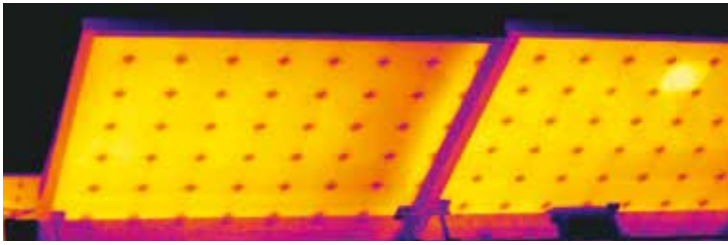

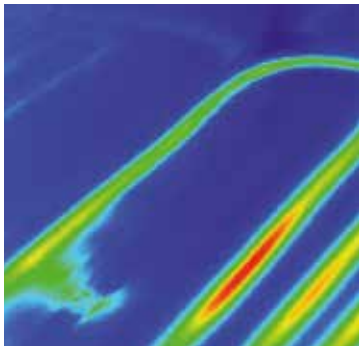

THERMAL IMAGING GUIDEBOOK FOR BUILDING APPLICATIONS

An informative guide for the use of thermal imaging cameras for inspecting buildings.

Content

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This booklet is produced in close cooperation with the Infrared Training Center (ITC).
The images displayed may not be representative of the actual resolution of the camera shown. Images for illustrative purposes only.

Introduction

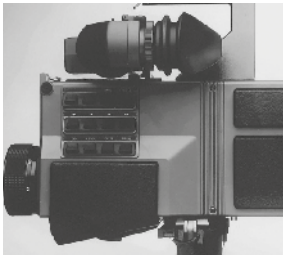
The first commercial thermal imaging camera was sold in 1965 for high voltage power line inspections, by what would later become FLIR Systems.

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.

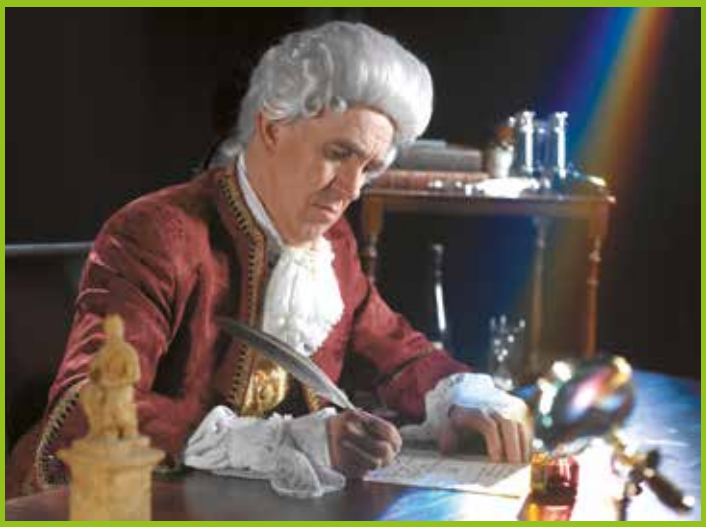
This, together with recent economic stimulus packages in many countries, is likely to drive up the demand for air tightness testing and other methods for energy efficiency investigation.

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.

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.



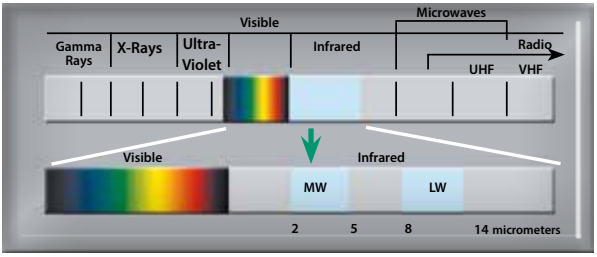
Sir William Herschel discovered infrared radiation in 1800.

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.

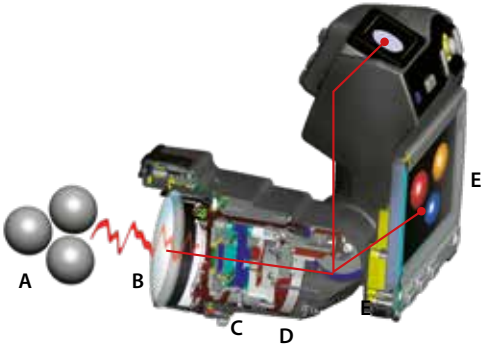
Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum. The primary source of infrared radiation is heat or thermal radiation. Any object that has a temperature above absolute zero (-273.15 degrees Celsius or 0 Kelvin) emits radiation in the infrared region. 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.



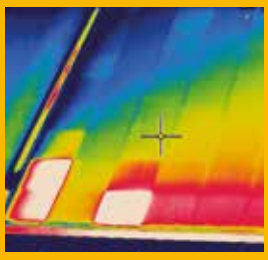
Infrared thermography is the art of transforming an infrared image into a radiometric one, which allows temperature values to be read from the image. So every pixel in the radiometric image is in fact a temperature measurement. In order to do this, complex algorithms are incorporated into the thermal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

2 Why use thermal imaging?

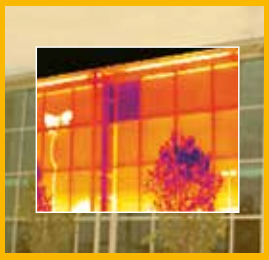
Thermal imaging cameras for building applications are powerful and non invasive tools for monitoring and diagnosing the condition of buildings, solar panels and windmills. With a thermal imaging camera you can identify problems early, allowing them to be documented and corrected before becoming more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

FLIR thermal imaging cameras:

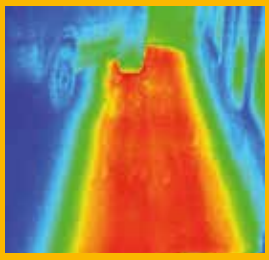
- Are as easy to use as a camcorder or a digital camera
- Give you a full image of the situation
- Identify and locate the problem
- Measure temperatures
- Store information
- Tell you exactly what needs to be fixed
- Help you find faults before real problems occur
- Save you valuable time and money



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.

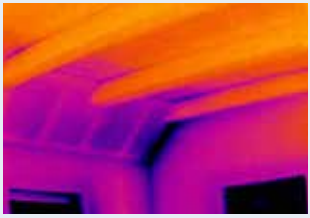
IR thermometer, temperature measurement in one spot


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.

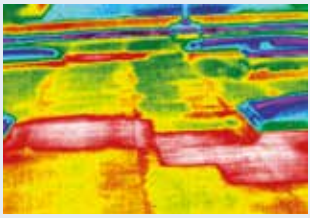
Use thousands of infrared thermometers at the same time
With an infrared thermometer you are able to measure the temperature at one single spot. FLIR thermal imaging cameras can measure temperatures on the entire image. The FLIR i3 has an image resolution of 60 x 60 pixels. This means that it is equal 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

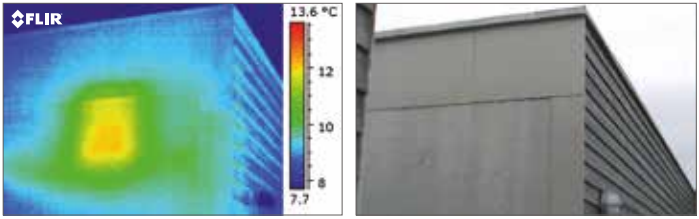
Thermal imaging cameras are the perfect tool for locating and identifying building failures because they make the invisible visible. On a thermal image problems seem to jump right out at you. A thermal imaging camera is the one tool that really lets you SEE it all.

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.

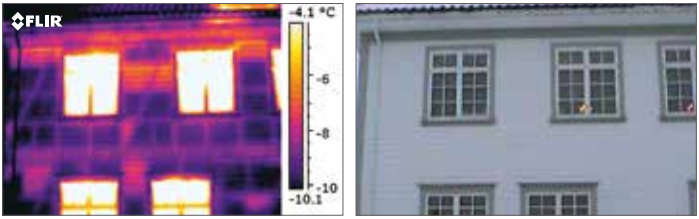
Thermal imaging cameras are such a valuable and versatile tool that it is not possible to list all the applications. New and innovative ways of using the technology are being developed every day. Some of the many ways in which thermal imaging cameras can be used within the range of building related applications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

Insulation defects and air leaks

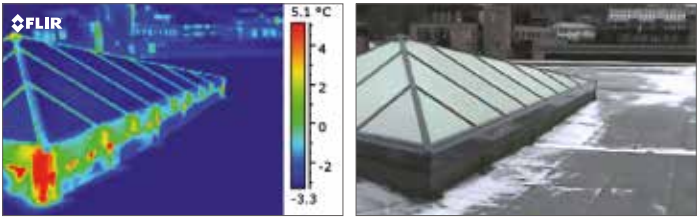
Thermal imaging is an outstanding tool to locate building defects such as missing insulation, delaminating render and condensation problems.



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.

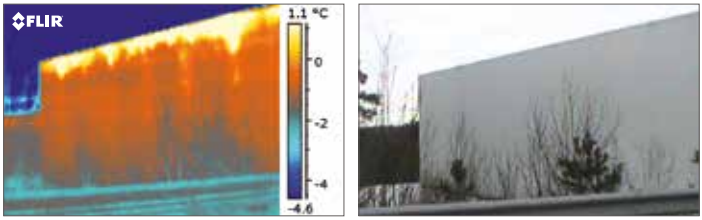


Framework construction. Many of the sections are missing insulation as indicated by the warmer colors.



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.

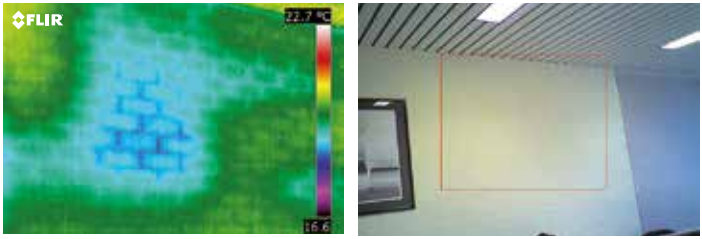
Warehouses with well insulated prefabricated walls and roof can experience energy loss from the joints between these parts.



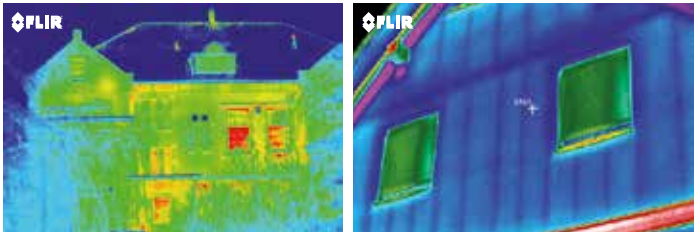
A warehouse with a lot of warm air escaping between the wall and the roof. These joints should be tightened to stop the energy loss.

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.

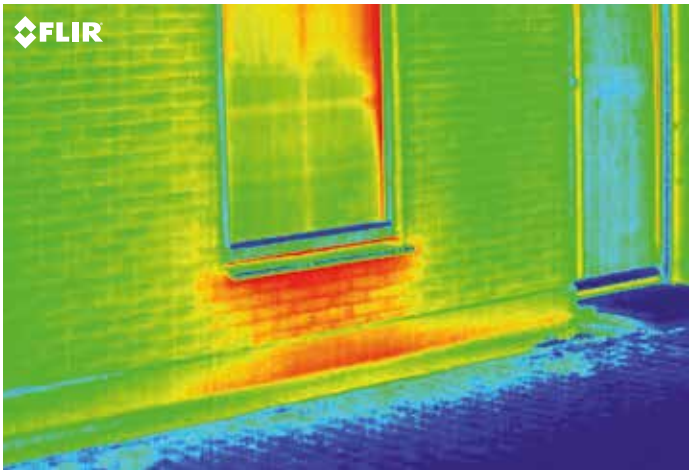
In cold climates, buildings are often inspected during winter time. In hotter climates, where it is important to see that the building is well insulated in order to keep the cool air that is generated by HVAC systems inside, the summer months can be ideal for this type of thermal inspections.



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.

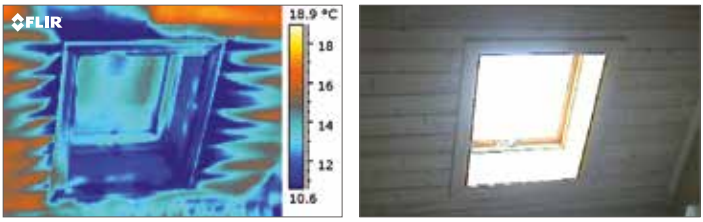
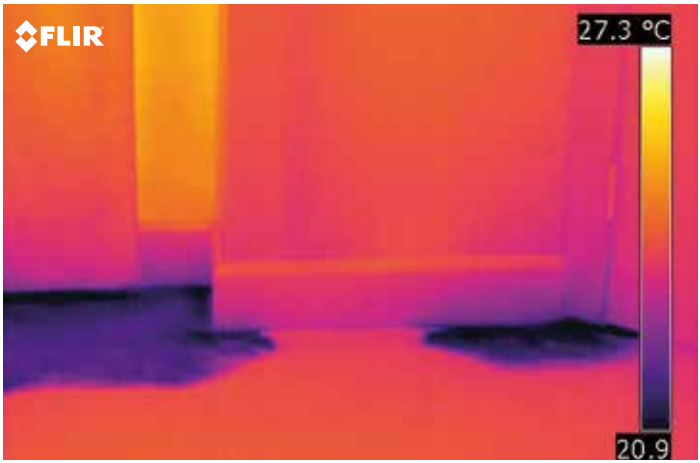


Image shows air leaks between the ceiling and the window.

Moisture Detection

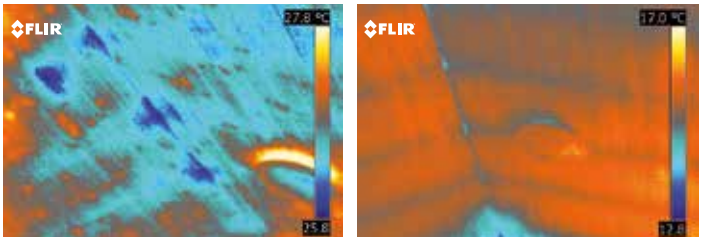
Moisture damage is the most common form of deterioration for a building. Air leakage can cause condensation to form within walls, floors, or ceilings. Wet insulation takes a long time to dry and becomes a prime location for mold and fungi.

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.



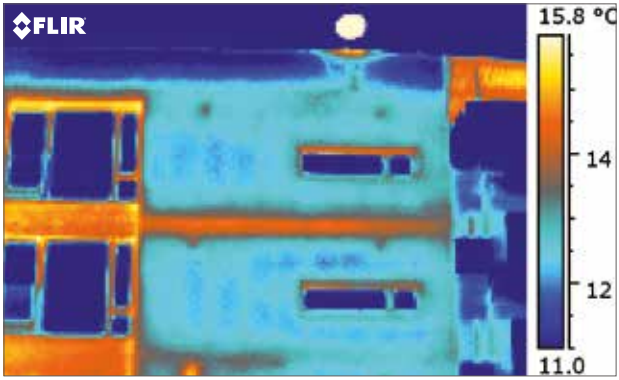
Thermal images taken of the same ceiling. In the left image the room temperature has been changed quickly by heating the room which makes the moisture clearly visible on the thermal image.

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

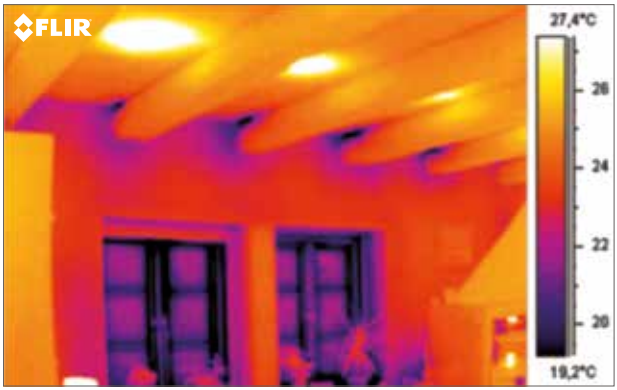
A thermal bridge is an area where the building envelope has a lower thermal resistance. It is caused by construction constraints. Heat will follow the easiest path from the heated space to the outside - the path with the least resistance.

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.

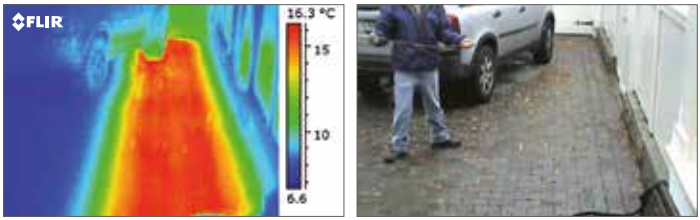


The thermal image shows thermal bridges between the roof beams and adjacent walls.

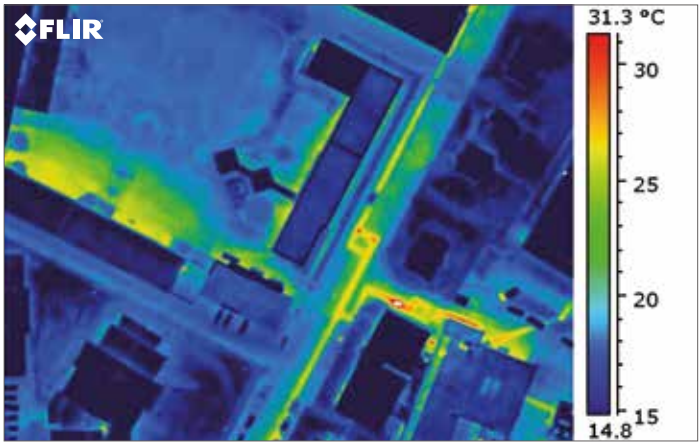
Supply lines and district heating
In cold climates, pavements and parking areas are sometimes heated.

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.

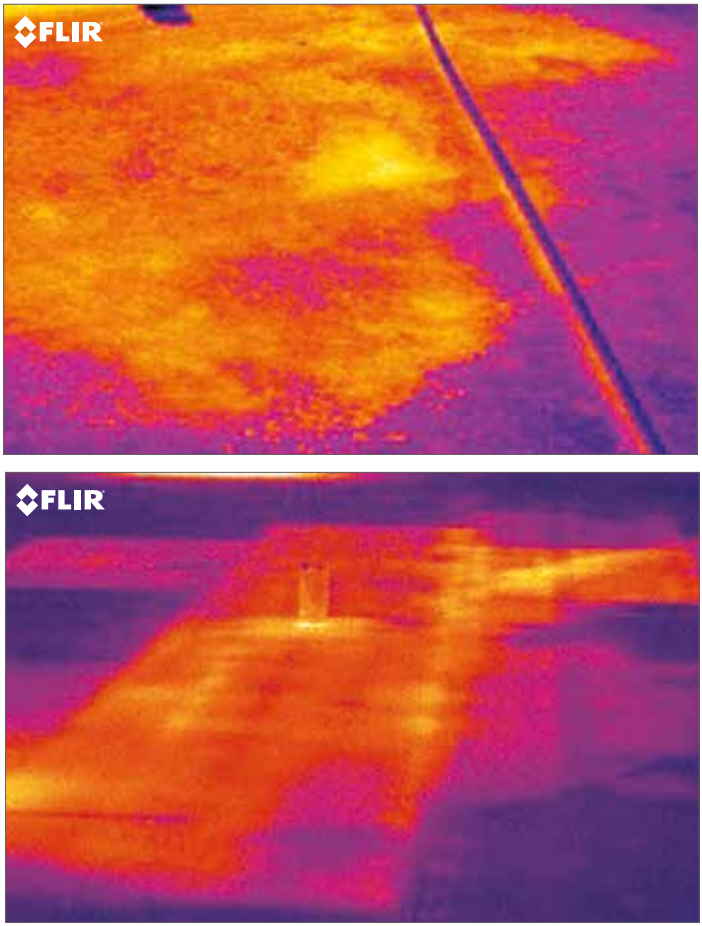


A thermal image, taken from the air, identifies leaks or insulation failure in the district heating system

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.

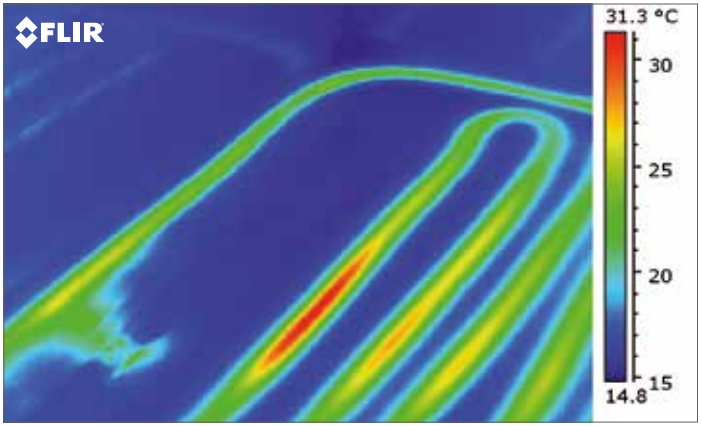
Tremendous savings can be made by repairing wet areas rather than replacing the entire roof.



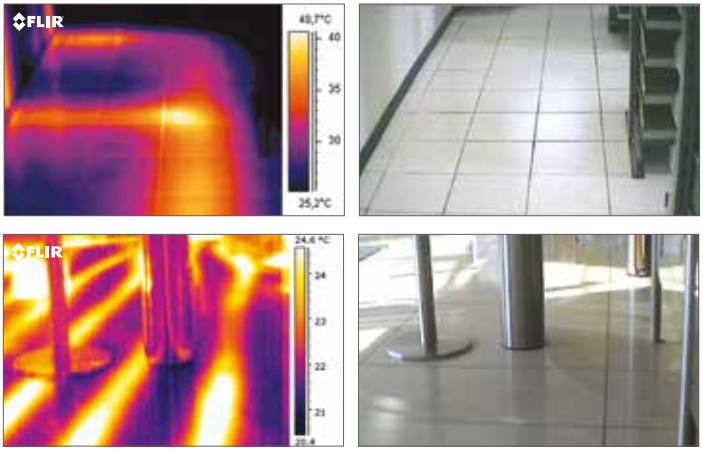
Water infiltration in flat roofs.

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.



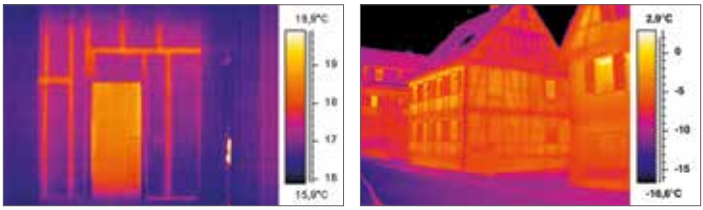
Underfloor heating problems can easily be detected with a thermal imaging camera.

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.

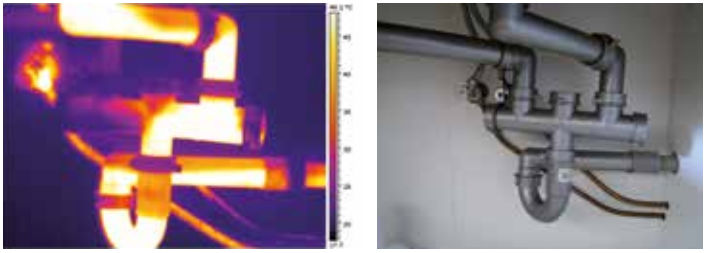
Building renovations
Thermal imaging provides valuable information during the renovation of buildings and monuments. Framework constructions hidden by mineral plaster can become clearly visible in a thermal image. It can then be decided whether exposure of these structures is useful. The detachment of 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

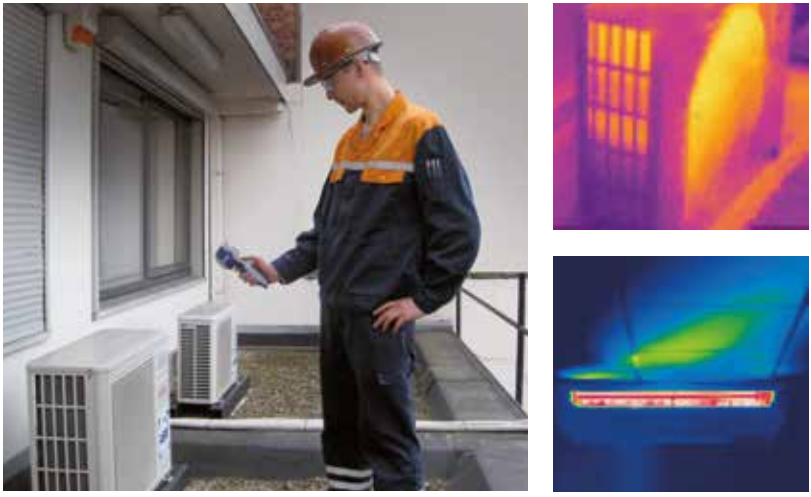
Thermal imaging is a perfect tool to detect blocked or broken pipes and other plumbing relates issues. Even if the pipes are laid under the floor or inside a wall it can be possible to determine the exact location of the problem by having hot water flowing through the pipes. The heat will radiate and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



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.

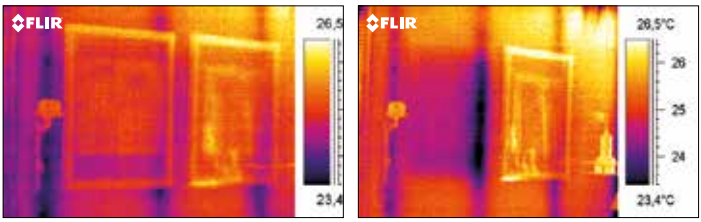
5. Influences on the outside of a building
It probably goes without saying that direct sunlight can influence thermal readings, but sunlight can have long lasting effects as well. Direct sunlight and shadows might even influence the thermal pattern on a surface many hours after the exposure to sunlight 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

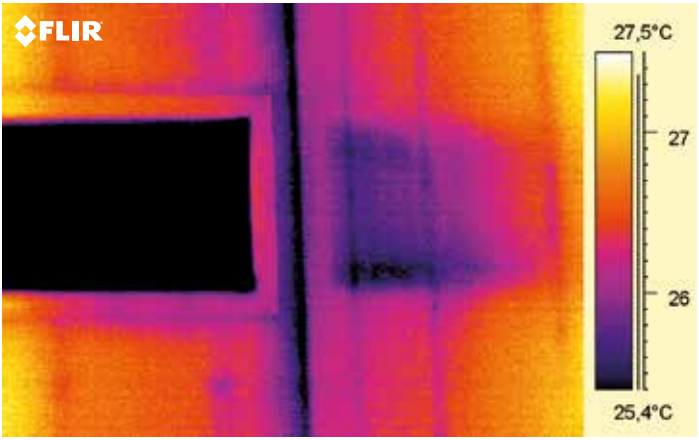
Bookshelves, cabinets and pictures hanging on the wall can also change the thermal pattern. These examples of furniture and wall decorations have an insulating effect. If these things are taken away from the wall, that area of the wall will show up in the thermal image as being colder. This might be 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

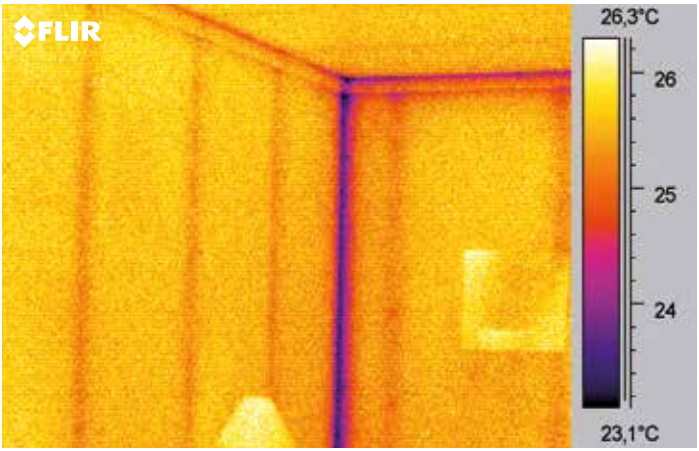
When scanning reflective targets, be sure to change your angle to minimize the reflections on the image. The reflection could be from your body heat, or some other heat source in the area, a piece of machinery, light bulb or a transformer. Reflections will give you incorrect data in the thermal image, 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.