A BSRIA Guide

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Thermal Imaging of Building Fabric

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The contents of this guide

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1 Introduction – what is thermal imaging?

Thermal Imaging has many applications in the construction industry from heat loss and moisture detection to electrical inspection. It provides a quick assessment method for problems that involve heat generation and transfer. It generates images that clearly locate hot and cold areas.

This Guide concentrates on thermal imaging for building fabric insulation. It aims to help people involved in constructing, owning and operating buildings to obtain the thermal imaging they need when they need it and to have a basic understanding of the information that can be obtained from thermal images.

Infrared (meaning below red) is the name given to the part of the electromagnetic spectrum just beyond the red end of the visible spectrum. Infrared (IR) radiation is emitted by all objects proportional to the fourth power of absolute temperature. It travels through space in similar fashion to visible light but at longer wavelengths, approximately 0.7 microns to 1000 microns (µm). The two wavelength bands used for thermal imaging, shortwave (SW) and longwave (LW) are shown in Figure 1 in relation to other electromagnetic wavelengths in common use. The amount and wavelength of infrared emitted by an object generally varies with its surface temperature. The efficiency of the surface in radiating infrared (the emissivity) also affects the amount of IR radiation emitted. The transmissivity of the air or other material between the source and the observer affects how much infrared radiation is received by the observer or a surface exposed to the radiation.

Thermal imaging produces a picture that maps the intensity of IR radiation across the field of view. Because of the relationship between intensity of radiation and temperature this can be converted to a map of apparent temperature based on a number of assumptions that are explained later in this Guide. The use of temperature calibrated thermal images is generally referred to as 'thermography' a person who performs the task as a 'thermographer' and the images are often referred to as 'thermograms'.

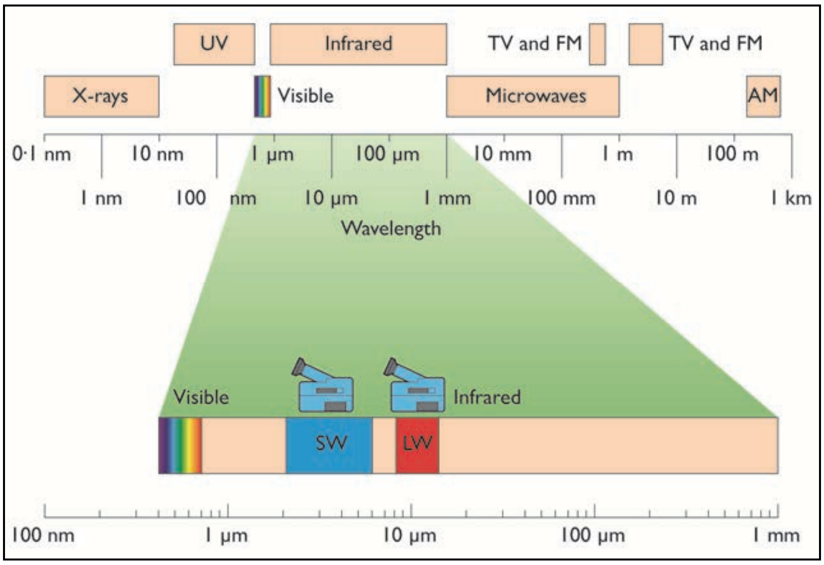

Figure 1: The electromagnetic spectrum

2 The need for thermal imaging

Thermal imaging is the best way to assess continuity of insulation once the building fabric is complete. It is also a very effective method of locating air leakage paths in a completed building. This section discusses the legal requirements in Building Regulations and also the availability of BREEAM credits.

Regulations

The focus here is on the *2010 England & Wales Building Regulations* and supporting guidance, specifically *Part L (Conservation of Fuel and Power).* Similar regulations and supporting guidance exist in *Scotland (Section 6)* and *Northern Ireland (Part F)*. It should be noted that Wales will have separate *Building Regulations* from England from the end of 2011, and that separate supporting guidance is expected to be published in 2013. At the time of writing this publication, it was not known what form these would take.

Building Regulations for England and Wales require that reasonable provision shall be made for the conservation of fuel and power in buildings by… limiting heat gains and losses… through thermal elements and other parts of the building fabric.

This requirement is supported by guidance in four Approved Documents:

- *Approved Document L1A - New Dwellings*
- *Approved Document L1B – Work in Existing Dwellings*
- *Approved Document L2A - New Non-Dwellings*
- *Approved Document L2B – Work in Existing Non-Dwellings*

All four Approved Documents provide the following guidance:

"The building fabric should be constructed so that there are no reasonably avoidable thermal bridges in the insulation layers caused by gaps within the various elements, at the joints between elements, and at the edges of elements such as those around window and door openings".

In the case of new buildings, linear transmittance values for the specific construction details used are fed into the CO_2 emissions calculations required by *Building Regulations*. Preference is given to accredited construction details by imposing a penalty in the CO_2 emissions calculations for non-accredited details. Also in the case of new buildings, it is a requirement to carry out airtightness testing, and the measured air permeability is fed into the CO_2 emissions calculations.

In the case of existing buildings, the guidance on continuity of insulation only applies where new thermal elements (for example walls, floors, and roofs.) are provided, for example when an extension is built. There are no requirements for CO_2 emissions calculations or airtightness testing on existing buildings.

6 Different approaches to the survey

The method used for a thermographic survey will depend on the objective of the survey and the features of the building. Experienced thermographers will choose the most appropriate method for each survey depending on site conditions and requirements of the specification or Regulations.

6.1 Qualitative or quantitative

Most thermographic surveys are qualitative, they show locations of anomalies that are abnormal thermal features, and do not attempt to quantify the heat loss from the anomaly or building as a whole. It is possible to quantify some aspects of the survey, such as condensation risk or surface areas of defects and to make approximate estimates of heat loss, but these methods are less often used.

6.2 External surveys

External surveys give a useful overview of a building and if they include a large enough area they can be useful for comparing one part of a building with another. If the internal temperature is known in each part of the building this can allow useful comparison of thermal performance between new and old parts of the structure. In the UK it is unusual to find suitable conditions in the summer months of May to September.

Greater temperature differences across the fabric and lower outside wind speeds next to the surface give best results for thermal imaging. For practical purposes the temperature difference should be at least 10°C, there should be no precipitation or mist and the wind speed for external imaging must be no more than 5 m/s. There should also be no very hot objects, like the sun, and no very cold objects, like a clear sky, which can be as cold as -50°C in the hemisphere facing the surface being imaged because these may be reflected by the surface, affecting the apparent temperature. They also affect the real temperature of surfaces by radiative heat transfer. Best results are usually obtained on cold, cloudy, dry still winter nights.

Since wind speeds exceed 5m/s and rain or mist occur for much of the winter when temperature differences are adequate, internal surveys are often more effective than external surveys in identifying anomalies. External surveys can be spoiled by solar radiation and clear skies. At night there may be a drop in the apparent surface temperature due to radiation to the sky. External thermography is fraught with problems that can make the results difficult to interpret. Figure 5 shows differences between two semi-detached houses, but it is difficult to tell whether the differences are caused by different internal temperatures, loft conversions, air leakage, double glazing or reflections.

8 Supplementary testing

Thermography is often used in conjunction with other tests to demonstrate additional properties of the structure and confirm the cause of anomalies that have been identified.

8.1 Heat flux

Estimation of thermal conductance, U value, by infrared thermography alone is only practical when precise environmental conditions are known and wind speed is minimal. More accurate results can be obtained by using a heat flux measurement device in at least one location. Thermography can then be used to compare other areas with this known thermal performance.

Most heat flux sensors comprise a disc of a material with a small thermal resistance about 5mm thick and very accurate temperature sensors to measure the temperature difference across it. The result can be converted into heat flow in W/m^2 because the resistance of the pad is accurately known. Temperature inside and outside the building have to be measured accurately and the measurements usually continued for ten days so that an average can be obtained to take account of variations in temperature and thermal storage.

8.2 Cavity inspection

Endoscopes (or borescopes) allow visual inspection, through a small hole, of gaps in insulation and air leakage pathways. As this method usually involves drilling holes in the fabric it has limited application in new buildings, but is often used to check where remedial work is suggested.

8.3 Moisture content

A hand-held moisture meter can be very useful in diagnosing thermal anomalies. Masonry walls are often found to have variable moisture contents leading to thermal patterns not directly related to insulation placement. Wet thermal insulation will also give thermal anomalies and can be confirmed with a moisture meter if the insulation is accessible.

8.4 Airtightness

Airtightness testing is a requirement of Part L of the Building Regulations. It gives a measurement of the air leakage at a pressure difference of 50 Pa and there are limits of acceptability in the Approved Documents. It accurately quantifies, but gives no location of air leakage. Thermography can locate the air leakage, but not quantify it so the two are complementary. Air pressurisation using the same blower door can be useful even if the building passes the airtightness test.

8.5 Coheating

The concept of coheating has been introduced to testing of dwellings because it allows a holistic approach to measuring the complete heating energy use. It usually involves heating a completed but unoccupied dwelling to a fixed temperature, at least 10 °C above the ambient temperature and measuring how much energy is required to maintain this temperature for an extended period, typically a week. Weather conditions are also measured so that corrections can be made to the heat input to predict how much heat would be required in standard conditions. Thermal imaging is used to show areas of heat loss and to demonstrate that a constant temperature is maintained across the whole house.