Thermal imaging report guide

How to interpret the results of a thermal imaging survey

Guide

NHBC FOUNDATION

Housing research & guidance

BSRIA

NF86

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Acknowledgments

This guide was prepared by BSRIA.

Image Credits

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Leeds Sustainability Institute, Leeds Beckett University

Please note:

- some images have been altered with photoshop for illustration purposes.
- the images used are purely for thermal imaging purposes not to assess compliance.

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Welcome

As new homes are constructed with higher levels of insulation and air tightness, and are built at greater speed, the need to ensure a quality-built, energy-efficient home is paramount. Today's potential buyers show a growing concern not just in the build quality of their new home but also in the impact that living in it will have on the environment. Hence the widespread adoption of quality management systems and the government's proposals for a 'Future Homes Standard'. This will hopefully help to promote quality consistency across all areas in construction and future proof new homes with low-carbon heating and high energy-efficiency standards.

Thermal imaging, also known as infrared thermography, has been used for some time to provide a non-invasive 'window' at various stages of construction. It can show the thermal performance of the external walls, roofs and internal services. It is a quick and relatively easy method of implementing quality checks and tests during construction and is an effective problem-solving tool after completion.

NHBC Foundation's latest guide, prepared in collaboration with BSRIA, aims to extend understanding of the benefits and potential applications of thermal imaging and should be of particular use to customer care personnel who may receive thermal imaging reports as part of their after-care duties. It provides guidance, and helps to identify good practice, as well as aiding interpretation of the information provided within a thermal imaging report. It also seeks to clarify what can and what cannot be done with thermal imaging in the house building process. It gives examples of what a good thermographic survey looks like, and also provides information designed to help ensure a successful thermal imaging survey, including the suitability of equipment and appropriate levels of competency.

The NHBC Foundation are grateful to BSRIA for their work in preparing this guidance document. We hope that you will find it both informative and useful.

Rt Hon Nick Raynsford
Chairman, NHBC Foundation

1 Introduction

What is thermal imaging?

Successive improvements to building regulations over recent decades mean that homes built today are far more energy efficient than ever before. This has been achieved by installing greater thicknesses of thermal insulation and using better-performing windows and doors; there has also been an increasing focus on achieving airtightness.

However, installing the additional insulation and improved windows and doors on site, while at the same time minimising gaps in the building fabric which would allow draughts, can present practical challenges for the house builder. The consequences of getting things wrong can include increased energy use and higher running costs as well as discomfort due to cold draughts. In the more severe cases, the resulting cold internal surfaces can cause condensation and mould growth.

One tool available to help check the quality of installation of thermal insulation and identify potential air leakage paths is thermal imaging. A thermal image is essentially a visual map of the surface temperatures of a floor, wall or ceiling, made from thousands of temperature measurements taken by infrared-sensing equipment, and displayed against a temperature scale. To achieve the best results with a thermal imaging report, it is recommended that thermal imaging surveys be undertaken, and the images accurately interpreted by a qualified specialist, to determine whether construction appears to be in accordance with good standards.

Some new homes are now fitted with underfloor heating, the performance of which is determined by the even installation of heating pipework loops in the floor. Thermal imaging may also be used to determine whether these loops have been installed satisfactorily, in accordance with the design layout.

A thermal imaging camera showing underfloor heating pipe layout

2 Taking and reading thermal images

The equipment used to take a thermal image

A thermal image is taken with a specialist thermal camera which maps energy loss from buildings or equipment. Thermal cameras are similar to digital photographic cameras, but they detect infrared radiation which is electromagnetic radiation (EMR) with longer wavelengths than those of visible light and is therefore generally invisible to the human eye.

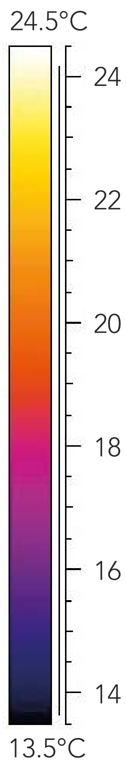
It is important to note that smartphone/tablet apps are not generally capable of taking thermal images when used on standard devices. However, in some cases an attachment housing an infrared detector can be added to enable the device to take thermal images.

How the camera converts the image

A thermal camera converts the intensity of radiation to a visible image or **thermogram** in which every pixel records a temperature that is assigned a colour. Warm objects stand out clearly against cooler backgrounds when viewed using a thermal imaging camera as the warmer the object, the more infrared radiation it emits. A temperature scale is added to the image to aid interpretation.

It is essential that the equipment is calibrated and set correctly to get accurate results.

The importance of the temperature scale



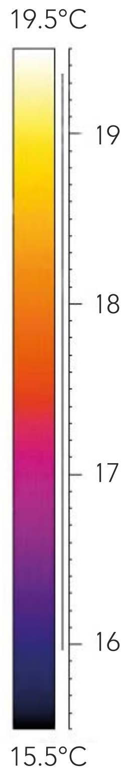
A vital feature in a thermal imaging survey is the temperature range used in the scale next to each thermal image.

It is very important to look at the temperature values on each scale as, although the colours may appear similar on a number of images, the temperatures on the individual scales used may, in fact, be different.

The scale on the left has a total temperature range of 11°C.

However, the range in scale on the right varies by only 4°C, even though the colours are similar.

This could affect the interpretation of a thermal image and whether there is a potential fault or an acceptable variation.



Colour Palettes

The colours used in thermal images can be based on different palettes, which are artificially added to make the images easier to interpret and are usually reproduced in a colour scale beside the image itself.

This scale shows the relative temperature indicated by the colour in the image. To the right of this scale, numerical values in degrees Celsius are given.

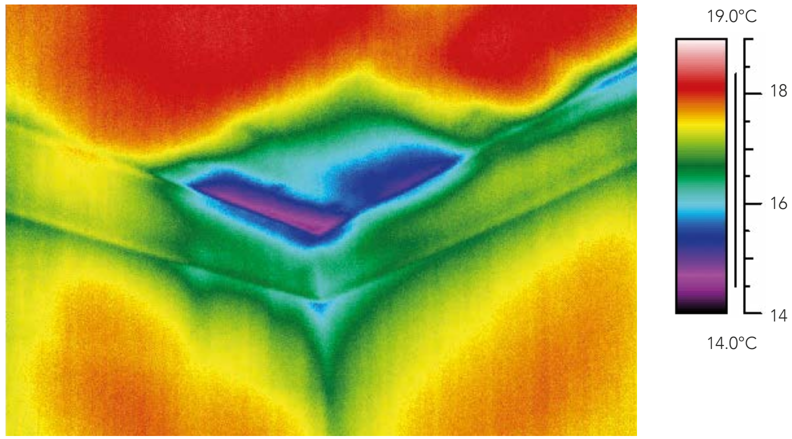
The **thermographer** (trained thermal imaging operative) can choose from a number of colour ranges, or palettes, to represent the range of temperatures in the image.

The two most widely used palettes are 'rainbow' and 'ironbow' (often shortened to simply 'iron'. The rainbow palette has more contrast than the ironbow palette. It also has the advantage of exaggerating small temperature differences.

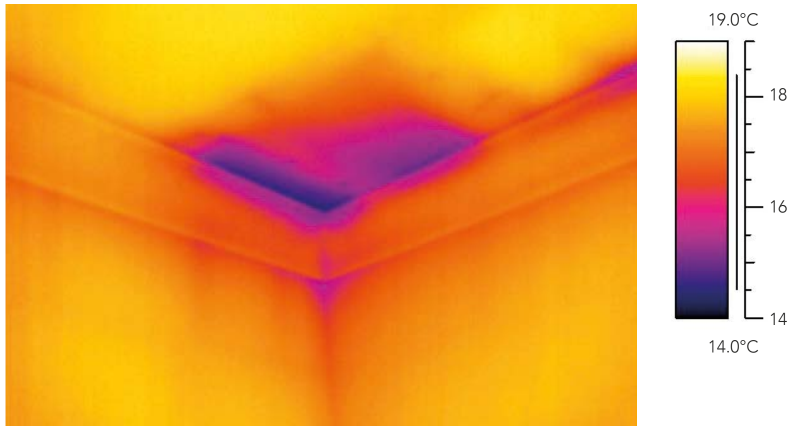
However, because the scale of the rainbow palette is equally bright at three different temperatures, it is difficult to interpret temperature differences without looking at the scale. It is impossible to do so when the image is presented in greyscale (for example if it is photocopied).

The ironbow palette has a steady colour and brightness gradient so it can be interpreted even when reproduced in greyscale and it is easier to estimate temperatures.

For this reason, the images in this publication are reproduced using the ironbow palette.



Rainbow palette



Ironbow palette

3 Interpreting a thermal image

What does a thermal image of the building fabric show?

Thermal imaging shows the temperature variations of the surface of walls, floors, ceilings, windows and doors of homes that might be the result of gaps in insulation or insulation bridged by building materials (e.g. mortar debris in cavity walls). Thermal bridging occurs where there have been breaches in the thermal insulation area of the external construction layer. (Known or designed bridges in this construction layer will be included in the thermal performance calculations).

It can also reveal electrical or mechanical equipment faults, concealed pipes or dampness; it may also show the path of warm or cold air leakage (these can be detected as cooler air entering the building can cool down the surfaces it contacts).

How to recognise faults?

Whenever a variation in temperature is seen in a thermal image, the first question to ask is whether this can this be explained by a known feature of the building. For example, there may be a water pipe running within the wall, which would be very different in appearance from continuous thermal insulation. It is normal for thermographic imaging to detect slightly lower temperatures at wall/floor junctions, and around openings. This is caused by the slightly higher level of heat loss expected in these locations and is not a sign of a problem.

Knowledge of the type of construction is also helpful. Typically, the types of variations found in masonry walls will be very different from those in timber frame construction. Potential faults that can't be explained by either a known feature or a construction detail, are likely to need further, intrusive investigation.

What are the limitations of thermal imaging?

There are limits on what thermal imaging can do.
Thermal imaging **cannot**:

- See through bricks, metal, plastic, etc. – it can only show the surface temperature
- Detect anything when there is no temperature difference between the inside and the outside of the home
- Measure the temperature of air or exhaust gases.

Thermal imaging should only be used to identify areas that require further investigation and it can be useful for problem solving.

A thermal image showing potentially higher heat loss than expected in an area does not always mean that any remedial work is necessary.

The importance of weather conditions during the survey

Having suitable weather conditions at the time of the survey is vital in achieving an accurate picture of the thermal performance of the home.

The conditions needed before and during a thermal imaging survey are as follows:

- No significant changes in external temperature during the 24 hours before the survey
- A temperature difference between inside the property and outside of at least 10°C during the survey
- No sun shining directly onto the external walls of the property during the survey
- No rain or high winds during the survey.

It is therefore unlikely that thermal imaging can be carried out during summer months in the UK, and a survey should not be carried out if it is raining or windy.

Heat loss through the building fabric

There is a temperature difference between the inside and outside of a home as it is heated, and the fabric of the building helps stops the heat escaping by providing resistance to the flow of heat. A well-insulated home with effective insulation provides a comfortable living environment without excessive energy usage.

Thermal images taken from the inside of a home will be more accurate than those taken externally as there will be less interference from wind, rain, sunshine and cold air.

Misleading features in the building fabric

Some features of building surfaces can give rise to misleading results. These include:

- Reflective surfaces such as metal finishes
- Stored heat (on a sunny day, brick, block and concrete can store heat and take a long time to cool down)
- Ventilated cladding such as tile hanging and curtain walling, which can obscure the temperature of the wall.

4 Common potential faults found using thermal imaging

A potential fault is anything that is unusual in terms of a warm or cold area where it is not expected and a number of these can be revealed through thermal imaging of the building fabric.

The following pairs of images highlight the most commonly-found potential faults in the construction of a home. For each pair there is an image with an even colour spread, indicating that the home has been built to a satisfactory standard. The second image shows a temperature difference, demonstrating a potential fault in the construction.

Some images here have been edited to accentuate the features being discussed. The images are for thermal imaging purposes only and not to assess compliance.

Is a potential fault critical?

The thermal images help to identify a difference from what would be expected. Its severity should be judged by its size and temperature difference from a normal area, which is shown by the difference in colour between the two areas.

The external envelope of the home should be at a relatively consistent temperature and in general the internal surface should be above 18°C. This temperature represents the dew point of the wall under normal atmospheric conditions assuming the wall has a U value not exceeding 0.7W/m2K as stated in Building Regulations, Approved Document C (clause 5.36) [1].

Window frames and glass are an exception as they will have inherently lower insulation values than other parts of the construction.

When interpreting each image, it is very important to check the temperature scale which appears alongside. Although the image may show a wide variation in colours, this may represent only a small temperature range if the camera has not been set correctly. The temperature scale on the camera is normally set automatically, based on the range of temperatures detected through the lens. This can be set manually, whereby the user dictates the temperature range seen in the image, and the subsequent temperature scale.

4.1 Gable wall

Thermographic image 1

Thermographic image 2

Thermographic image 1: Good construction

Full-fill insulation batts have been built into this masonry cavity wall. The even colour across the gable wall indicates that the insulation has been installed well, with no gaps, resulting in low levels of heat loss across the whole wall area.

Thermographic image 2: Potential fault

The brighter yellow areas at the wall apex and in line with first and second floor joists indicate a higher surface temperature in these places, suggesting higher local heat loss. This may be due to inconsistency in the installation of the insulation batts with some areas of the cavity having gaps between the batts or a build-up of mortar debris.

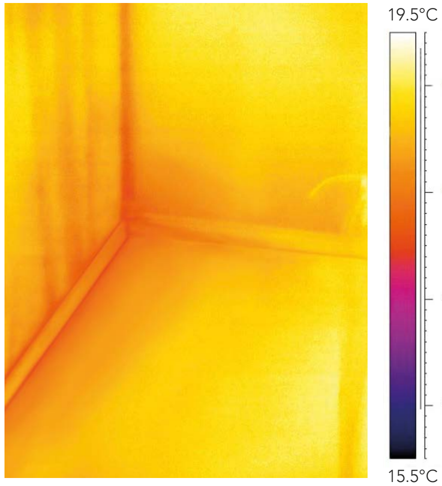
4.2 Perimeter of ground floor

Thermographic image 3: Good construction

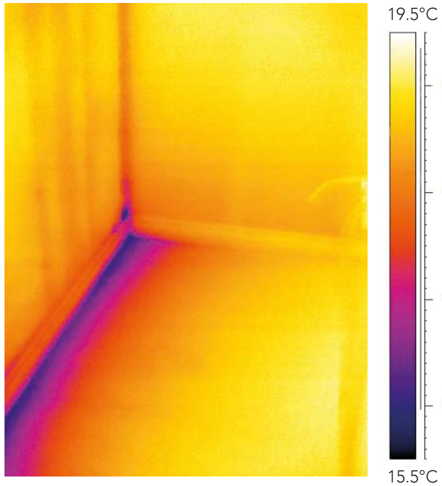
The even colour at the junction between the external wall on the left and the floor suggests that the thermal insulation has been installed to a satisfactory standard, with no areas of excessive heat loss indicated.

Thermographic image 4: Potential fault

The solid dark line along the external wall and floor junction suggests a lower temperature in this location. This can indicate higher localised heat loss, suggesting that the insulation around the external perimeter of the floor may not have been installed correctly or is missing.



Thermographic image 3



Thermographic image 4

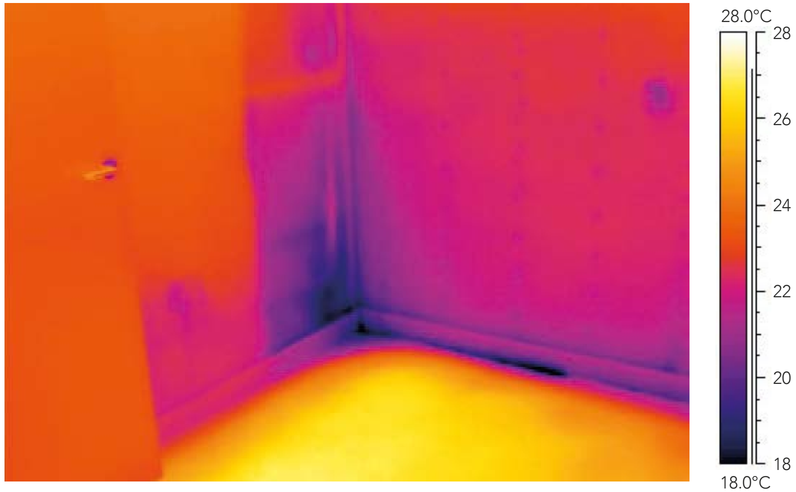
4.3 External wall – timber frame construction

Thermographic image 5

Thermographic image 5: Good construction

The consistency of the orange colour across the wall surface indicates that the thermal insulation has been installed to a satisfactory standard to limit heat loss and so the wall temperature is uniform.

It is normal for thermographic imaging to detect slightly lower temperatures at external corners of walls, both horizontal and vertical; this is caused by the slightly higher level of heat loss expected in these locations and is not a sign of a problem.

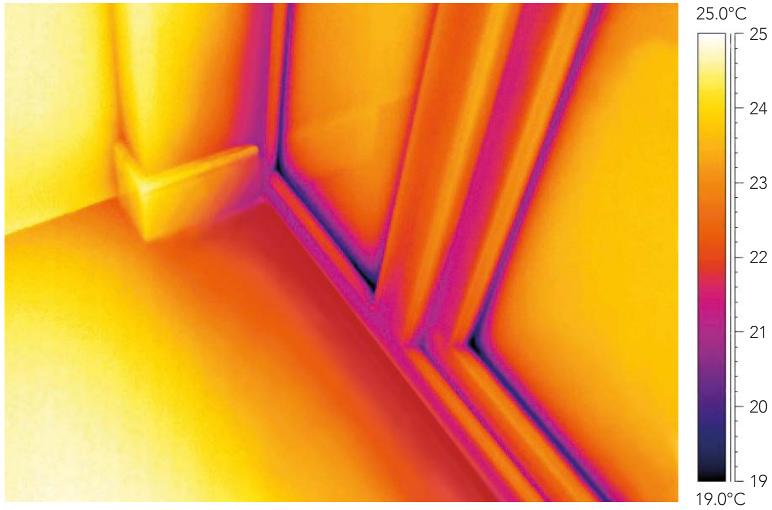


Thermographic image 6

Thermographic image 6: Potential fault

The patch of darker colour indicates that part of the wall area in the corner is at a much lower temperature, indicating higher localised heat loss. The regular shape, together with what appears to be the structural timber, suggests that an area of insulation may be missing or has been poorly installed between the vertical studs.

4.4 French doors



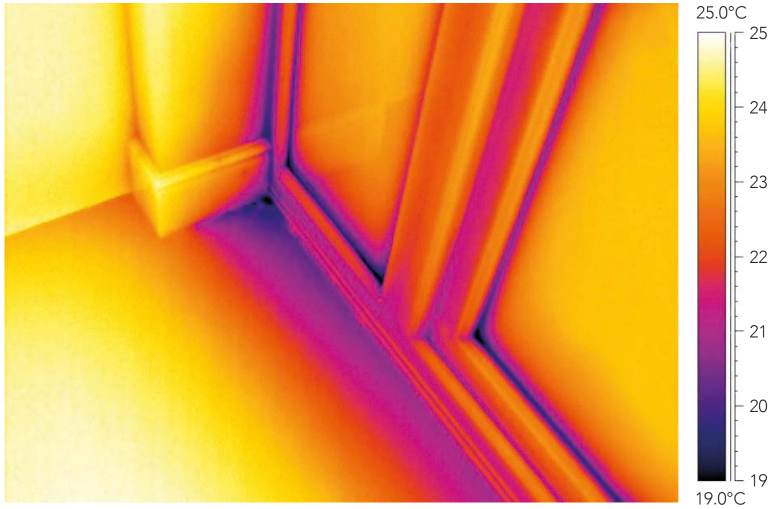
Thermographic image 7

Thermographic image 7: Good construction

The yellow and orange colours around the junction between the floor and wall indicate that the door has been correctly installed to reduce heat loss. The slightly lower temperatures around the door frame indicate a marginally higher level of heat loss, which is expected in this location and is not a sign of a problem.

Thermographic image 8: Potential fault

The darker areas around the French doors reveal lower temperatures, particularly at the junction with the floor. This indicates higher localised heat loss. The pattern suggests poorly installed insulation at the threshold and possibly – a problem with closing the cavity or poor sealing around the door frame.



Thermographic image 8

4.5 Windows

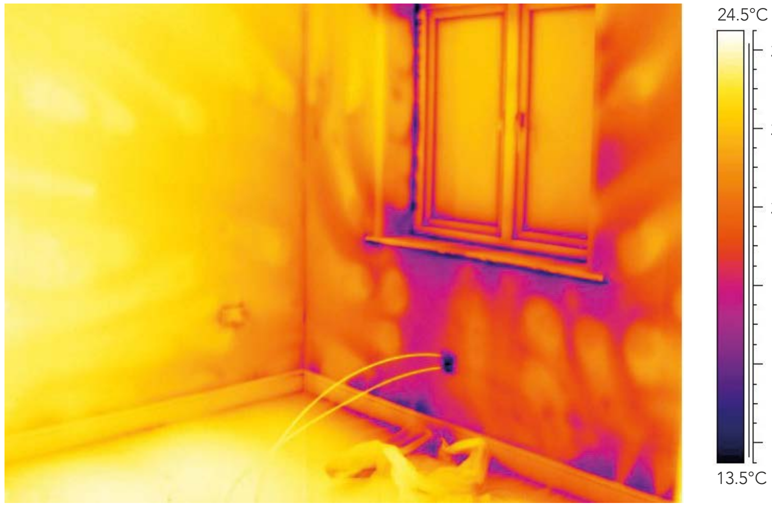
Thermographic image 9

Thermographic image 9: Good construction

The even colour across the wall around the window indicates that the window has been correctly installed to minimise heat loss.

Thermographic image 10: Potential fault

The darker areas around the window indicate a lower temperature. This indicates heat loss higher than normally expected that may have been caused by the incorrect installation of the window frame and sill and possibly, a problem with closing the cavity around the window opening.



Thermographic image 10

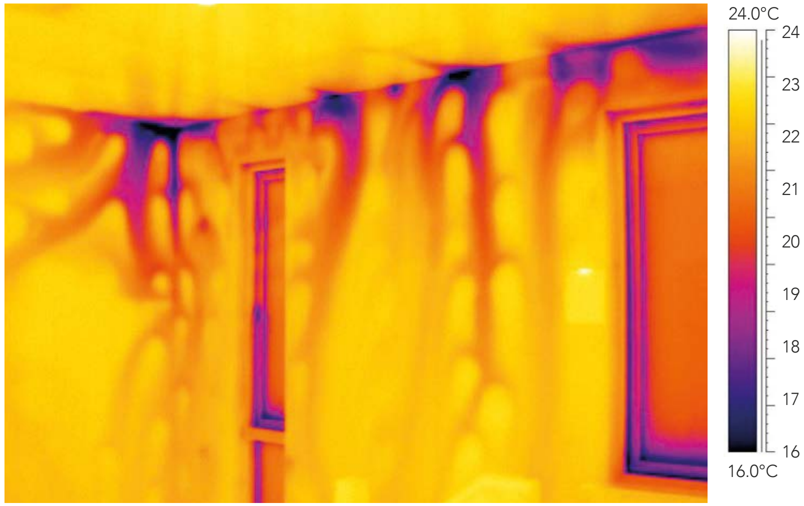
4.6 Dry lining

Thermographic image 11

Thermographic image 11: Good construction

The even colour across the walls indicates that the thermal insulation has been installed to a satisfactory standard and that the perimeter of the plasterboard dry lining has been sealed, resulting in low levels of heat loss across the whole wall area.

It is normal to detect slightly lower temperatures at external corners of walls, both horizontal and vertical; this is caused by slightly higher level of heat loss expected in these locations and is not a sign of a problem.

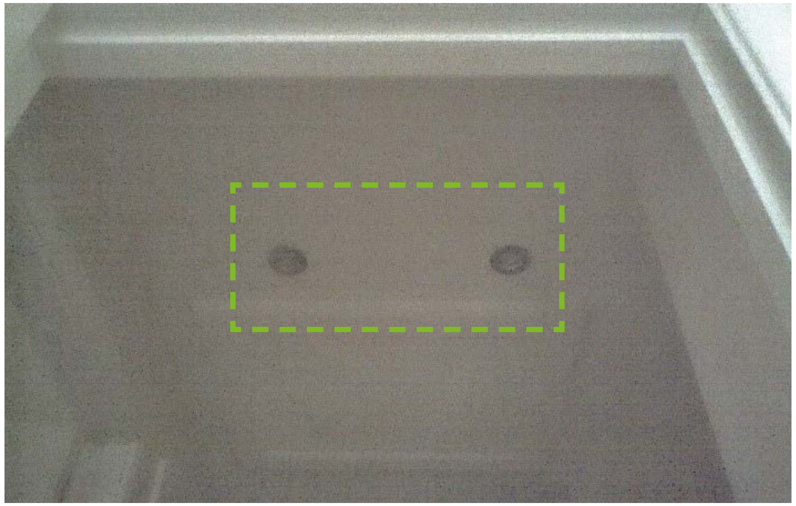


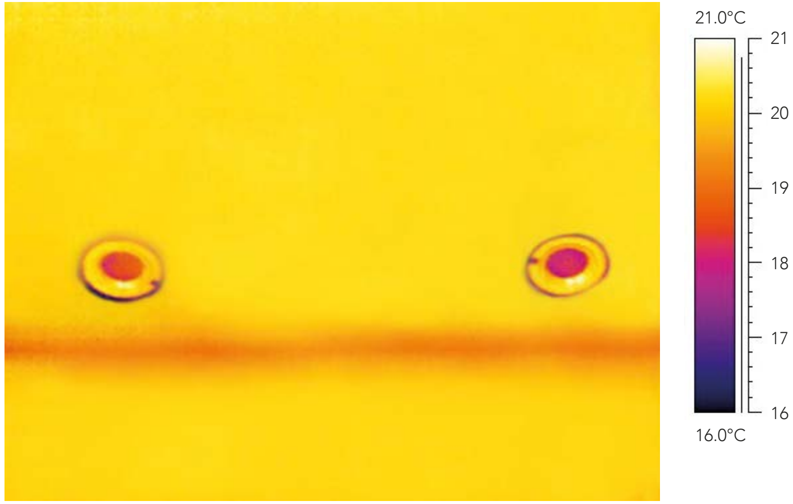
Thermographic image 12

Thermographic image 12: Potential fault

The dark areas along the top of the wall, together with the darker vertical 'plumes', suggest that air is moving behind the plasterboard dry lining resulting in the lower temperatures being detected. These patterns of vertical air movement may be due to inadequate sealing along the top of the dry lining. This may not necessarily be a fault (affecting thermal performance) that requires any remedial work.

4.7 Ceiling – downlighters



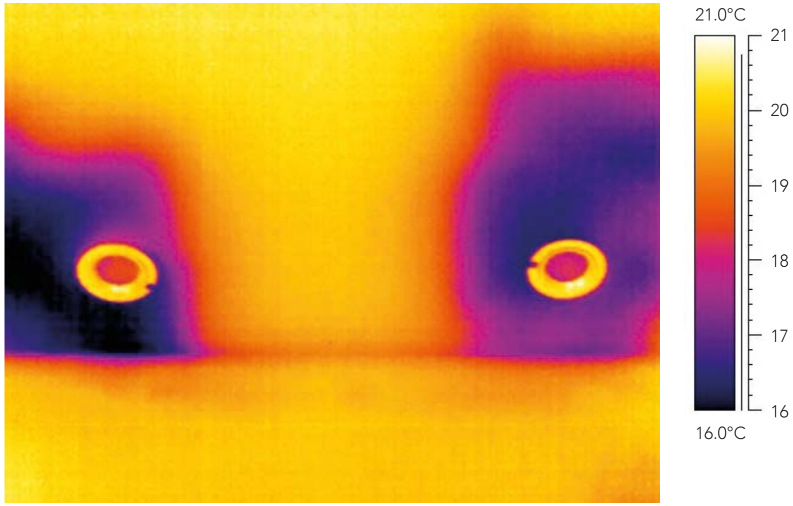


Thermographic image 13

Thermographic image 13: Good construction

The even yellow colour across the ceiling indicates that the loft insulation appears to be have been installed uniformly and has been cut neatly to fit around the downlighters (the red band indicates the slightly cooler frame of the loft hatch which is expected).

N.B. Dependent on the type of light fitting and the level of heat produced, it may be necessary for a small gap to be left in the loft insulation to allow for ventilation.

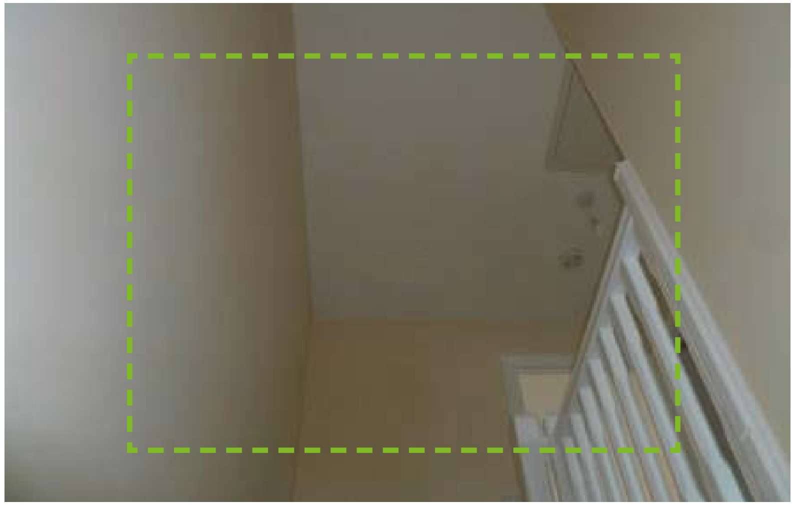


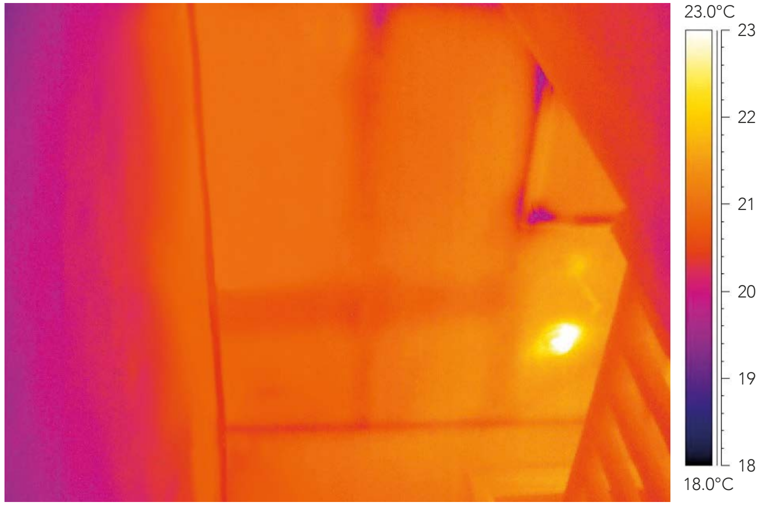
Thermographic image 14

Thermographic image 14: Potential fault

The darker colours show large areas of lower temperature around the downlighters, indicating higher localised heat loss. The regular shape suggests that insulation around them is missing, has been disrupted or does not fully fill the space between adjacent joists – even allowing for ventilation of the light fitting.

4.8 Ceiling – at junction with gable wall

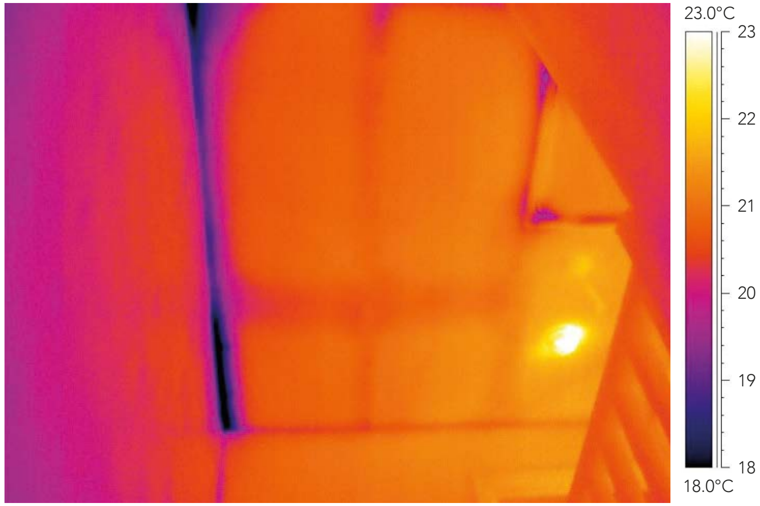




Thermographic image 15

Thermographic image 15: Good construction

The consistency of the orange colour of the ceiling suggests that the loft insulation has been installed to a satisfactory standard across the whole area and abuts with the gable wall. The regular pattern of slightly darker lines across the ceiling indicates the positions of the rafters and is perfectly normal.



Thermographic image 16

Thermographic image 16: Potential fault

The strip of dark blue demonstrates a lower temperature between the final rafter and the external gable wall. This suggests that thermal insulation is missing or has been poorly installed in this position, resulting in higher localised heat loss into the loft space.

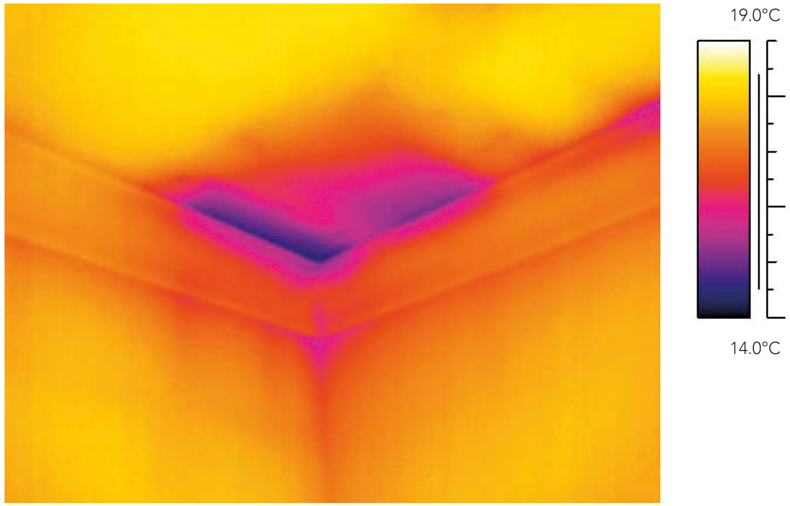
4.9 Ceiling – at junction with external walls

Thermographic image 17

Thermographic image 17: Good construction

These images show the ceiling of an upper floor at an external wall corner. The even yellow colours indicate the loft insulation has been installed to a satisfactory standard and is overlapping with the wall insulation.

The slightly lower temperatures around the wall and ceiling junction indicate the marginally higher level of heat loss expected in this location and is not a sign of a problem.

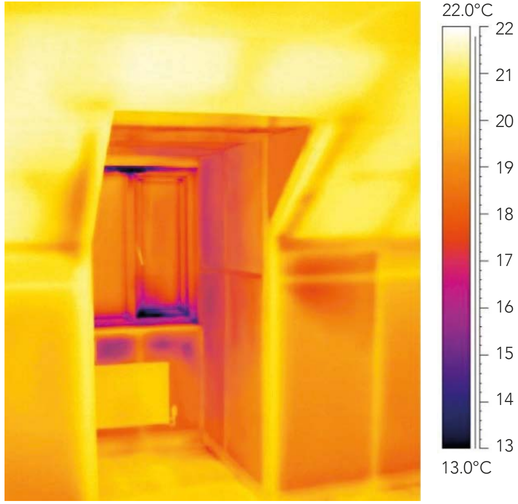


Thermographic image 18

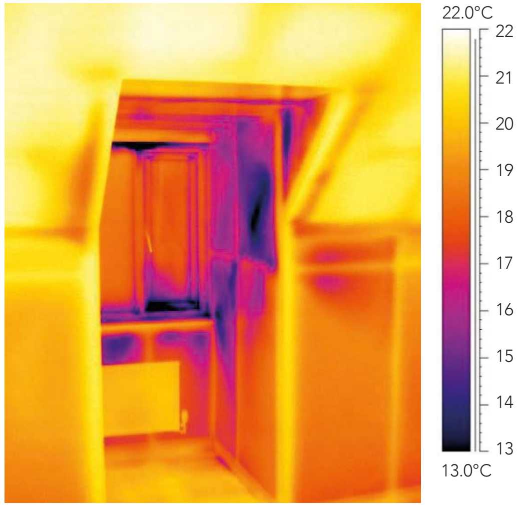
Thermographic image 18: Potential fault

The darker colours in the corner reveal an area at a lower temperature; this indicates higher localised heat loss, and the regular shape suggests that insulation above is either missing in the corner or has been installed to an unsatisfactory standard.

4.10 Dormer window



Thermographic image 19



Thermographic image 20

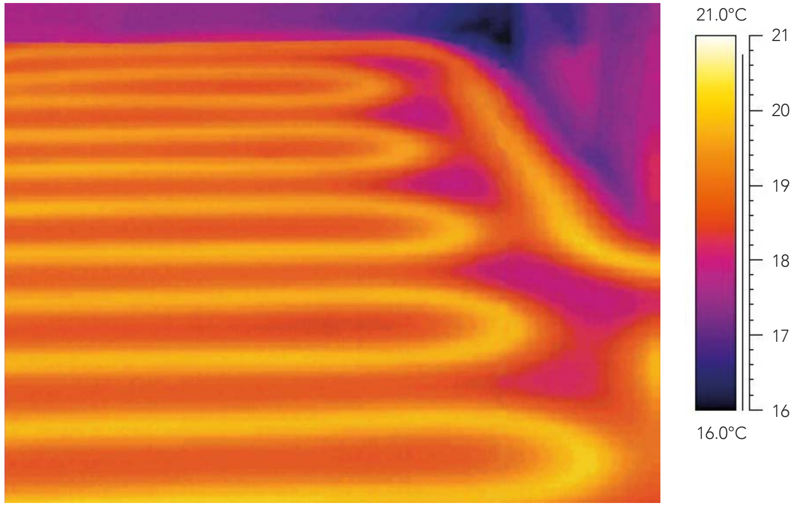
Thermographic image 19: Good construction

The even yellow and orange colours of the wall and ceiling around the dormer window indicate that the insulation has been installed to a good standard.

Thermographic image 20: Potential fault

The darker areas on the dormer 'cheek' wall to the right of the window and to the wall underneath the window indicate a lower surface temperature. This suggests that the insulation in these areas is missing, has not been fitted tightly or is of a different thickness or material, causing higher localised heat loss.

4.11 Underfloor heating



Thermographic image 21

Thermographic image 21: Good construction

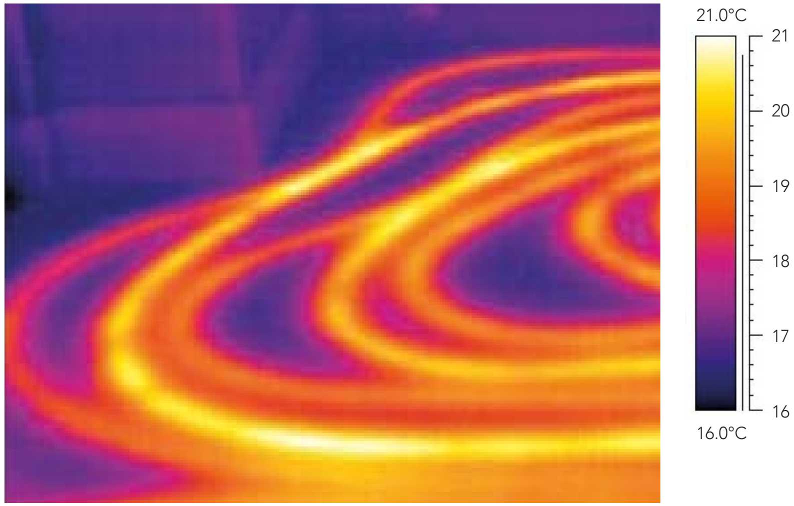
The underfloor heating pipework is equally spaced and laid to a regular pattern, resulting in an even temperature across the floor.

This indicates well-installed pipework, which should result in good internal comfort during the heating season.

Thermographic image 22: Potential fault

There is a very irregular pattern of pipework, with inconsistent spacing, overlaps and gaps.

This can result in a wide variation in temperatures across the floor area. The brightest areas may indicate excessive floor temperatures which could result in an irregular heating pattern and possibly damage to the screed. However, if the installed system is providing adequate heat to the property, remedial work may not be required to rectify the solution.



Thermographic image 22

5 Typical variations in thermal images

Thermal imaging can tend sometimes to suggest that heat loss is occurring due to a problem with the construction, however careful interpretation may suggest that the surface temperature in a given area is to be expected. The following images are examples of this, where the raised or lowered surface temperature is not indicative of a fault.

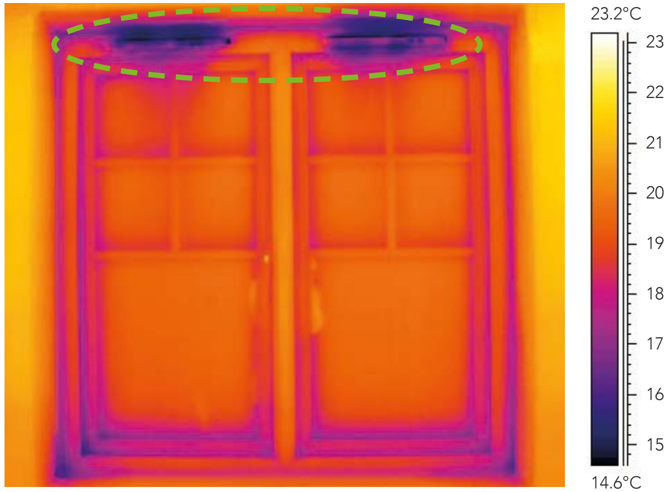
Thermographic image 23: Window trickle ventilators

The two darker areas highlighted reveal a lower temperature around the trickle ventilators fitted into the window heads.

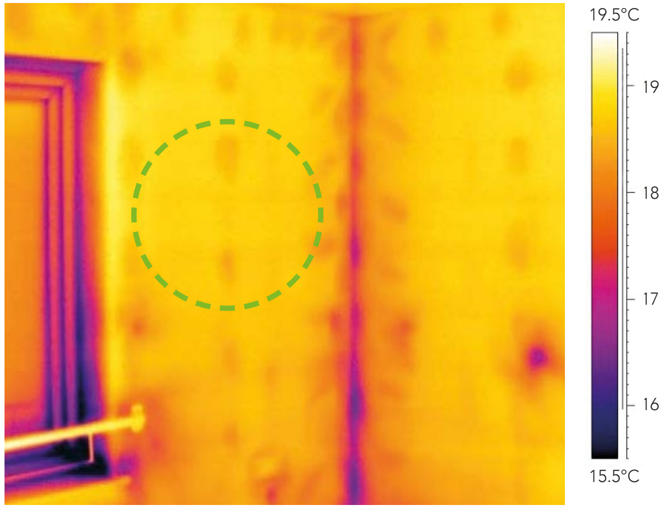
When closed their surface temperature may be slightly lower than the window frame and when open, they will allow cooler air to be drawn into the room.

Thermographic image 24: Plasterboard dabs

The slightly darker patches in a regular pattern show the adhesive dabs used to fix the plasterboard dry lining to the wall.



Thermographic image 23



Thermographic image 24

External thermographic images

External thermographic images may be less accurate due to weather conditions at the time of the survey.

Thermographic image 25: Front wall

The bright colour of the roof tiles appears to indicate excessive heat loss through the roof, suggesting that the loft insulation is either missing or has been installed to an unsatisfactory standard.
In fact, the higher surface temperature of the roof tiles is more likely to be explained by the loft space being heated up during the day and the heat being retained as the external temperature falls at night time.

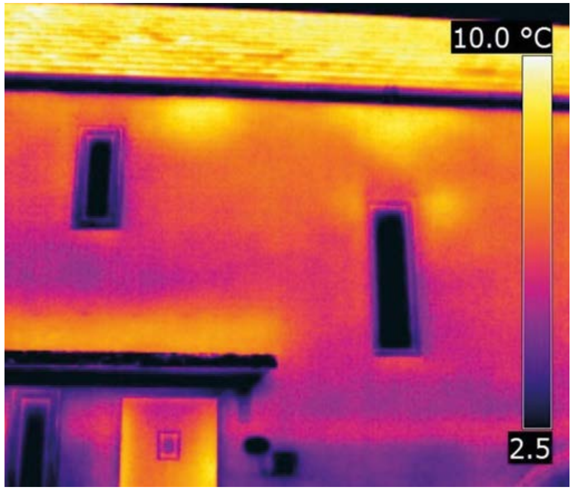
The bright yellow patch above the front door roof canopy appears to suggest that the cavity wall insulation is missing in this area, giving rise to heat loss, causing the external surface temperature to increase.
In fact, during the day, sunlight may have been reflected onto the wall by the roof canopy, causing the temperature increase.
The dark colour of the windows suggests the ambient external air temperature is cold and as glass is reflective it could be reflecting the sky temperature.

Thermographic image 26: Gable wall

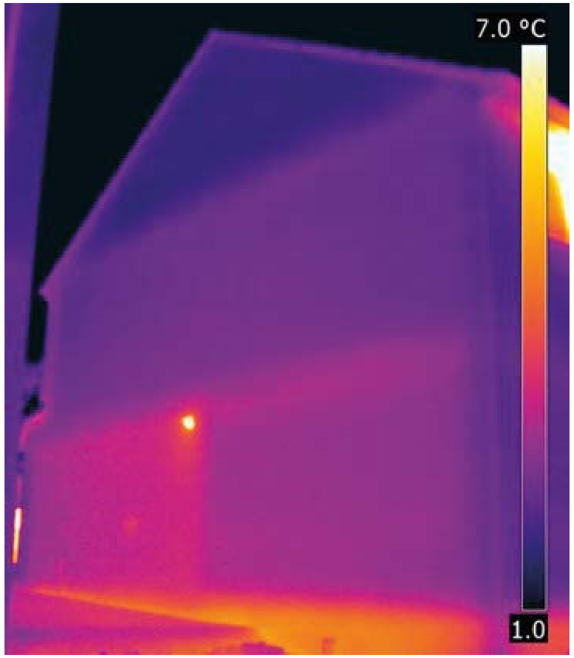
This house is full-fill cavity, masonry construction. The darker colour at the top indicates a loft space that has been well insulated to keep the heat within the habitable rooms.

The ground floor has a more orange colour to the left. This is because there is an integral garage. As this is not a habitable space it will be constructed differently. It will have the same level of insulation within the cavity walls, but the internal walls will, most likely, not be plastered. This may allow more air movement and therefore may contribute to heat loss.

The bright yellow dot suggests the position of a boiler flue from a boiler in the garage. The yellow/orange colour at the perimeter suggests that there may be missing insulation at the ground floor/wall junction.



Thermographic image 25



Thermographic image 26

Thermal imaging used with airtightness testing

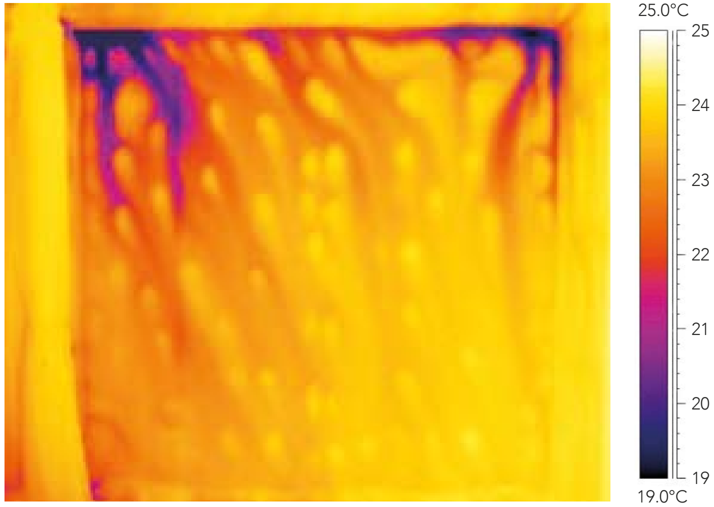
An air tightness test being carried out using a blower door kit

Thermal imaging can be used in conjunction with airtightness testing to help identify paths that would cause uncomfortable draughts or give rise to unwanted heat loss. The air tightness test is carried out at the same time as the thermographic survey is undertaken inside the home.

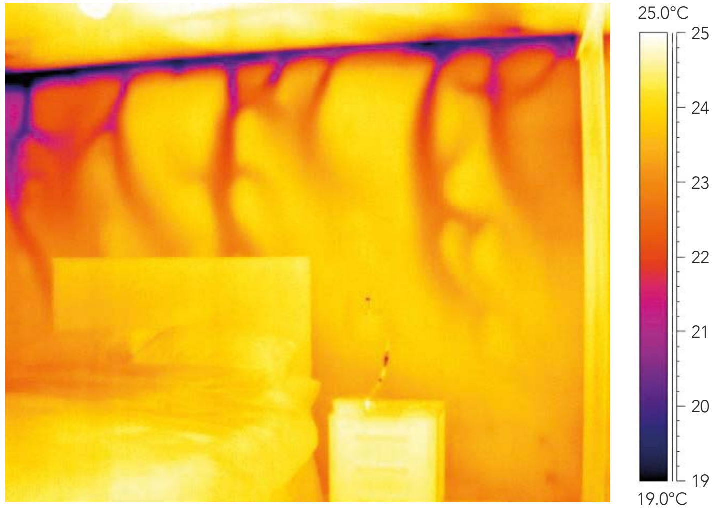
Building Regulations requires that all new dwellings achieve a minimum standard for air tightness, to avoid excessive energy use due to heat loss. To prove the air tightness standard of the dwelling, pressure tests on nominated properties are carried out. This involves temporarily fitting a blower door rig into an external door, and air is blown into – or sucked out of – the dwelling to create a pressure.

Even if air leakage paths are identified during airtightness testing - this is expected. If the home has passed the air leakage testing regime required by the Building Regulations, Approved Document F [2], then no further action is normally required.

The darker plumes on images 27 and 28 indicate noticeable air movement behind the plasterboard dry lining.



Thermographic image 27



Thermographic image 28

6 Ensuring a good thermal imaging survey

Thermal imaging standards requirements

Thermographic surveys should be undertaken in accordance with BS EN 13187:1999 [3] and BS EN ISO 6781 – 3:2015 [4].

The purpose and extent of the survey must be clear from the outset.

Thermographer qualifications

It is advisable that the specialist carrying out a thermal imaging survey is suitably qualified and have the following qualifications:

- A professional thermographer for building surveys should be qualified to ABBE Level 3 [5] in Building Thermography or have a Category 2 qualification in accordance with BS ISO 18436-7 [6] and a qualification in building technology
- Surveys may be conducted by people with a lower Level/ Category 1 qualification if their work is quality assured by a Category 2 thermographer.

Thermal imaging surveys should include:

- Site name and address
- Customer name
- Thermographer name, qualifications, contact details, equipment specification
- Survey objectives, date and time of survey
- Environmental conditions including external weather conditions and internal space temperatures
- Suitable imagery
- Conclusions and recommendations.

Types of Thermal imaging survey

External Surveys – thermal images taken of the outside surface of a heated building in cold weather can show defects such as thermal bridging, missing insulation and air leakage.

Internal surveys – thermal imaging taken inside a building can be more precise because there will be less interference from external weather conditions.

The thermal imaging survey generally reveals the quality of the building envelope in several areas:

1. The continuity of thermal insulation within the construction
2. The presence of 'non-repeating thermal bridges' which occurs at junctions between elements, such as a wall and floor or a window and wall
3. The occurrence of unwanted air leakage through gaps in the construction.

What to do if a potential fault is identified

Where the thermal image appears to be highlighting a fault, this should be raised with the construction team. They will be able to assess the impact of what is shown, and what its cause may be.

Dependant on what the potential fault reveals, the construction team will need to decide on the most suitable investigation method.

For example, where the potential fault suggests an area of missing or poorly installed insulation, it may be appropriate to open up areas of the wall to investigate further and undertake any necessary remedial works.

Beware!

Beware of thermographic surveys that have not been undertaken to a professional standard in accordance with good practice.

The most common issue found in reports is the inaccurate assessment of the impact of temperature difference highlighted in an image. This is often a result of not having paid sufficient attention to the temperature scale associated with the particular image – a large colour difference does not always mean a large temperature difference.

If you are unhappy with the report provided by the thermographer; if the report fails to meet the objectives, the first action to take is to go back to the thermographer and explain the issues you have. The thermographer may be able to amend the report, perhaps enhancing certain images to make an issue clearer, or adjust the temperature scale to make comparisons between temperatures easier.

In a few rare cases, it may be necessary to carry out the thermal imaging survey again, either because the environmental conditions at the time of the survey make the results unreliable, or they do not address the original needs requirements of the survey.

References

1. Building Regulations 2010, Approved Document C; Site preparation and resistance to contaminates and moisture. 2013. HM Government.
2. Building Regulations 2010, Approved Document F; Ventilation 2010. HM Government.
3. BS EN 13187:1999 Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method. British Standards Institute. 1999.
4. BS EN ISO 6781-3:2015 Performance of buildings. Detection of heat, air and moisture irregularities in buildings by infrared methods. Qualifications of equipment operators, data analysts and report writers. British Standards Institute. 2015.
5. ABBE Level 3 Certificate in Domestic Infrared Thermography Class 1 Operators. ABBE (Awarding Body for the Built Environment).
6. BS ISO 18436-7:2014 Condition monitoring and diagnostics of machines. Requirements for qualification and assessment of personnel. Thermography. British Standards Institute. 2014.

Further reading

Thermal Imaging of Buildings - a pocket guide, BSRIA Guide BG 72/2017.

Thermal Imaging of Building Fabric, BSRIA Guide BG 39/2011.

The NHBC Foundation

The **NHBC Foundation**, established in 2006, provides high quality research and practical guidance to support the house-building industry as it addresses the challenges of delivering 21st century new homes. To date we have published over 80 reports on a wide variety of topics, including the sustainability agenda, homeowner issues and risk management.

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