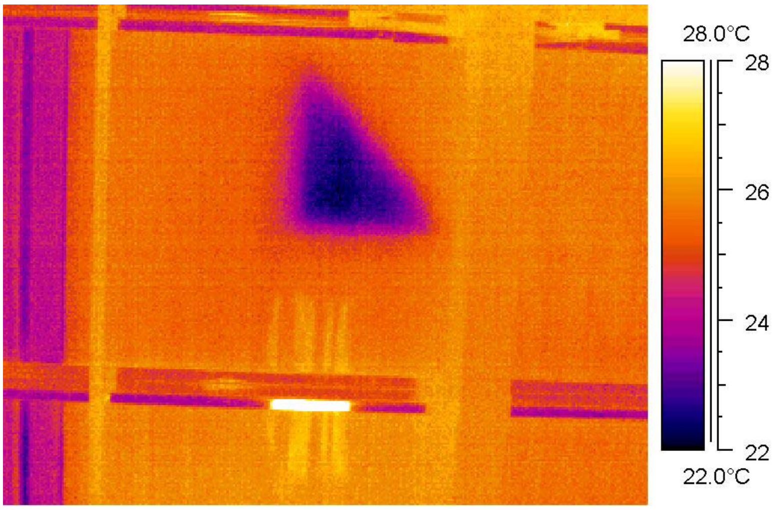
Code of Practice

Number 2



Assessing thermal bridging and insulation continuity

Credits

This Code of Practice was produced by a working group including expert thermographers, building contractors and construction product manufacturers. Additional consultation with other persons and organisations results in this document being widely accepted by all sides of industry.

Working Group

Ray Faulkner	iRed Ltd
Colin Pearson	BSRIA
Norman Walker	AWE
Stewart Little	IRT Surveys

Consultation with:
Building Control
Stuart Borland - Building Sciences
B&Q Properties

UK Thermography Association,
BINDT, 1 Spencer Parade, Northampton NN1 5AA, www.ukta.org

Purpose

This document sets out a method for determining pass or fail criteria of building thermal insulation based on quantitative and qualitative thermographic survey data.

Over the last few years the equipment, applications, software and understanding connected with thermography have all developed at an astonishing rate. As the technology has gradually become integrated into mainstream practices, a corresponding demand for application guides, standards and thermographer training has arisen.

The UKTA is publishing this Code of Practice in order to establish a consistent approach to quantifying the results for a 'Continuity of Thermal Insulation' examination. It is intended that specifiers should refer to this document as a guide to satisfying the requirement in the Building Regulations for continuity of thermal insulation as the procedure will enable the qualified thermographer to issue a pass or fail report.

[1] …………..

Background information

Thermography can detect surface temperature variations as small as 0.1K and graphic images can be produced that visibly illustrate the distribution of temperature variations on building surfaces.

Variations in the thermal properties of building structures, such as poorly fitted or missing sections of insulation, cause variations in surface temperature on both sides of the structure. They are therefore visible to the thermographer. However, many other factors such as local heat sources, reflections and air leakage can also cause surface temperature variations.

The professional judgement of the thermographer is usually required to differentiate between real faults and other sources of temperature variation. Increasingly, thermographers are asked to justify their assessment of building structures and, in the absence of adequate guidance, it can be difficult to set definite levels for acceptable or unacceptable variation in temperature.

The current Standard for thermal imaging of building fabric in the UK is BS EN 13187:1999[1]. However, this leaves interpretation of the thermal image to the professional expertise of the thermographer and provides little guidance on the demarcation between acceptable and unacceptable variations. Guidance on the appearance of a range of thermal anomalies can be found in BINDT Guides to thermal imaging[2]

Requirements
A thermographic survey to demonstrate continuity of thermal insulation, areas of thermal bridging and compliance with Building Regulations needs to:

1. Show thermal anomalies
2. Differentiate between real thermal anomalies, where temperature differences are caused by deficiencies in thermal insulation, and those that occur through confounding factors such as localised differences in air movement, reflection and emissivity
3. Quantify affected areas in relation to the total insulated areas
4. State whether the anomalies and the building thermal insulation as a whole are acceptable

Quantitative appraisal of thermal anomalies

Any thermographic survey can show differences in apparent temperature of areas within the field of view. To be useful, a thermographic survey must systematically detect all the apparent defects and assess them against criteria agreed between the thermographer and the client. It must reliably discount those anomalies that are not real defects, evaluate those that are real defects and report the results to the client.

This document sets out an approach to:

1. Selecting the critical temperature parameter
2. Selecting maximum acceptable defect area
3. Measuring surface temperature difference caused by the defect
4. Measuring area of the defects

Selecting of critical temperature parameter

The BRE Information Paper IP17/01[3] sets useful guidance on minimum acceptable internal surface temperatures and appropriate values of critical surface temperature factor, f_{CRsi}. The use of a surface temperature factor allows surveys under any thermal conditions to show areas where there is a risk of condensation or mould growth under design conditions.

The actual surface temperature will depend greatly on the temperatures inside and outside at the time of the survey but a 'surface temperature factor (f_{Rsi})' has been devised that is independent of the absolute conditions. It is a ratio of temperature drop across the building fabric to the total temperature drop between inside and outside air.

$$f_{Rsi} = T_{si} – T_e / T_i - T_e$$

T_{si} = internal surface temperature
T_e = external air temperature
T_i = internal air temperature

Typically a value for f_{CRsi} would be 0.75 to prevent mould growth in dwellings or 0.9 for swimming pools and other high humidity areas. The recommended value for f_{CRsi} in offices and retail premises is 0.5, but in many cases a more stringent value of 0.75 is used to ensure higher standards of occupant comfort.

A similar approach can be used for an external survey. Although, a defect will usually produce a smaller temperature difference on the outside of a wall exposed to external air movement, missing or defective insulation can often be more readily identified.

For external surveys

$$f_{Rse} = T_{se} – T_i / T_i - T_e$$

T_{se} = internal surface temperature
T_e = external air temperature
T_i = internal air temperature

For external surveys the critical external surface temperature factor should be taken as 0.9 for most buildings. This is higher than the internal surface temperature factor because the external surface layer resistance is typically 0.05 m²K/W and the internal surface layer resistance is typically 0.12 m²K/W

Selecting maximum acceptable defect area
The allowable area of defect is a quality control issue. It can be argued that there should be no area on which condensation, mould growth or defective insulation will occur and any such anomalies should be included in the report. However, a commonly used value of 0.1% of the building exposed surface area is generally accepted as the maximum combined defect area allowable to comply with the Building Regulations. This represents one square metre in every thousand.

Measuring Surface temperature
Measurement of surface temperature is a relatively straightforward function of the infrared imaging system, provided that emissivity and background temperatures are properly taken into account.

Measuring area of the defects
Measurement of area can be performed by pixel counting in the thermal analysis software provided that the angle of view is known and the distance to the object is measured and recorded at the time of the survey.

Buildings consist of numerous construction features that are not conducive to thermal insulation surveys these are:

1. Windows (although qualitative comparisons within a building may be useful)
2. Rooflights
3. Luminaries
4. Heat emitters
5. Cooling equipment
6. Service pipes
7. Electrical conductors

Additionally, anomalies that create apparent temperature changes may occur when hot or cold services nearby are reflected. Such anomalies may be discounted but this will require the operator changing the angle of view.

Conditions and equipment

To achieve best results from a thermal insulation survey it is important to consider the environmental conditions and to use the most appropriate thermographic technique for the task.

Thermal anomalies will only present themselves to the thermographer where temperature differences exist and environmental phenomena are accounted for. As a minimum, the following conditions should be complied with.

- Temperature difference across the building fabric to be greater than 10°C.
- Internal air to ambient air temperature difference to be greater than 5°C for the last twenty four hours before survey.
- External air temperature to be within +/- 3°C for duration of survey and for the previous hour.
- External air temperature to be within +/- 10°C for the preceding twenty-four hours.

In addition, external surveys should also comply with the following

- Necessary surfaces free from direct solar radiation for at least one hour.
- No precipitation either just prior to or during the survey.
- Ensure all building surfaces to be inspected are dry.
- Wind speed to be less than 10 metres / second.

As well as temperature, there are other environmental conditions that should also be taken into account when planning a thermographic building survey. External inspections for example, may be influenced by radiation emissions and reflections from adjacent buildings or a cold clear sky, and even more significantly the influence the sun may have on surface temperatures.

Additionally, where background temperatures differ from air temperatures either internally or externally by more than 5K, then background temperatures should be measured on all effected surfaces to allow surface temperature to be measured with sufficient accuracy.

Infrared cameras for this type of survey must have sufficiently high resolution to detect small anomalies at a reasonable distance. Typically cameras use detectors with 320 x 240 (=76,800) pixels. The total pixel count should be at least 40,000 for good results, and the camera should have a temperature sensitivity of at least 0.2°C (usually specified as NETD or noise equivalent temperature difference) so that surface anomalies with small temperature differences can be detected.

Survey and analysis

The following provides some operational guidance to the thermographer.

The survey must collect sufficient thermographic information to demonstrate that all surfaces have been inspected so that all thermal anomalies are reported and evaluated.

Images of anomalies must be captured in such a way that they are suitable for analysis:

1. The image is square to any features of the wall or roof.
2. The viewing angle is nearly perpendicular to the surface being imaged.
3. Interfering sources of infrared radiation such as lights, heat emitters, electric conductors, reflective elements are minimised

Additional data must be collected, as with any thermographic survey including:

1. Internal temperature in the region of the anomaly.
2. External temperature in the region of the anomaly.
3. Emissivity of the surface.
4. Background temperature.
5. Distance from the surface.

The method of analysis will depend somewhat on analysis software used, but the key stages are as follows:

1. Produce an image of each anomaly or cluster of anomalies.
2. Use a software analysis tool to enclose the anomalous area within the image, taking care not to include construction details that are to be excluded.
3. Calculate the threshold temperature for the image using the appropriate critical surface temperature factor. This may be automated in the analysis software.
4. Calculate the area below the threshold temperature for internal surveys or above the threshold temperature for external surveys. This is the defect area. Some anomalies that appeared to be defects at the time of the survey may not show defect areas at this stage.
5. Add the defect areas from all the images, ΣA_d
6. Calculate the total area of exposed building fabric. This is the surface area of all the walls and roof. It is conventional to use the surface area associated with the survey type; internal survey, then internal surface area. For a simple shape building this is calculated from overall width, length and height.

$$A_t = (2h(L+w)) + (Lw)$$

7. Identify the critical defect area, A_c.
   This Provisionally this is set at one thousandth or 0.1%of the total surface area.

$$A_c = A_t/1000$$

8. If $\Sigma A_d < A_c$ the building as a whole can be considered to have 'reasonably continuous' insulation.

Training and Certification

With the extensive availability, relative cheapness and greater sophistication of thermal imaging cameras on the market today, the need for properly trained and experienced thermographers has never been more prevalent. However, it is recognised that the only approved academic certification process in the UK is still in its infancy and will take some time for the expected number of required thermographers to become fully trained.

In general, it would be expected that a thermographer be qualified to PCN Level2 with civil applications endorsement or equivalent. As an interim, membership of a recognised thermographic trade organisation and a minimum of two years demonstrable experience may be accepted as suitable experience.

Reporting

Reports should comply with customers requirements and as a minimum include the information required by BSEN 13187. The following data is normally required so that survey can be repeated following remedial action.

1. Background to the objective and principles of the test
2. Location, orientation, date and time of survey
3. A unique identifying reference
4. Thermographer's name and qualifications
5. Type of construction
6. Weather conditions, wind speed and direction, last precipitation, sunshine, degree of cloud cover.
7. Ambient temperatures inside and outside before, at the beginning of the survey and the time of each image. Air temperature and radiant temperature should be recorded
8. Statement of any deviation from relevant test requirements
9. Equipment used, last calibration date, any known defects.
10. Name, affiliation and qualifications of tester
11. Type, extent and position of each observed defect
12. Results of any supplementary measurements and investigations
13. Reports should be indexed and archived by thermographers

Considerations and limitations

The choice between internal and external surveys will depend on:

- Access to the surface *Buildings where both the internal and the external surfaces are obscured, eg by false ceilings racking or materials stacked against walls may not be amenable to this type of survey.*
- Location of the thermal insulation. *Surveys are usually more effective from the side nearest to the thermal insulation*
- Location of heavyweight materials *Surveys are usually less effective from the side nearest to the heavyweight material*
- The purpose of the survey. *If the survey aims to show risk of condensation and mould growth it should be internal*
- Location of Glass, bare metal or other materials that may be highly reflective *Surveys are usually less effective on highly reflective surfaces*

References

[1] BS EN 13187:1999, Thermal Performance of buildings – Qualitative detection of thermal properties in building envelopes – Infrared method (ISO 6781:1983 modified)
[2] Infrared Thermography Handbook; Volume 1, Principles and Practice, Norman Walker, ISBN 0903132338, Volume 2, Applications, A N Nowicki, ISBN 090313232X, BINDT, 2005.
[3] Information Paper IP17/01, Assessing the effects of thermal bridging at junctions and around openings. Tim Ward, BRE, 2001
[4] Information Paper IP17/01, Assessing the effects of thermal bridging at junctions and around openings. Tim Ward, BRE, 2001