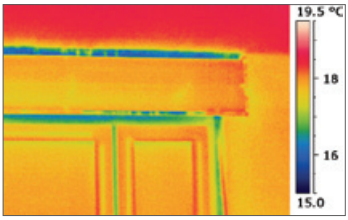
The relative humidity alarm alerts you to the areas where there is a risk of condensation. In this image the area at risk is indicated as blue color.



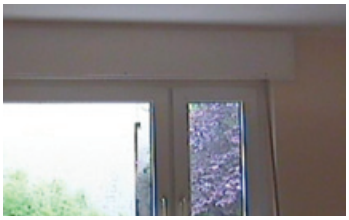
The insulation alarm shows where the areas below or above a set temperature are by making them appear in a different color.

Digital camera

Sometimes it can be very difficult to see what components are shown in a thermal image. In such cases it can help a great deal if you also take a visible light picture of the subject. Most of FLIR's thermal imaging cameras have a built in digital camera. Most building professionals that use thermal imaging cameras claim that they always take a visible light picture as well, to make sure that they know what is shown in the thermal image.



Thermal image



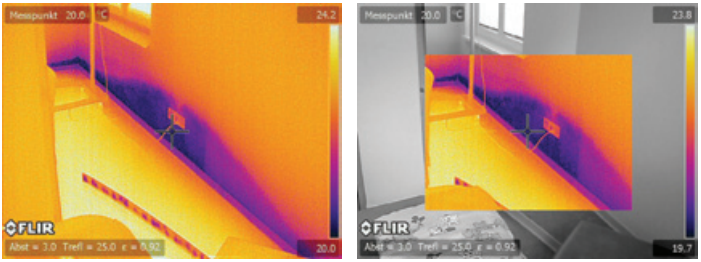
Visual image

LED lights

Having a light in your camera ensures that the built in digital visual light camera will be able to produce the clear pictures you need to make the most of the Picture-in-Picture and Thermal Fusion features, regardless of the lighting conditions.

Picture-in-Picture

With the Picture-in-Picture feature the operator can combine the images from the digital camera and the thermal imaging camera. The combined image will show a frame on top of the digital photo with a portion of the thermal image in it that can be moved around and resized. This helps the operator to better locate problems.



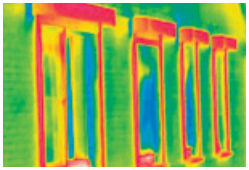
This case of water damage clearly shows the advantage of the Picture-in-Picture feature, since the client can quite easily see where this thermal image is located, while this would be more difficult with only the thermal image.

Thermal Fusion

This allows the operator to smoothly combine the two images by setting temperature parameters within which thermal data is shown and outside which the digital photo is shown. This helps to isolate problems and to enable more efficient repairs.



Visual image



Thermal image



Thermal Fusion image

Laser pointer

Some thermal imaging cameras have a built in laser pointer. There are several reasons why this is an important asset.

The laser pointer allows you to see precisely where the thermal imaging camera's lens is focused. With one simple push of a button the laser position will allow you to see exactly where the thermal imaging camera is pointed at so you can identify the measuring target without any guesswork.

Another reason is safety. The laser pointer eliminates the tendency to finger-point at objects, which can be dangerous in certain settings.

Interchangeable lenses

Once you start using a thermal imaging camera and discover all its possibilities your needs might change. Interchangeable lenses can help you to adapt your thermal imaging camera to every situation. For many situations the standard lens might be a good solution but sometimes you simply need a different field of view.

In some cases there is not enough room to step back and see the whole picture. A wide angle lens can be the perfect solution. With a wide angle lens the operator can inspect an entire house from just a couple of meters distance.

These lenses allow building inspectors to survey an entire building from just several meters away. When the target in question is a bit farther away it may be useful to use a telephoto lens. They are ideal for small or distant targets.

Ergonomic design and ease of use

Every tool that is used often needs to be light, compact and easy to use. Since most building inspectors will use thermal imaging cameras often and for extended periods of time, ergonomic design is very important. The menu design and physical buttons should also be very intuitive and user friendly, in order to allow efficient use.

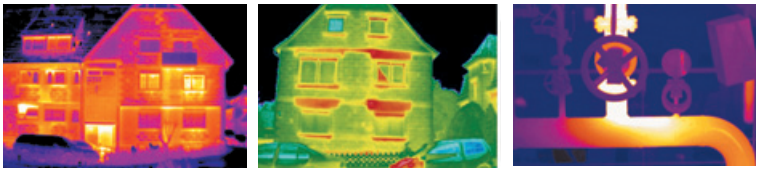


FLIR Systems tries to perfectly balance weight, functionality and ease of use for every thermal imaging camera it produces. This policy has lead to several award winning designs.

Image format

A factor in speedy reporting is the image format in which the thermal imaging camera stores the thermal images. Some thermal imaging cameras store the thermal data and images in a proprietary format, which means that you will need additional software to convert the thermal images into a standard JPEG image.

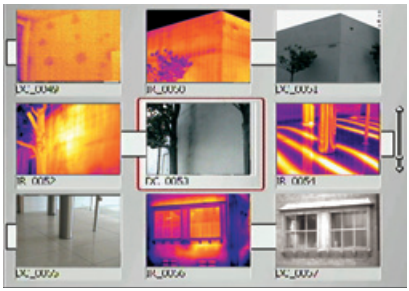
A FLIR camera delivers a fully radiometric JPEG. This means that all temperature data is included in the image and you can easily integrate the images in standard software.



All FLIR thermal imaging cameras store images in JPEG format.

Thumbnail image gallery

When recording thermal images on location it can be important to find and compare previously recorded thermal images in the camera's memory. All FLIR thermal imaging cameras therefore have an easy-to-access thumbnail image gallery that will help you to quickly review your saved thermal images to find the one you want – a massive convenience and time saver!



Voice and text comments

To further speed up both inspections and the documentation phase some thermal imaging cameras allow you to write text comments with a built in touch screen keypad, making the writing of a report much easier and faster. Some thermal imaging cameras even allow you to record voice comments while you work, which can reduce the time you spend on writing notes during thermal inspections to zero.



GPS location

Did you ever forget where a certain thermal image was taken? And you couldn't find the notes that you wrote to remind you of that location? Some of the most advanced models have a GPS feature for tagging the thermal image with its geographic location. This GPS technology will help you to record the location information of where each thermal image was taken.



Compatibility with external test & measurement tools

Sometimes the temperature alone gives you too little information about equipment. To get a complete picture, many building inspectors use external sensors, such as moisture meters. The values from the moisture meter are written down and later on the inspector will copy the written values into his report. This method is inefficient and prone to human errors.

To enable reliable and efficient inspections, FLIR Systems offers thermal imaging cameras that can automatically save the values from a moisture meter in the thermal image using Bluetooth MeterLink connectivity. Writing down notes will be a thing of the past as readings from Extech multifunction moisture meters will automatically and wirelessly be transferred to the camera and stored in the corresponding thermal image.



MeterLink allows to wirelessly connect an Extech moisture meter to a FLIR thermal imaging camera.

Wireless connectivity

With WiFi technology you can communicate wirelessly with the camera for instance by sending images directly from the camera to a smart phone or a tablet PC (iPhone or iPad).



5. Software



After performing the inspection you probably have to present the results of the inspection to colleagues or clients. Analyzing thermal images and creating comprehensive inspection reports are important tasks. You should make sure that your thermal imaging camera comes with a basic software package that allows you to do this.

Most software that comes with a thermal imaging camera will allow you to do basic reporting and analysis. Measuring the temperature on a single spot and some other basic measurement tools will be included. If you need more analysis and reporting options, the thermal imaging camera manufacturer should offer a more extensive software package. Features in this package should include things like:

- Flexible report page design and layout for customized reports
- Powerful temperature analysis tools: multiple spots, areas, temperature difference measurement
- Triple Fusion Picture-in-Picture (movable, sizable, scalable)
- Trending functionality
- Formula creation using thermal imaging measurement values
- Play radiometric sequences directly in the report
- Search functionality to quickly finding images for your report
- Panorama tool for combining several images to a large one



Armed with good analysis information and a good thermal report, you will be able to clearly show your management or customer where potential problems are located and convince them about the preventive actions that need to be taken.

6. Training Demands

FLIR co-operates with the Infrared Training Center (ITC), a global training organisation, operating in compliance with worldwide standards. ITC offers everything from short introduction courses to certification courses. For more information, visit www.infraredtraining.com or www.irtraining.eu.

itc INFRARED TRAINING CENTER

9 How to carry out thermal inspections

So the thermal imaging camera has been delivered and the inspecting can begin. But where do you start? In this section of the guidebook some thermal imaging methods will be present in order to get you going.

1. Define the task
Start the assignment by interviewing the client about the conditions of the building. For instance: has there been a recent increase in energy usage? Is it cold inside? Is there a noticeable draft? Then determine both the inside and outside temperature and make sure that the temperature difference is sufficient for building inspections (a difference of at least 10 °C is advisable).

2. Start from the outside
Start the thermographic inspection from the outside. Missing insulation or cold bridges can quickly be located from here. It is important to also take thermal images from areas where conditions seem to be ok. It will allow comparing the result with images that show faults, to evaluate the extent of the different problems found.

3. Continue inside
The next step is looking at the situation from the inside. This requires thorough preparation, however. To prepare for the interior thermal scan, the inspector should take steps to ensure an accurate result. This may include moving furniture away from exterior walls and removing drapes. It is advisable to do so at least six hours before the inspection, so the insulating properties of furniture no longer influence the thermal readings from the thermal imaging camera. As stated previously, the requirement for accurate thermographic inspections is a large temperature difference (at least 10 °C) between the inside and outside air temperatures.

When these conditions are met the inspector can start scanning every room in the building with the thermal imaging camera. In doing so the inspector should make sure that he takes accurate notes of where each thermal image was taken, perhaps by marking the location with arrows on a floor plan to show exactly from which angle the thermal images have been taken.

4. Set up an air tightness test
Small cracks and crevices can cause a draft. This is not only annoying, it can also cause severe energy loss. Air leakage can account for up to half of the energy consumed for heating purposes. An air thightness test, often referred to as a 'BlowerDoor' test can make the smallest cracks visible.

The 'BlowerDoor' helps exaggerate air leaking through defects in the building shell.

A 'BlowerDoor'system includes three components: a calibrated fan, a door panel system, and a device to measure fan flow and building pressure. The 'BlowerDoor' fan is temporarily sealed into an exterior doorway using the door panel system. The fan is used to blow air into or out of the building, which creates a small pressure difference between inside and outside.





The 'BlowerDoor' equipment is normally installed in the entrance door.

A ‘BlowerDoor’ system employs a fan to either suck air out of the room or blow air into it, causing a pressure difference. In situations where the outside air is colder, the most common method is to suck air out of the room using the ‘BlowerDoor’. As a result the pressure inside the room is lower than the outside air pressure; usually the difference is about 50 Pascal.

Due to this pressure difference the outside air will rush into the room through the cracks that are present. The outside air will cool down the location where a crack is present. This temperature difference will clearly show up in the thermal image as a cold spot or cold area, allowing the operator to accurately locate and map the air infiltration pathway.

5. Analysis and Reporting
When all rooms have been inspected it is time to return to the office to do the analysis of the images and to summarize the findings in a report.

FLIR proprietary software programs such as FLIR Tools, BuildIR and Microsoft Word compatible Reporter allow the inspector to quickly and efficiently draw up a comprehensive building inspection reports to show to colleagues or clients.



FLIR BuildIR

The FLIR BuildIR software helps to analyse the thermal images and quantify building related problems like air infiltration, insulation defects, thermal bridges and moisture problems in a professional report. With new and unique features it also enables quantifying and estimating the cost of the energy losses.

The software includes an Image Editor for advanced analysis of the thermal image, a Panorama tool and a Sensor tool for making graphs of the conditions during the inspection. The Panorama functionality allows stitching several images together into one big image as well as crop and perspective corrections. Other highlights include a Grid/ Area Quantifying function, Energy Cost Estimation Calculator and customizable templates for building related reports.

FLIR Reporter

The fact that it is based on the commonly used word processor software Microsoft Office Word makes FLIR Reporter intuitive and easy to use. Since most people already know how to use Word a minimum of training is required to start producing professional reports using familiar Word features including the automatic spelling and grammar check.

FLIR Reporter also includes numerous advanced features, including: Picture-in-Picture, Thermal Fusion, embedded GPS location data, digital zoom, color palette changes, play back of voice comments recorded in the field, and automatic conversion of reports to Adobe .pdf format.



NOTES



FLIR i3 / i5 / i7



FLIR Ebx-Series



FLIR B-Series



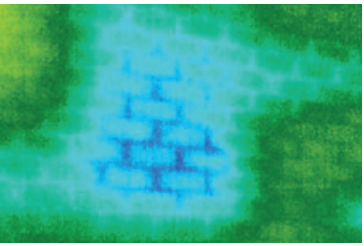
FLIR T640bx

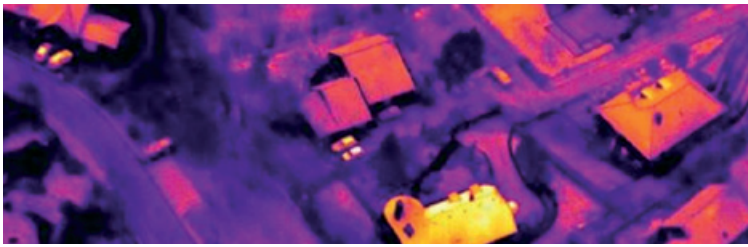


FLIR B620/B660



** After product registration on www.flir.com*





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