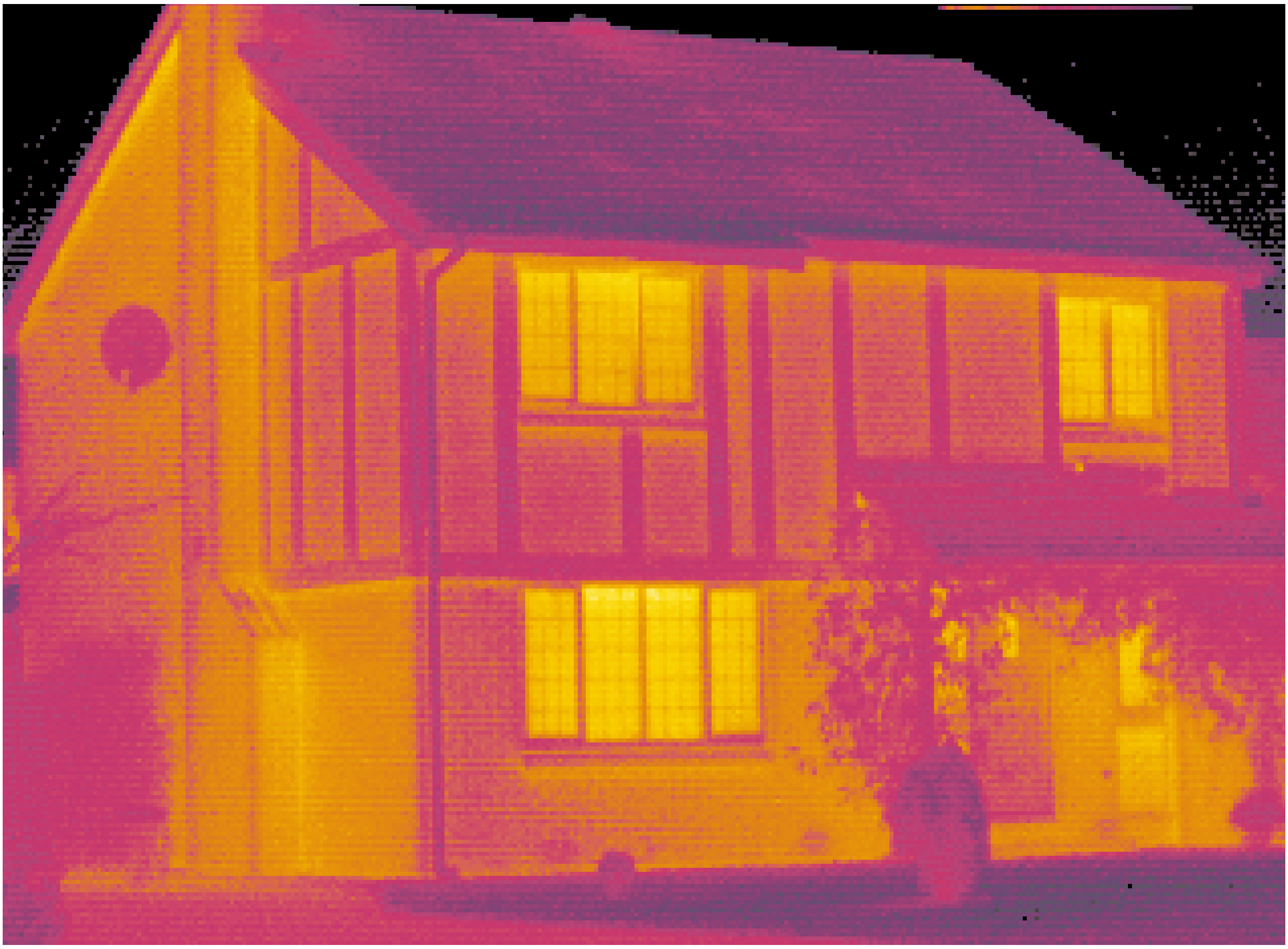
GENERAL INFORMATION REPORT 64

Post-construction testing

– a professional's guide to testing housing for energy efficiency



ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

GENERAL INFORMATION REPORT 64

CONTENTS

1 INTRODUCTION

Improved standards of thermal insulation in new and refurbished dwellings, coupled with a wider range of construction methods, have made the performance of the building envelope a key component in achieving energy efficiency. It is essential that energy efficiency measures are detailed and installed correctly if the completed house is to achieve its intended performance. As work proceeds, defects are rapidly covered up and become hidden within the depth of the structure. This can lead to increased running costs, discomfort to the occupants from draughts, and deterioration of the building fabric due to the presence of moisture.

This Report is for anyone trying to improve the performance of new and upgraded housing and is, therefore, suitable for designers, contractors and surveyors alike. Published as part of the Government's Energy Efficiency Best Practice programme, it describes some of the available tests, their advantages and, where appropriate, gives guidance on specification.

References and recommended further reading are listed on page 16.

TEST METHODS

Physical examination causes disruption and can cause more extensive damage to the structure than necessary. Alternatively, there are a number of non-destructive testing (NDT) techniques and devices available to assist in the assessment of energy efficiency measures. These range from very simple hand-held devices to more complex thermal imaging assessments.

The principal techniques are:

- thermal imaging
- fan pressurisation
- glazing systems identification
- borescope inspection.

There are other tests available, which are either more complex or primarily intended for assessing other aspects of performance, including:

- in situ measurement of thermal transmittance (U-value)
- fabric heat losses
- moisture measurement
- ultrasonic scanning
- radar examination.

Discussion with acknowledged experts to determine the suitability of a proposed technique is essential, particularly as some of the more complex techniques require specialist knowledge and experience to interpret the results. While the interpretation of the results may have a degree of uncertainty associated with it, limited physical examination is often all that is needed to confirm the findings or calibrate the results.

A summary of these tests is provided in figure 1.

INTRODUCTION

Figure 1 Summary of test methods covered in this Report

Test method	Applications	Complexity	Cost range
Thermography	Thermal performance Missing insulation Thermal bridging Comparative assessment	3	£££
Fan pressurisation testing	Measurement of airtightness Identification of air leakage routes	2	£
Glazing system identification	Identification of installed glazing	1	£
Remote visual inspection	Identification of construction details Confirmation of survey results	2	££
In-situ U-value measurement	Measurement of rate of heat flow through construction	3	£££
Assessment of fabric heat losses	Assessment of specific heat loss from building	3	£££
Moisture measurement	Assessment of moisture content of building materials	1	£
Ultrasonic scanning	Identification of defects within construction	3	£££
Radar	Identification of defects within construction	3	£££

NOTES

Complexity of the test or analysis of the results is indicated by a number.

1 Indicates a test that can be carried out by a competent person with knowledge of construction methods and materials, such as a building surveyor.

2 Indicates that the test can be carried out by a competent person with knowledge of construction methods and materials, but specialist training will be required in the use of the equipment and interpretation of the results.

3 Indicates a need for specialist experience and knowledge of building physics to successfully carry out the test and interpret the results.

The costs related to the simpler techniques (glazing system identification and moisture measurement) are associated with the purchase or hire of the equipment and generally fall below £500. The costs associated with the more complex techniques will be determined by the extent of data analyses required and ease of carrying out the inspection. As a general guide the costs have been increased in £500 steps with no upper limit.

2 THERMOGRAPHY

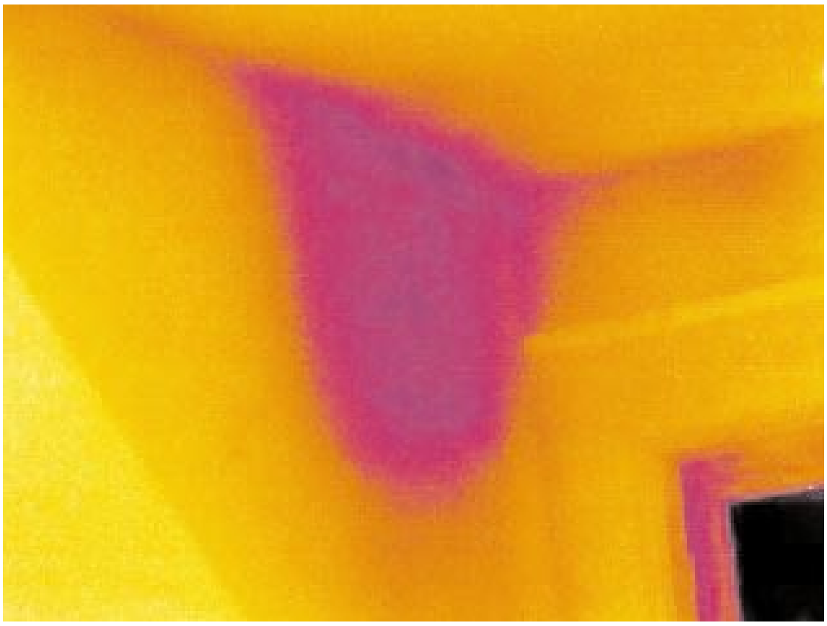


Figure 2 Thermal pattern due to missing insulation, viewed from the interior

Thermal imaging, or thermography, allows the pattern of heat losses from a building's surface to be visualised and quantified. Areas of unexpectedly high heat loss can be quickly located and, with a knowledge of the building's construction, possible causes suggested. The technique offers a number of advantages:

- rapid scanning of large areas
- an instantaneous picture of heat loss allowing a quick assessment of defects
- an accurate, non-contact method of surface temperature measurement.

Surveys can be undertaken to investigate four aspects of the building envelope.

- To assess the workmanship in the installation of the thermal insulation to the building. This may be of new build or of a retrofit measure, such as the installation of injected cavity wall insulation where the completeness of the cavity fill needs to be established.
- To investigate a failure in the thermal performance of the building envelope. This may be associated with the ingress of damp to the building and the subsequent loss of performance from the insulation, or it may be associated with air leakage through the building envelope.
- To assess the extent and impact of thermal bridging.
- To compare the performance of a building before and after refurbishment.

THE THERMOGRAPHIC TECHNIQUE

All surfaces above absolute zero (-273ºC) exchange radiant energy with their surroundings. Some of the radiation will be emitted directly by the surface and some will be transmitted or reflected. The total quantity of radiation emitted is mainly a function of the surface temperature and the emissivity* of the surface. The infrared scanner detects this radiation, converts it into an electrical signal and displays the result as an image. Lightweight and portable systems have been developed with a range of lenses to give different fields of view.

The instantaneous thermal image produced is, in its basic form, a black and white image where the variations in light intensity correspond with variations in the quantity of radiation received. The darker areas of the image represent cooler surface temperatures compared to the warmer lighter areas. Images may be recorded onto electronic media (floppy disks) or videotape. The recorded and printed image is called a thermogram. Thermograms may be colour enhanced to improve visualisation.

Calculating the surface temperatures from the thermal image allows the survey results to be quantified. When carried out under suitable environmental conditions the variations in the measured surface temperature relate to the heat transmission through the building fabric.

Infrared thermography is not the same as infrared photography and similar results cannot be achieved using conventional photographic techniques and infrared film.

** Emissivity is the ability of a surface to emit thermal radiation. Most building materials have a high value of emissivity (typically greater than 0.9) and tend not to reflect much radiation.*

THERMOGRAPHY

Surveys should be carried out under suitable environmental conditions to ensure that a satisfactory interpretation of the results can be made. Typically these occur at night-time during the winter months.

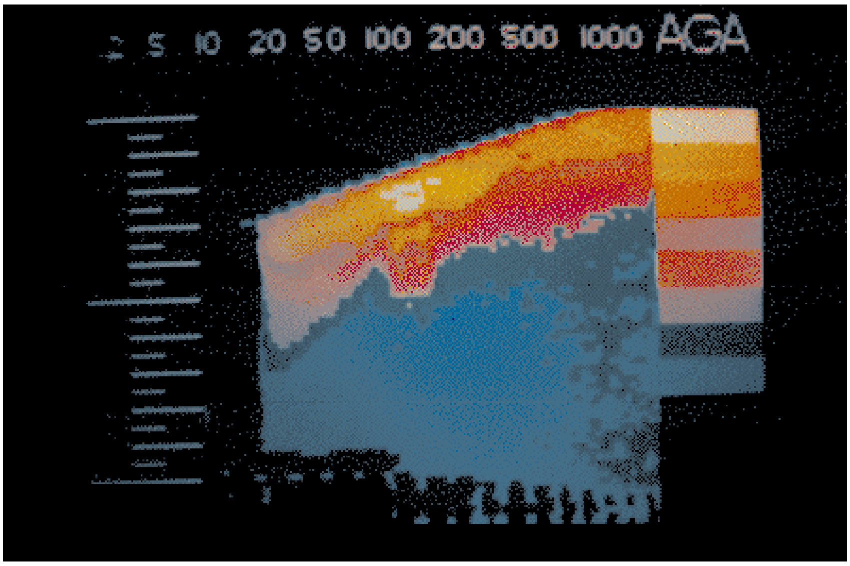


Figure 3 Thermal pattern due to missing cavity wall insulation, viewed from the exterior

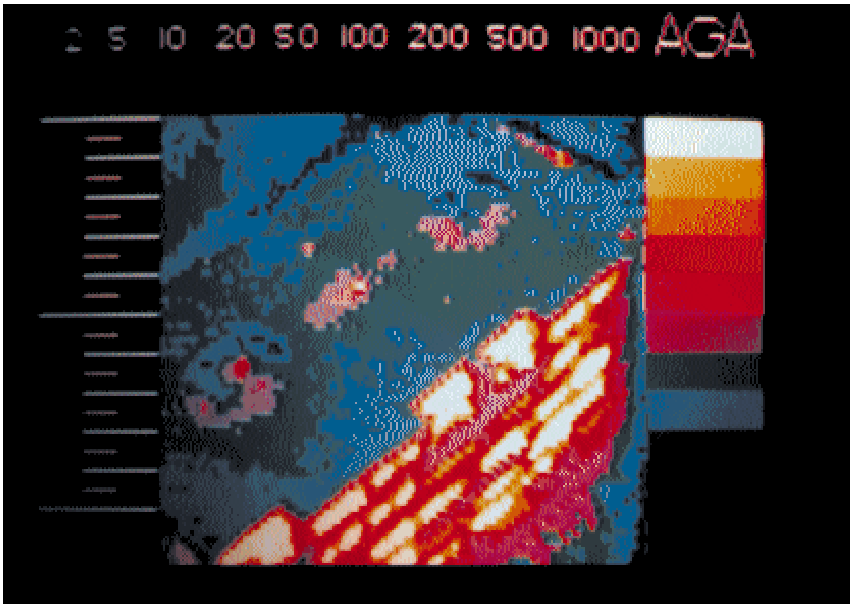


Figure 4 Aerial thermogram of flats

A thermographic survey may be carried out from ground level, or from the air. Aerial surveys allow information on the performance of the roof and walls to be collected, which can be an advantage on larger sites.

Thermography can be used in conjunction with a number of other techniques to highlight failures of the building envelope. For example, the impact of cold air leakage through a joint in the structure can be clearly illustrated using a combination of fan pressurisation (to produce a negative pressure within the building), and thermography (to visualise the cooling effect caused by cold air entering the building).

SURVEY METHOD AND REPORTING

The survey method and the environmental conditions required to enable a satisfactory interpretation of the results are described in ISO 6781 'Thermal insulation – Qualitative detection of thermal irregularities in building envelopes – Infrared method'[1]. The specific requirements for a survey would need to be varied according to the thermal properties of the building envelope under examination. However, for most housing investigations the requirements can be summarised as follows.

- A minimum internal to external temperature difference of 10ºC for at least four hours prior to the survey.
- No sunshine on the façade for at least four hours prior to the survey. (This period will need to be lengthened significantly if the structure has a high thermal mass, such as a solid brick wall.)
- The building surfaces are dry, with no rain occurring for the duration of the survey.
- Wind speeds are typically less than 8 m/s (light to moderate breeze).

A thermographic scan can be carried out from within the building or from outside. If access is available, scans of both the interior and exterior surfaces of the building envelope should be carried out as this aids interpretation of the results.

THERMOGRAPHY

Interpreting the thermal images is crucial to the success of the survey. Irregularities in the thermal insulation or the airtightness of the building will produce variations in the pattern of surface temperatures. Certain types of defects have characteristic shapes. ISO 6781 describes examples of these characteristics, as follows.

- Missing insulation produces regular and well-defined shapes not associated with features in the building structure. The defect area has a relatively even temperature distribution.
- Air leakage, often at joints and junctions in the building envelope, frequently produces irregular shapes with uneven boundaries and large temperature variations.
- Moisture present in the structure normally produces a mottled and diffuse pattern. Temperature variations are not extreme within the pattern.

SPECIFICATION

The specification of a survey should clearly establish the scope of the work and the extent of reporting required. The scope of work should state the aims of the survey and the building(s) and elements (roof/walls) to be included.

The thermographic report will include, but not be limited to, the following issues.

- A brief description of the construction of the building, the parts surveyed and the objectives of the survey.
- Specification of the equipment used, including model and serial numbers and evidence of calibration.
- Date and time of survey, together with a description of the environmental conditions prior to and during the survey. An indication of any other factors influencing the results.
- Thermograms together with descriptions of the images and their location. Note that consistent temperature scaling is to be used whenever possible to enable direct comparison of thermograms with each other.
- Sketches and/or photographs showing the locations of the thermograms.
- Results of any analyses carried out.
- Recommendation for further investigation of any areas identified during the survey.

The report should provide a complete record of the survey, the equipment used, the environmental conditions, the results and the interpretation of them. If required, a video of the survey and a commentary should be specified. Typically, results will be presented as a series of thermograms which will illustrate areas of anomalous heat loss from the building surfaces and defect-free areas of the building. Thermograms should be presented with a description of the image and, where appropriate, the range of surface temperatures measured. Potential faults located by the survey should be clearly marked on sketches of the building. This will enable follow-up investigations, such as a borescope examination (see section 5), to be carried out successfully.

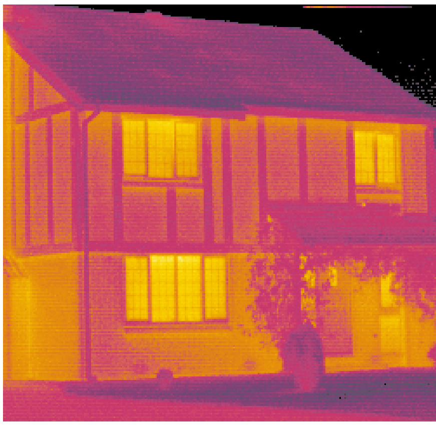


Figure 5 A thermogram of a typical house, highlighting areas of relatively low insulation, such as windows, and the high levels of insulation in the roof space and wall cavities

Figure 6 Thermographic survey equipment

3 FAN PRESSURISATION TESTING

Fan pressurisation testing allows the airtightness of a building to be assessed and the air leakage rate to be determined. The technique is straightforward and applicable to new and existing housing. Improving the airtightness characteristics of a house reduces draughts and space heating energy requirements.

In recent years the maxim 'build tight – ventilate right' has been promoted. This means that the building envelope should be as airtight as possible and controllable ventilation should be provided by natural or mechanical means, or a combination of both. Adoption of this approach requires a standard of airtightness to be specified. This should be consistent with the proposed method of ventilation, and compliance with the specification should be demonstrated.

There are other applications of the test:

- assessment of the potential for reducing air leakage in an existing house
- identification and quantification of air leakage paths through a building envelope
- comparison of the air leakage characteristics of a number of buildings
- measurement of the impact and effectiveness of air leakage reduction methods.

Test results can be used in energy rating software to improve the estimate of air infiltration rates.

The technique is equally applicable to larger, non-domestic buildings as described in BRE's Information Paper IP6/89 'Use of BREFAN to measure the airtightness of non-domestic buildings'[2].

Figure 7 The fan pressurisation technique employs a fan fitted in a dummy door panel

THE FAN PRESSURISATION TECHNIQUE

A fan is mounted in a dummy door panel (the original door remains in place, but is open so that the dummy door can be fitted into the rebate) and used to move air into or out of the building. The air leakage characteristics are determined by measuring the rate of air flow through the fan that is needed to maintain a given pressure difference between the inside and outside of the building.

It is important both to pressurise and depressurise the building. Research carried out by BRE[3] has found that the results may differ by as much as 20%. The reasons for this are associated with differing air flow characteristics through the actual air leakage paths under positive and negative pressure differences. For example, an opening light in a window may be pulled tighter on its draught seals when the building is depressurised, but forced apart when pressurised.

In addition, equipment to measure wind speeds and temperatures will be needed. It can also be handy to have some smoke pencils available to demonstrate the position of an air leakage path.

FAN PRESSURISATION TESTING

TEST PROCEDURE

In the UK the recommended procedure for fan pressurisation testing of dwellings is described in a BRE occasional paper[4]. In Europe, CEN (the European Committee for standardisation) has plans to adopt a revised version of ISO 9972 'Thermal insulation – Determination of building airtightness – Fan pressurisation method'[5], as a separate CEN standard.

In advance of the test it is useful to have calculated the building volume for the envelope to be tested. Typically for a dwelling this would include the heated floor zones and exclude any porches, garages and loft spaces.

The test can be carried out on a completed or nearly completed dwelling. Preparation for the test will normally include the closure of all adjustable ventilation openings in the building envelope (eg trickle ventilators), sealing any extract fans and chimneys with polythene sheet and masking tape, and checking that all plumbing traps are filled with water. Gas, oil and solid fuel appliances should be turned off for the duration of the test. During the test all exterior doors and windows should remain shut and the internal doors be left open to allow free air movement.

With the building prepared, the fan test equipment can be set up in a convenient exterior door and the test carried out. Fan pressurisation tests should not be carried out in wind speeds greater than 5.5 m/s (light breeze), as this makes taking the readings difficult, and increasing wind speeds affect the air flow through any leakage routes. With the equipment set up, the test can be carried out by taking readings over a range of pressure differences (10-60 Pascals (Pa)) and noting the flow of air through the fan. Checks should be carried out during the test to ensure that polythene sheeting does not become detached and that the loft hatch does not become displaced. On completion of the first stage of the test, the equipment can be re-arranged to give the opposite pressure difference and the test procedure repeated.

Analysis of the results is typically carried out on site with a portable computer, allowing a quick assessment of the results. A full description of the analysis of the data is outside the scope of this Report, but is discussed in the BRE recommended procedure[4]. In the event that the building fails to meet a required standard, the building can be depressurised and air infiltration routes traced with the aid of a smoke pencil.

The time taken to complete a test depends on the amount of preparation required, but, typically, an experienced operator would be able to complete a test of a family-sized house within two hours.

The results of the test are usually presented in tabular form as the mean air leakage rate in air changes per hour (ach) at 50 Pa applied pressure difference. This can cause confusion because ventilation rates are also measured in air changes per hour. The two are not directly comparable because of the different pressure conditions under which they are measured. The mean air leakage rate can be directly compared with published benchmarks for best practice standards[2] (see the table overleaf). The results can be presented graphically showing both the positive and negative pressure curves.

The results can also be presented as a calculation of the effective leakage area. This is a measure of the total area of all the leakage paths in the tested envelope and can be useful for helping designers 'visualise' the size of opening that a particular leakage rate equates to.

Alternatively, the results can be quoted as an air flow rate per unit of surface area[6]. This is known as an 'air leakage index' and is derived by dividing the air leakage flow rate at a reference pressure by the surface area of the building envelope tested. This method is particularly appropriate for large, non-domestic buildings.

FAN PRESSURISATION TESTING

Ventilation options	Target pressure test air leakage rate
Local extraction and background ventilators	5-7 ach at 50 Pa
Whole house ventilation systems	4 ach at 50 Pa or less

Suggested pressure test leakage rates for different ventilation options

SPECIFICATION

Any specification for airtightness testing should establish the standard required for the building and the number of buildings to be tested. It should also establish the objectives of the test, the method to be used and the presentation of the results.

SCOPE OF WORK

Experience has shown that apparently similar buildings on the same site can have markedly different air leakage rates. It is, therefore, difficult to specify a percentage number of dwellings to be tested with any confidence. A suggested approach is as follows:

- for a development with 10 dwellings or less, test all the dwellings
- for a development with more than 10 dwellings, test a minimum of 10 dwellings and at least 10% of the total; the test contractor should randomly select dwellings for test with consideration to the construction programme.

If all the tested dwellings comply with the airtightness specification then all the dwellings are deemed to comply. If any fail, remedial works should be applied to all the dwellings on the development and the tests repeated.

Example

Fan pressurisation tests should be carried out on the first two houses completed and then a randomly selected sample of up to 10% of the total number of dwellings on the development. The test contractor should make the selection.

Tests should be carried out in accordance with BRE's recommended procedure[4] by a contractor with demonstrable experience of the technique.

All dwellings tested should achieve an air leakage rate of better than [X] ach at 50 Pa applied pressure difference at completion (see the table on the left).

In the event of failure to achieve this standard, air leakage paths will be identified by the test contractor and remedial measures applied by the main contractor until the specified level is achieved. All remedial measures should be applied to all dwellings in the development.

TEST REPORT

The report should provide a record of the tests carried out, the results and identification of any air leakage routes.

Example

The test report should include, but not be limited to, the following:

- a brief description of the building, its construction and volume
- date of test and the test conditions, indoor and outdoor temperatures, wind speed and direction
- a graphical and tabulated presentation the results of the test
- the mean value of air leakage, expressed in ach at 50 Pa applied pressure difference
- comments on any major air leakage paths detected during the test and methods of remediation.

4 GLAZING SYSTEM IDENTIFICATION

Surveyors may be required to either confirm that the correct glazing units have been installed or specify replacement units for damaged ones. In addition, the correct identification of the use of laminated glass, instead of toughened glass, in potentially hazardous locations, needs to be confirmed.

The wider use of double-glazed units with larger air gaps and the introduction of glazing units with low-emissivity (low-e) coatings have made it difficult for surveyors to identify the type of glazing units without removing the unit.

Commercially available laser gauges provide a simple way of identifying accurately the type of glazing installed within a window. The gauges enable the glass thickness, width of air gap and presence of any low-e coating or laminate to be identified. In addition to identifying the presence of a low-e coating, it is possible to confirm that the unit has been installed the correct way round, which is essential for the full performance to be achieved. However, the gauges cannot be used to detect the presence of an argon or similar gas filling within a double-glazed unit or the type of coating applied to the glass.

The gauges offer a simple solution in preference to trying to measure the overall thickness of a multiple glazing unit using calipers. Gauges can be purchased for under £200.

SURVEY METHOD

The gauge is placed against the glazing unit to be assessed and powered up. Laser light is passed through the glazing unit, reflecting off each surface struck to give an instantaneous reading on a calibrated measurement scale. The thicknesses of the glass and air gap are highlighted as a pair of lines, of similar brightness, on the measurement scale. The presence of a low-e coating causes a greater quantity of light to be reflected, showing up as a brighter line on the scale. The location of the coating is indicated by which line is brightest – either the second or third. For a correctly installed unit, measured from the internal surface, the second line should appear brightest.

Manufacturers claim readings can be taken to an accuracy of 0.1 mm and on units up to a total thickness of 65 mm. Direct sunlight does not affect the taking of readings.

Figure 8 Laser gauges provide a simple way of identifying the type of glazing installed within a window

5 REMOTE VISUAL INSPECTION

Remote visual inspection of building construction carried out by a rigid borescope (or fibrescope) allows positive identification of hidden defects with minimal damage to the building structure.

Applications for remote visual inspection within the building industry include the inspection of services, particularly drains and sewers, and the investigation of voids within walls, floors and roofs. Investigation of these voids enables the confirmation of construction details, the presence of damp-proof courses, and hidden defects such as failed wall ties to be determined. When used as a follow-up investigation to a thermographic survey, the exact cause of a thermal pattern can readily be determined, for example missing or poorly installed insulation.

Remote visual inspections may be carried out, using a rigid borescope or a flexible fibrescope depending on the available access and location. Developments in digital technology have allowed improved image recording facilities and measurement capabilities, and high-definition portable devices are now available.

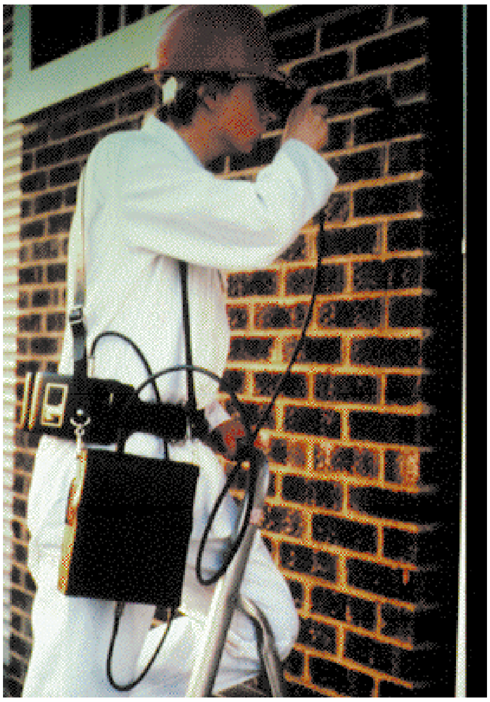
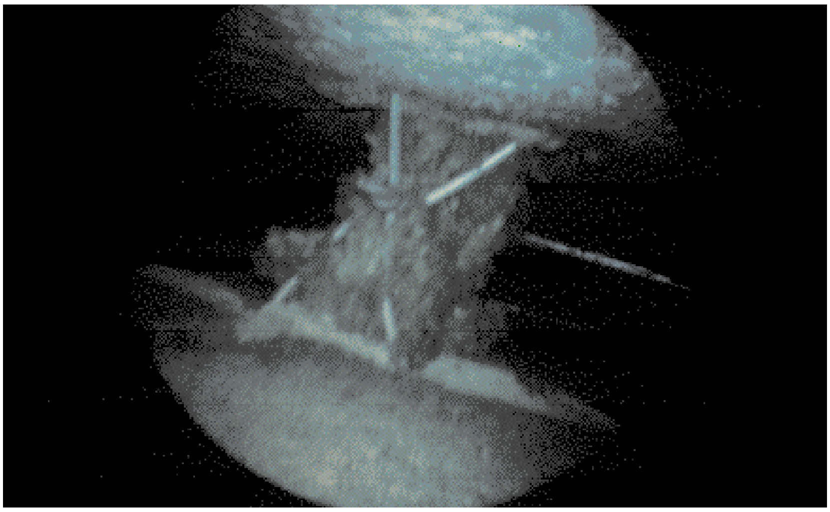


Figure 10 Borescope examination of wall cavity

Figure 9 Bridged wall tie



SURVEY METHOD

The systems typically consist of a portable, high-intensity light source, a fibre optic light guide and an optical viewing system. In the case of a follow-up inspection to a thermographic survey, an inspection hole (approximately 13 mm in diameter) is drilled using the thermal image as a guide to location, and the instrument inserted. The viewing systems normally permit rotation through 360 degrees. Within the image, an indicator shows the orientation of the scope. With the level of illumination available from the high-intensity light sources, defects within 1.5 m to 2 m can be readily identified. Results can be recorded either by directly attaching a conventional photographic camera or video camera to the system.

6 OTHER PERFORMANCE MEASUREMENTS OF THE BUILDING ENVELOPE

Under certain circumstances it can be useful to make an assessment of the actual thermal performance of the building envelope. Principally this will be to investigate the effects of workmanship on the performance of the insulation materials used or to make comparisons between the performance of different types of insulation. Buildings constructed to energy-efficient standards, with high standards of insulation and airtightness, only need simple heating systems. If such designs are to perform successfully then the building envelope must not compromise the performance of the heating systems. Two approaches are described below, one to measure the U-value of a wall on site and the other to assess the specific heat loss of the house.

THE MEASUREMENT OF THERMAL TRANSMITTANCE (U-VALUE) ON SITE

Standard techniques for the measurement of the thermal properties of a material in a laboratory are well established. The resulting values are used in the calculation of a theoretical U-value for the construction. There are a number of reasons why the predicted values may not be achieved in the completed building. These include: differences between the design and the built structure; variations in the material's thermal properties (increased moisture content); and increased heat flows due to thermal bridges in the structure. International Standards have been developed that give a procedure for making site measurements.

Steady state thermal conditions never occur within buildings, and as a consequence measurement of heat flows needs to be carried out over a long enough period for the influence of thermal mass to be negligible. The measurement of a U-value should not, therefore, be considered a straightforward process, particularly in structures with a high thermal mass.

Using a combination of thermal imaging and a heat flux meter, the thermal performance of a structure can be assessed in-situ and a comparison with design values made.

To measure the U-value of a wall the heat flux meter needs to be positioned in a representative area and away from the influence of heat sources. To best achieve this, a north-facing wall should be selected to reduce the influence of solar gains and a thermal image of the internal wall surface produced. Once a representative area has been chosen the heat flux meter can be installed, together with probes to measure both internal and external air and wall surface temperatures. Output from all sensors should be measured and recorded at regular intervals by suitable data-loggers.

Heat flux meters are extremely sensitive devices and will respond rapidly to any variations in their surface temperature. It is, therefore, essential that the meter is in intimate contact with the wall surface and sited away from any possible influence from heat gains.

A constant heating regime should be maintained for the duration of the measurement, and the measurement should continue for a long enough period for the thermal mass of the structure to have a minimal effect. Typically this can take up to 14 days for a masonry structure; a shorter period would be possible for a structure of lower thermal mass. This would have to be determined by reviewing the recorded data. Once a sufficient period has elapsed, the U-value may be derived from the time-averaged heat flux divided by the average air temperature difference between inside and outside. A more rigorous analysis of the data, taking account of the effects of thermal storage, can be made using the methods described in ISO 9869 'Thermal insulation – Building elements – In-situ measurement of thermal resistance and thermal transmittance'[7].

ASSESSMENT OF FABRIC HEAT LOSSES

As described earlier, the thermal performance of the building envelope can be critical to the overall energy efficiency of the building. It is possible to carry out an assessment of the overall thermal performance of the building envelope by making

OTHER PERFORMANCE MEASUREMENTS OF THE BUILDING ENVELOPE

an assessment of the specific heat loss. This can be particularly useful for assessments of the comparative performance of different forms of construction. In making an assessment there are a range of issues that should be considered. These will introduce errors to the measurements and are mainly associated with incidental heat gains and heat losses. Making comparative measurements on pairs of houses experiencing the same environmental conditions will limit the impact of some of the issues.

Measurements of internal and external temperatures and the space-heating fuel consumption allow the assessment to be carried out.

Careful consideration should be given to the selection of the dwellings for measurement and the time of year they are constructed. Measurements made during the heating season will benefit from short periods of solar gain. The exposure of the dwellings to the prevailing wind and their orientation for solar access will all influence the rate of heat loss. Recording of the wind speeds and directions at the site will allow assessment of the influence of the wind on the results.

Measurement of the internal environmental temperature[8] should be in sufficient locations to allow the mean internal temperature to be described. In practice, a minimum of four locations should be chosen, with two on the ground floor and two on the first floor.

Measurement of external temperatures should be carried out in a location where it will not be unduly influenced by solar radiation.

All temperature data should be recorded at regular intervals, typically 15 minutes, on solid state data-loggers. Measurements should be continued for a sufficient period to overcome the impact of thermal mass, typically up to 14 days.

Due to the uncertainties of the efficiencies of gas heating systems, consideration should be given to continuously heating the test dwellings for the duration of the test with portable electric heaters. Monitoring of the total electricity consumption for the duration of the test with no other loads connected would permit the space-heating fuel use to be calculated. Monitoring of the electricity consumption needs to be arranged, and the method chosen will depend on the type of electricity meter.

The recorded temperatures and power consumption should be reduced to daily averages, and the specific heat loss derived from the division of the space-heating fuel use by the average temperature difference.

MOISTURE MEASUREMENT

Excess moisture in masonry or timber usually results in visible staining to decorations and the onset of wet or dry rot in wood. Electrical moisture meters can provide a useful indication of the presence of moisture but concentrations of salts at the surface may give a misleading reading.

A variety of meters are available, measuring resistance, conductance or the reflection of radio frequency emissions. Where an indication of moisture is recorded in timber, then some reliance can be placed on the actual value measured. In masonry materials the reading may indicate the presence of hygroscopic salts, usually chlorides and nitrates, particularly within a humid atmosphere. The pattern of readings taken at several locations on the surface can give a clue to any problem present. High readings at low to mid-wall height with no reading above that level may well indicate rising damp. Readings only in the middle of a wall may have uncovered localised rain penetration.

A quantitative method of moisture sampling is to drill a small amount of powder from the masonry, weigh it as found, then dry it in an oven and reweigh it. From these values the percentage moisture content can be calculated. Alternatively, a carbide meter can be used to give an on-site reading. A laboratory test should be undertaken to test for hygroscopicity. Full details of these methods are given in BRE Digest 245[9].

OTHER PERFORMANCE MEASUREMENTS OF THE BUILDING ENVELOPE

ULTRASONIC SCANNING

This is a widely used technique with many medical and industrial applications. The technique uses high-frequency sound waves, usually above 20 000 Hz, to provide a cross-section through the material being examined. The equipment used in the examination of buildings does not produce an image, and therefore a reasonable degree of skill and experience are required to interpret the results.

The technique can be used across very fragile surfaces without causing any damage, and as a consequence has been used in a number of instances on historic buildings. It is a comparative technique which can only detect areas of weakness in an otherwise sound material or when compared to a reference sample. The principal application is in the investigation of timbers to determine the presence and extent of any decay. Useful information can be gathered from the examination of stonework for fault planes and zones of weakness.

The technique will not provide useful information where the structure has a high number of discontinuities within it, such as a rubble wall, because the signal will be scattered off the various interfaces.

RADAR EXAMINATION

This technique has been developed from military and geo-technical applications over the last 10 years and has found wider applications in the examination of both structures and roadways. It involves an echo-sounding technique using low-power radio pulses to determine structural make up and condition. Data is collected continuously, giving a cross-section through the structure. The technique is suitable for covering large areas rapidly to determine the extent of a problem, or investigating a localised problem. It is effective in most construction materials.

An antenna connected to a transmitter and receiver is passed over the surface of the structure at a controlled speed. The reflected energy is collected by the receiver and subsequently processed. Real-time viewing of the data on site can give an indication of areas for subsequent investigations, but full analysis would generally be carried out off site. Data processing has benefited from the advances in computer technology with more rapid data capture possible and improved analysis with the removal of signal noise.

Expert assessment of the strength and scatter of the signal can give an indication of the presence of cracking, corrosion and changes in moisture content and compaction. The technique has been successfully applied to locating and measuring voids, and the identification of discontinuities within walls and floors. The technique is particularly effective at mapping the layers within a construction with different system configurations being used to vary resolution and depth (shorter wavelengths for shallower features and longer wavelengths for deeper features).

Radar offers the advantage of only requiring access to one surface for the scanning to be done. The systems usually need to be calibrated on site and cannot penetrate highly conductive materials such as metals. Specialist companies with the necessary expertise in analysing the results should be engaged to carry out the technique.

REFERENCES AND FURTHER READING

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FURTHER READING

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- Petterson, Bertil and Axen, Bengt. 'Thermography. Testing of the thermal insulation and airtightness of buildings'

BRE

- BR176 'A practical guide to infrared thermography for building surveys'
- IP7/90 'An introduction to infrared thermography for building surveys'

ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Energy Efficiency Best Practice programme publications are available from the BRECSU Enquiries Bureau. Contact details are given below.

Good Practice Guides

79 Energy efficiency in new housing – a guide to achieving best practice
224 Improving airtightness in existing homes
227 Selecting energy-efficient windows

This Report is based on material drafted by Rickaby Thompson Associates Ltd under contract to BRECSU for the Energy Efficiency Best Practice programme.

Energy Efficiency Best Practice in Housing

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www.est.org.uk/bestpractice

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