Guidelines GB 9.0 – Thermal Imaging

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Introduction

This document is being issued by Trakhees' Sustainability Department with a view to provide the stakeholders of the jurisdiction and the built environment community a broad perspective of the "Thermal Imaging" in terms of the role it plays in sustainability. In addition this document has been developed to support the stakeholders with the guidance required to comply with the regulatory requirements pertaining to the "Thermal Imaging".

Thermal imaging is a simple, non-intrusive technique that is generally used to locate the so called 'weak' points in the building envelope. This could be in in one or more of the following forms; missing insulation, air leakage, cold-bridging, presence of moisture etc. Thermal survey is considered a cost-effective solution and is being widely employed these days for energy savings, building audits, facilities management, envelope tightness etc.

Scope

This general guideline is applicable to all the stakeholders involved in the Green building projects within Dubai World business units under the Ports, Customs and Free Zone Corporation (PCFC).

Aim

The aim of this document is to highlight the importance of Thermal Imaging in building diagnostics and further provide relevant information and references to assist the community in gaining a reasonable level of insight on this science. It is expected to help the stakeholders in making informed decisions

Sections

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For the sake of clarity, this document is divided into following sections

1. Infrared Thermography
2. Understanding Thermal Imaging
3. Why Thermal Imaging
4. Applications of IR Thermal Imaging
5. Typical Images / Sample Pictures
6. Inspection methods / criteria
7. Applicable Reference & standards

Infrared Thermography

Infrared thermography is an advanced, non-invasive method of assisting in diagnosing the condition of a building. A thermal image identifies abnormal thermal patterns that may indicate moisture intrusion, damaged insulation, insulation voids, air infiltration, air exfiltration, and anomalies in electrical and HVAC systems. It is a low cost inspection process. When correctly calibrated by a trained professional, an infrared imaging inspection can show the movement of cooled inside air to the exterior of the envelope.

An infrared camera shows exactly where the problems are and helps focus the inspectors' attention allowing him or her to properly diagnose areas with energy loss. This strategy saves considerable amount of time that would have otherwise been spent and lost in identifying the problems. Thus Infrared thermography is the easiest and quickest method to detect energy waste, moisture and electrical issues in buildings.

Envelope Components

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The envelope is made up of all of the exterior components of the building, including walls, roofing, foundations, windows, and doors. Finish materials like siding and decorative items are not usually considered a part of the envelope. Insulation, building paper, and other components aimed at controlling moisture and airflow are typically included in the building envelope design.

Understanding Thermal Imaging

All the objects that we see around us (be it movable or immovable i.e. walls, motors, cars etc.) have certain temperature and they emit waves of energy (heat energy) called 'infrared radiation' (IR). This is so called as these waves fall in the infrared portion of the electromagnetic spectrum. The human eye is unable to see infrared waves so we use thermography to enable us to see and measure heat. The hotter the object, the more energy it emits. A thermal imaging camera registers the invisible waves and translates them (energy waves) into a viewable image, which shows a "heat picture" of the object the camera is pointing towards at the time. A trained thermographer can interpret infrared images and use the results in a building and system analysis

Just like our eyes receive energy in the form of "visible light", IR camera receives wavelengths of heat energy called "infrared". It should be noted that in reality, no thermal imaging camera can actually see through solid materials such as masonry walls, slabs, ceiling, MEP services, insulation panels etc. and none of these objects are actually 'transparent' to infrared. *The IR cameras can only "see" the temperature difference on any given surface.*

The slightest of temperature differences on the walls, slabs or envelope will show up in the camera. If there is an air leakage through wall or water leakage through an embedded pipe, it affects the surface temperature of the wall in the area of the leak and it will be captured by the camera right away in most cases. It's the same with air

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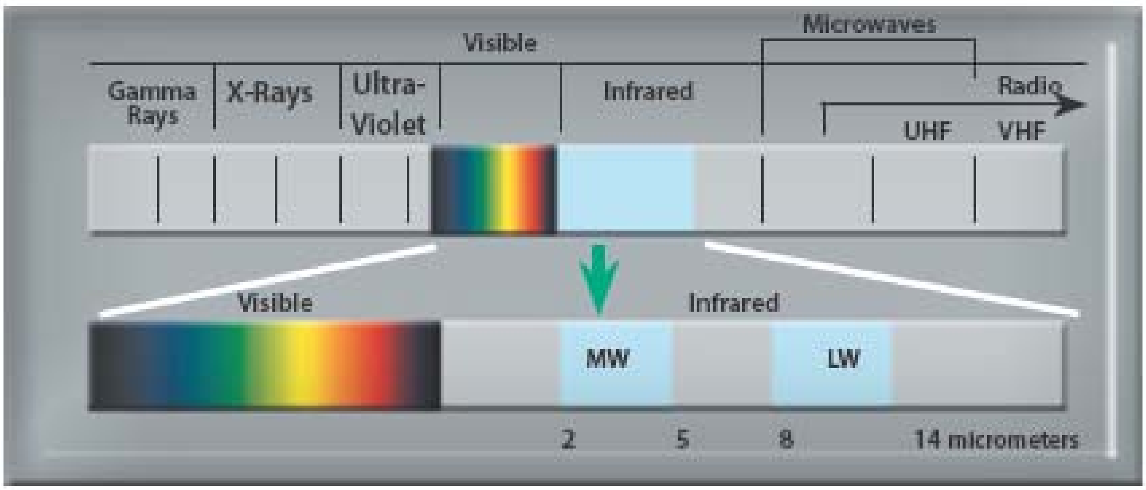
penetration through the insulation; the cool/warm air will blow onto the back on the wall hence affecting the temperature on the surface of the wall.

A typical electromagnetic spectrum is indicated below.



Electromagnetic Spectrum

Why Thermal Imaging?

Built Environments by process involves due diligence at design, construction and operation phase of the facility. Notwithstanding the fact that a building project crosses these phases, it cannot be said with certainty that they have been robustly followed. Inconsistencies, errors, defects and poor workmanship do creep in, in the course of the project activity on account of which the buildings no longer deliver the originally stated performance. In reality the building is forced to put up with some or all of the below mentioned issues

a) Leaky envelope

b) Air loss through buildings and internal members

c) Moisture in roof, insulation and wall

d) Air Leakage through ducts

e) Plumbing leaks

f) Mold

g) Verification of energy performance (conduction and air leakage)

Some of these defects may lend themselves to easy identification while others may not be noticeable till permanent damage has already occurred. Leaky envelope leads to exorbitant wastage of precious energy from the buildings which in turn lead to high operating costs. The process of identification of the defects is also cumbersome especially so when none of these are visible to the naked eye.

Further, built environments are stated to be responsible for more than a third of the global Greenhouse gas (GHG) emissions and accordingly widely targeted for combating the threat of climate change. Under these circumstances, it is only prudent to look for strategies that assist in improving the performance of the buildings and reducing the GHG emissions in a cost effective manner.

Thermal imaging comes to the rescue as it is a powerful and non-invasive tool for monitoring and diagnosing the conditions of the buildings. With this technique it is possible to diagnose the defects and rectify them before it gets serious. In addition, they offer the following advantages

a) Convenient to handle and use

b) Provides a full picture of the area under study

c) Identifies the location and pinpoints the problems

d) Serves as multiple infrared thermometers and stores the collected information

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e) Provides exact advise on what needs to be fixed

f) Early assessment before the real danger

g) Cost effective and saves time

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Applications of IR Thermal Imaging

The following are the general applications of thermal imaging technique

1) Building diagnostics

Buildings may be quickly and thoroughly scanned using a FLIR thermal imager, identifying problem areas that can't be seen by the naked eye. Poor or inadequate insulation, moisture, building envelope leaks, and substandard work are costly to building owners. Thermal cameras can detect gaps or poorly installed insulation quickly and effectively. Wall insulation thermography has shown to be very effective in determining insulation quality and highlighting poor workmanship that cannot otherwise be determined

An infrared camera can help in quickly identifying areas where energy efficiency can be improved.

2) Energy Auditing and Building Inspection

Excessive air leakage can account for up to half of the energy consumed to condition buildings. The leakage pathway is often complex and, without thermal imaging, extremely difficult to visualize. Air Tightness and Thermal Imaging testing are important quality control measures for new construction and renovation. Energy losses in buildings can account for up to 50% of the total energy consumption and comes from air leakage through chimneys, attics, wall vents and badly sealed windows/doors. Thermal Imaging allows the contractors to quickly identify and repair the problem areas to stop the energy loss immediately.

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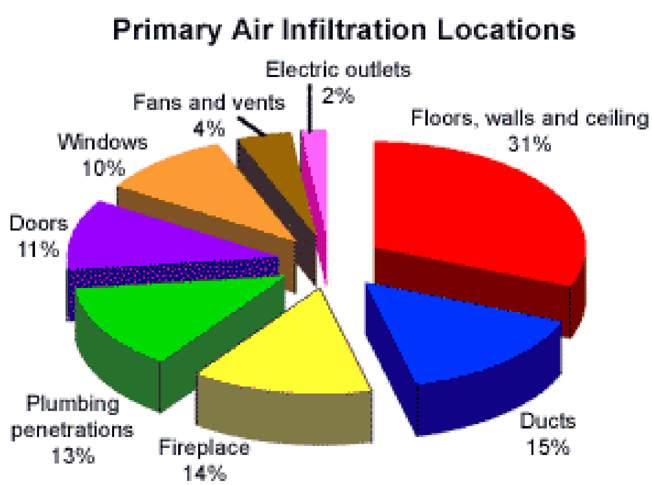
All new buildings are required to demonstrate air tightness by complying with the applicable regulations. By reducing air leakage, it is possible to obtain a better comfort in the building. In the process, the building can also be climate controlled more efficiently to conserve energy and save money

Air leakage through conditioned spaces can be considered as one single source for loss of precious energy. This happens through leaky envelope, sub-standard construction, improper maintenance and other issues. The figure below shows the air leakage locations based on a study of buildings in Australia. While it is for illustration purposes only, the picture provides a broad perspective of the seriousness of the issue and more importantly its relevance to a place like UAE having a harsh environmental condition.

Both New constructions and existing building suffer from this problem and beg for due attention. Mass scale deployment of this technique for new construction and existing buildings would no doubt lead to significant savings in energy and bottom-line

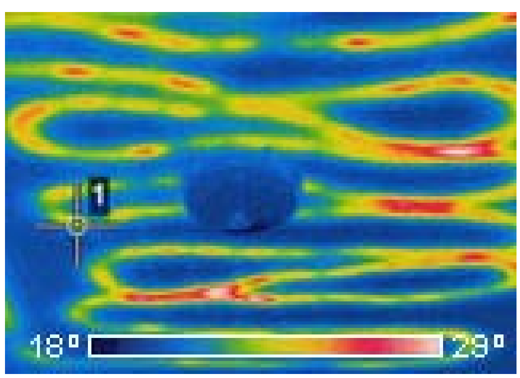


Energy conservation and efficiency requires a thorough identification of leakage in terms of areas of energy wastage and consumption points. It is in this aspect that infrared imaging has quickly become a valued tool in identifying problems related to energy loss, missing insulation, inefficient HVAC systems, water damage on roofs, and much more. A thermal imaging camera identifies patterns of heat loss that are invisible to the naked eye. Thermal imaging will quickly indicate the air leaks within a property.

3) <u>HVAC and plumbing</u>

Indoor environment can be compromised by poor insulation, poorly sealed windows and doors, inadequate or poorly sealed ductwork, plumbing leaks, or other plumbing issues relating to Heating Ventilation and Air Conditioning (HVAC) systems.

Thermal imaging is a practical tool that helps building professionals see the big picture. IR cameras enables scan of an entire building and assess the relation of HVAC system, building envelope, and plumbing issues. It also assists in deciding when and where energy saving solutions can be implemented. The works possible are wide starting with determining insulation effectiveness and moves to diagnosing faulty ductwork



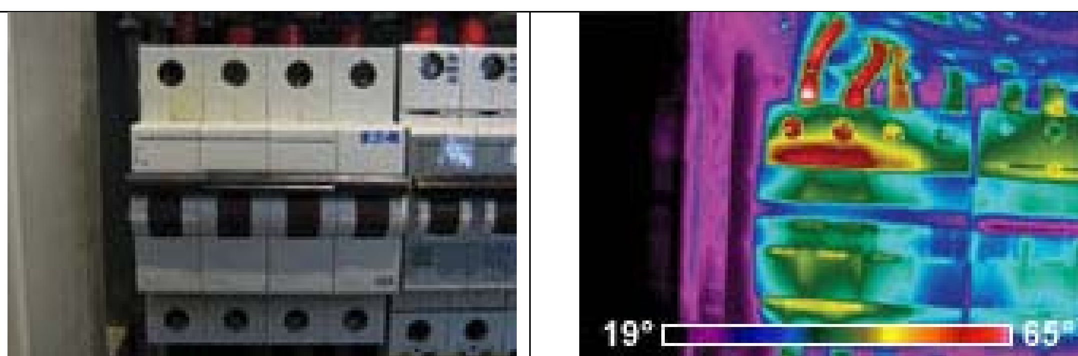
Hot spots in the ceiling

4) <u>Property and Facility management</u>

Infrared thermography is a powerful & non-invasive method of monitoring and troubleshooting the conditions of buildings. It is a valuable tool in predictive maintenance of electrical, mechanical, and structural systems, to detect problems, prevent downtime, guide corrective action, and increase work safety. Since IR operates without physical contact, it gives building managers a safe, on-line, and cost effective means to evaluate a buildings operating integrity. While many borderline problem areas typically remain undetected during an off-line physical inspection, they can easily be seen using infrared.

Aside from detecting heat and energy loss in structures, thermal imaging has proved to be an accurate & effective tool in today's facilities predictive maintenance (PdM) programs

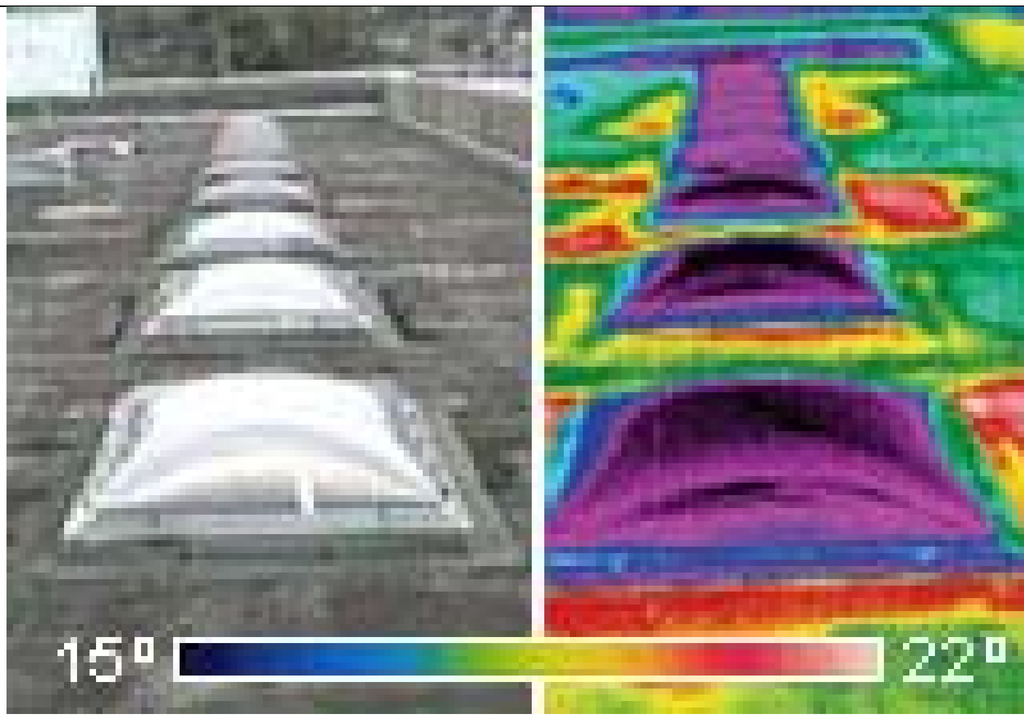
Given that technological improvements have generally driven the costs down, the scope of FM has been widely increased to include building envelope and surveys of energy wastage.



Inspection of this fuse box discovers that the two left connections are overheated.

5) Moisture and Restoration

The presence of moisture in building envelopes, either from leakage or condensation, can have serious consequences. With infrared images, water damage is easily detected. An infrared camera helps pinpoint water intrusion, find moisture beneath the surface, and document dryness with accuracy and confidence



Infrared image revealing the deteriorated areas of the roof.

6) Renewable energies

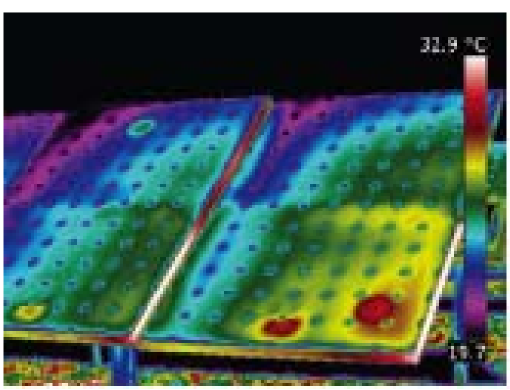
Building professionals all over the world engage thermal imaging cameras to inspect solar panels installed on rooftops or in solar parks. Thermal imaging cameras can play an important role in the wind turbine predictive maintenance programs. Potential problem areas can be detected and repaired before actual problems or failures occur.

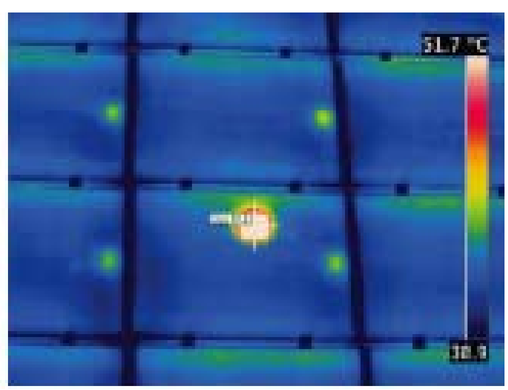
There is an increasing trend in the energy communities to either switch over to renewable sources of energy or to having an energy mix that includes renewable sources of power. This is in the wake of concerns on dwindling fossil fuels, Greenhouse gas emissions and threat of climate change. The renewable sources comprise solar PV, wind turbines, tidal etc.

Thermal imaging technique is used in Solar panel evaluation as well as checking the health of wind mills. Given that solar panels are prone to wear, IR imaging offers the benefit of giving the feedback through crisp thermal image. In addition, this technique can be applied when the solar system is up in running. Similarly, a windmill contains a lot of mechanical and electrical components that can easily be checked with a thermal imaging camera. Correct maintenance inspections of all parts of a windmill ensure that they will keep generating electricity for many years to come.

Thermal Imaging being carried out on solar panel and on wind turbines are depicted in the illustrations below

Thermal Imaging being carried out on Solar PV panels





Thermal Imaging being carried out on Wind turbines

Inspection methods / Criteria

Generally, the designer of the building envelope must specify the acceptable thermal intrusion for the building under design. This is the trickiest part as it presents a trade-off between envelope mass and material thermal resistance versus daylight and views through glazed openings. Higher thermal resistance of the entire envelope can be achieved with smaller areas of glazing, but without adequate glazing, natural light and views are affected. It is the task of the designer to provide a balanced compromise of design once optimization of building orientation and dynamic light/shade systems have been introduced

Thermal intrusion testing is normally done by performing thermal imaging of the envelope components. When using a thermal imaging camera to find missing insulation or energy losses, the difference in temperature

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between the inside of the building and the outside should be preferably at least 10 °C. These images will indicate areas of excess thermal intrusion in wall or roof areas and can indicate the presence of thermal bridging of structural elements and also the presence of air leaks when the building is under test pressure.

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. On that count, the process generally consists of the following key steps.

Step-1 Selecting the critical temperature parameter

Step-2 Selecting maximum acceptable defect area

Step-3 Measuring surface temperature difference caused by the defect

Step-4 Measuring area of the defects

Thermal anomalies will only present themselves to the thermographer where temperature differences exist and environmental phenomena are accounted for. Generally, the below mentioned parameters may be considered as recommended prerequisite for the environmental conditions before proceeding with the thermal imaging for building diagnostics

- 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

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- 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 prior to survey.
- No precipitation either just prior to or during the survey.
- Ensure that all building surfaces to be inspected are dry.
- Wind speed to be less than 10 metres / second during the operation.

Besides temperature, there are other environmental conditions that should be duly taken cognizance of 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. Sun may also have a significant influence 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 used for the survey must have sufficiently high resolution to detect small anomalies at a reasonable distance. The total pixel count should sufficient enough 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.

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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

Survey & Analysis

The survey must collect sufficient thermographic information to demonstrate that all eligible surfaces have been inspected so that thermal anomalies are reported and evaluated. Images of anomalies must be captured in such a way that they are suitable for further analysis. Some conditions are stated as under:

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 minimized to the extent possible.

Additional data that must be collected in the survey include

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 on software being used for analysis

Reporting

Thermal Imaging 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.

a) Background to the objective and principles of the test

b) Location, orientation, date and time of survey

c) A unique identifying reference

d) Thermographer's name and qualifications

e) Type of construction

f) Weather conditions, wind speed and direction, last precipitation, sunshine, degree of cloud cover.

g) 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

h) Statement of any deviation from relevant test requirements

i) Equipment used, last calibration date, any known defects.

j) Name, affiliation and qualifications of tester

k) Type, extent and position of each observed defect

l) Results of any supplementary measurements and investigations

Reports should be indexed and archived by thermographers

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IR Camera System requirements

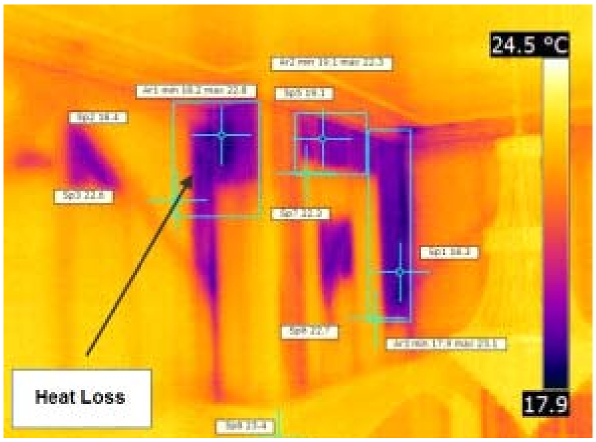
The Infrared thermal imaging system should be calibrated by the manufacturer. The field verification of the calibration shall be made by the operator on a periodic basis to ensure the system is within calibration. The written records of the calibration should be maintained and should be available upon request

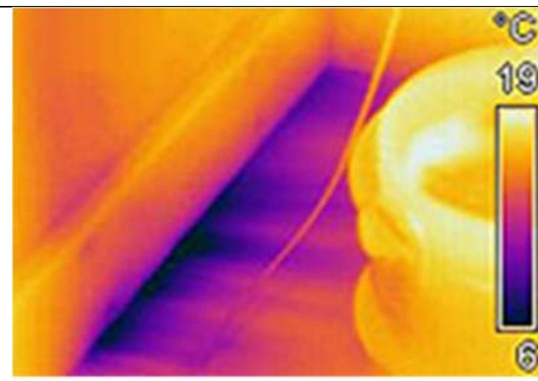
To be sure of reliable result from the thermographic survey, it is important to ensure that the thermal imaging is carried out by thermographers who are suitably qualified. In addition, the thermographer should possess a reasonable experience in building enclosures and building physics in order to diagnose in an accurate manner and make suitable recommendations to the contractor. Certification to an appropriate standard by an accredited body provides assurance that the thermographer has the required qualification, knowledge, skill and experience to carry out the specific task.

The international organization for standardization ISO 18436 part 7 sets out requirements for the certification of thermographers at 3 levels, referred to as categories in the standard

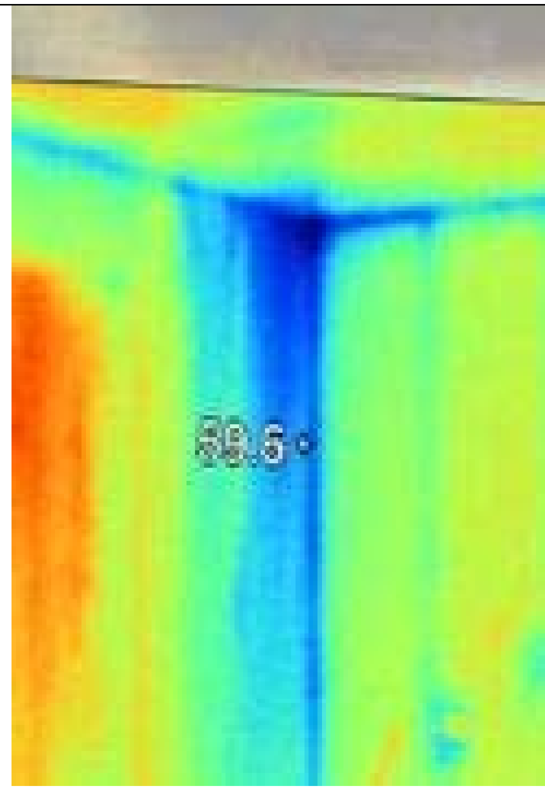
Category-I	Qualified for obtaining good images and reporting under the guidance of a more experienced and better qualified thermographer
Category –II	Qualified for conducting thermograpic surveys and producing reports
Category –III	Qualified to setup and supervise monitoring programs, train and develop methods

Thermal Imaging – Sample Pictures





Detection and visualization of Infiltration / Exfiltration. Air leakage through the gap between the wall and the floor.

	
Water Behind the wall not visible to the naked eye	***Water Behind the wall that has been captured by the IR camera.***

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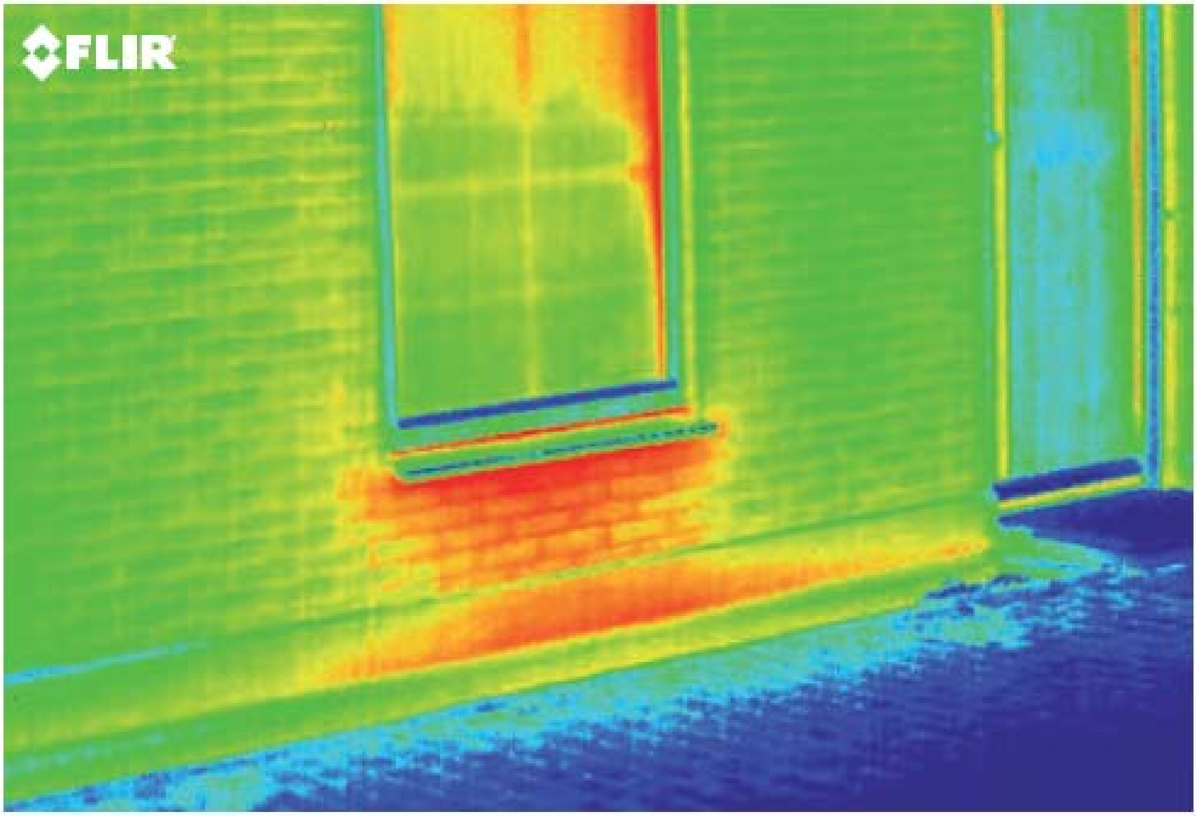
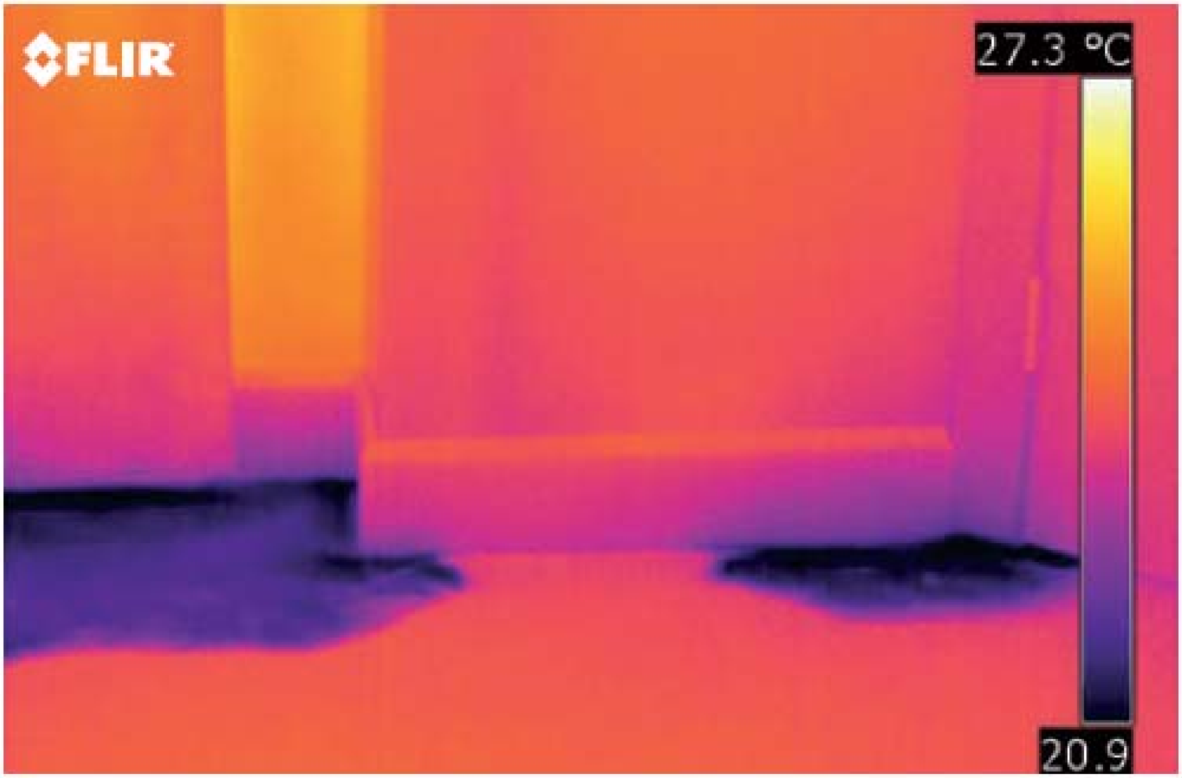
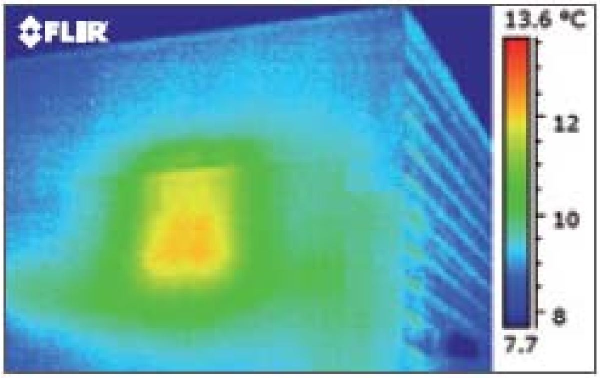


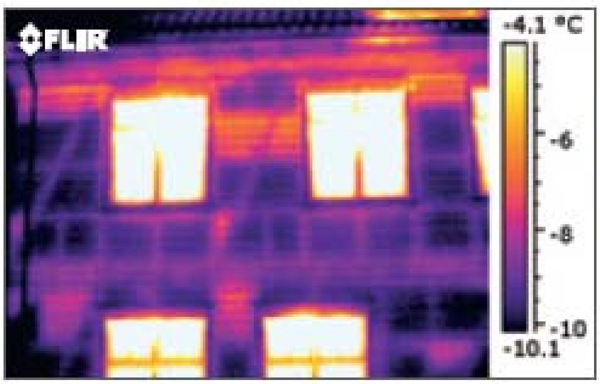
The thermal image clearly shows insufficient insulation in the wall below the window.



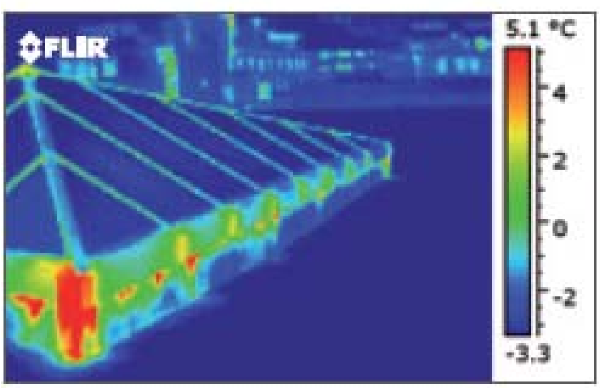
Moisture intrusion in floor, impossible to see with the human eye, but clearly visible on the thermal image.



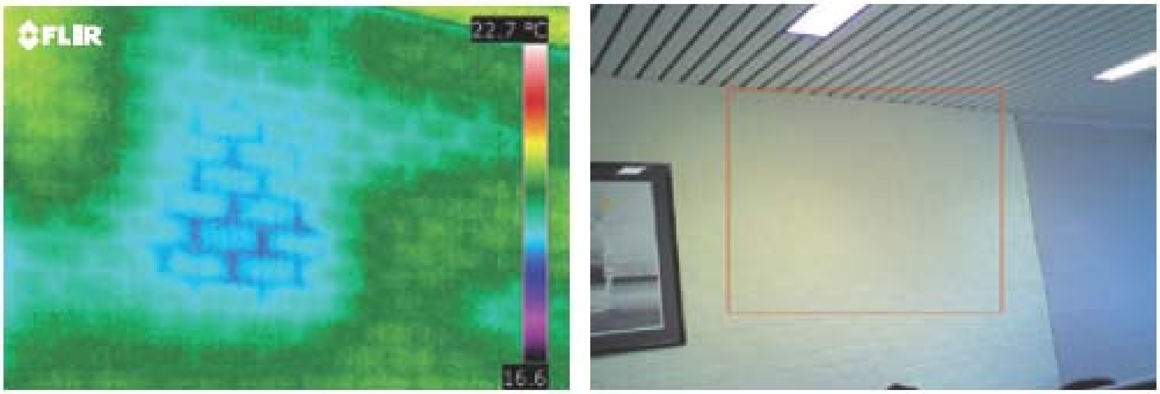
This building is warmer on the inside. It is a sandwich construction, concrete - insulation - concrete. One section of insulation is missing which is not possible to see visually either from the inside or the outside. Here thermal imaging can see what the human eye can't.



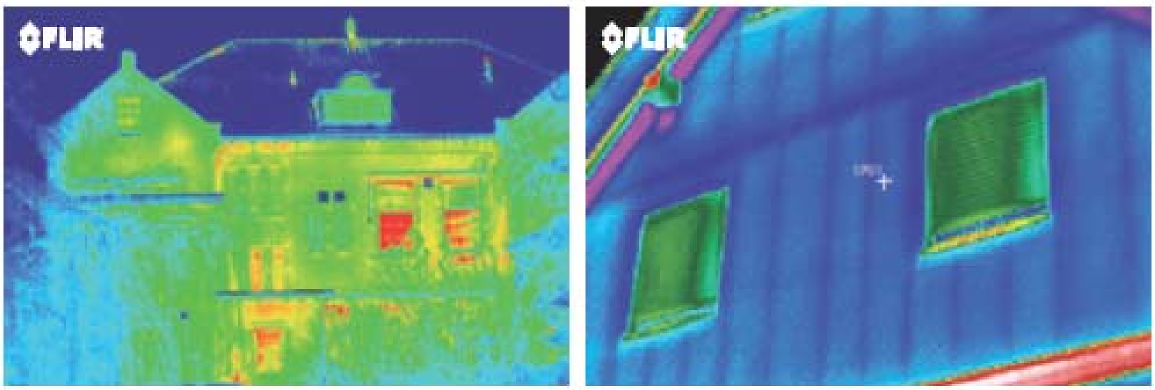
Framework construction. Many of the sections are missing insulation as indicated by the warmer colors.



Glass roof above an atrium. It is watertight, but not air tight. Warm air escapes because of the over pressure.The solution is to air tighten the glass roof.



Missing insulation in parts of the wall.



Thermal survey from outside, the thermal images clearly indicate poor or missing insulation.

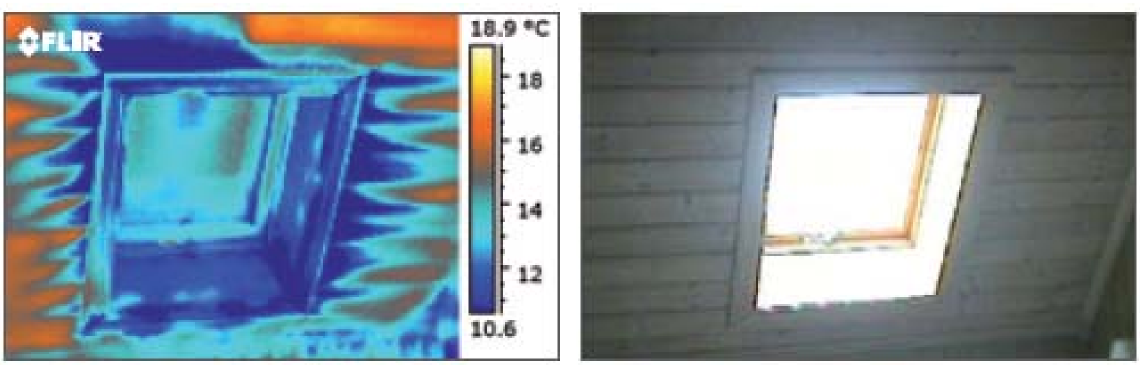


Image shows air leaks between the ceiling and the window.

Fig. 2: When conditions are right, it is possible to locate missing or poorly performing insulation, such as this urethane spray foam, that appears to have separated from the wood framing, creating a vertical cool insulation void in this residential home.

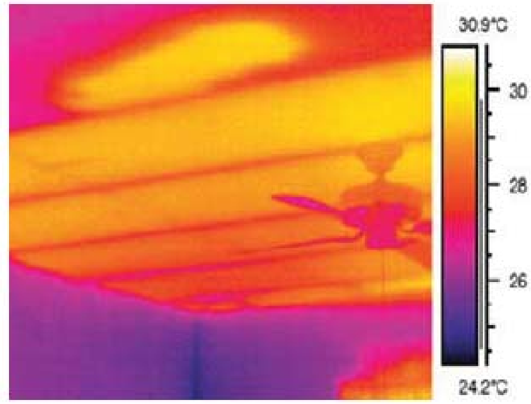


Fig. 3: The insulation voids between the ceiling joists are clearly seen here in warm-weather conditions where there are missing fiberglass batts.

Applicable Reference and Standards

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*
5. *Thermal Imaging guidebook for building and Renewable Energy application*
6. *Testing building envelope systems using infrared thermography - Matt Schwoegler and Jim Fritz, The Snell Group, USA*

7. *Code of Practice- No 2-Assessing the Thermal Bridging and Insulation connectivity UK Thermography association*

8. *ASTM C 1060-97 Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings*

9. *ASTM C-1153-97 Practice for the Location of Wet Insulation in Roofing Systems Using Infrared Imaging*

10. *ISO 6781 Thermal insulation, qualitative detection of thermal irregularities in building envelopes, Infrared Method*

11. *BSRIA Guide -Thermal Imaging of Building fabric – Colin Pearson*

12. *http://www.nashvillethermalimaging.com/about_thermal_imaging.html*

13. *http://www.flir.com/cs/emea/en/view/?id=41612*

14. *http://www.csemag.com/single-article/building-envelope-testing-and-commissioning-best-practices/0855bab5a4e601e9254a616b00983a92.html*.

Conclusion

Traditionally, building envelopes have been commissioned by architectural inspection using punch lists for tracking the corrections needed . Due to the increased interest in high-performance buildings, more attention is being paid to how envelope assemblies affect interior comfort and energy performance. The traditional contractor's quality process has not been effectively used on building envelopes due to the fact that the assemblies are field built by multiple contractors at various times during the construction process. The building envelope consists of an exterior cladding, water channel layer, air barrier, vapor barrier, and an insulation barrier, each of which must be installed correctly without holes or voids in any of the layers to provide the intended performance

It is beyond doubt that both building inspector and a thermal imaging inspector play very important roles from the point of view of ascertaining that the building has been constructed with proper workmanship and consistent with the best industry practices .However there is a difference in that thermal imaging camera can see signs of what's happening behind the walls, floor and ceiling reveal areas of leaks. The Thermal imaging cameras detect temperature differences on any given surface, and when an inconsistent pattern is noted in the camera, it is a sign of a problem and the camera helps in locating the origin and the finishing point of the problem. It is always recommended to have a thermal imaging scan before a building inspection.

A thermographic survey to demonstrate continuity of thermal insulation, areas of thermal bridging and compliance with Building Regulations needs to fulfill the following requirements:

1) Show areas / regions of 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 localized 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

When properly used by qualified individuals, this remarkable technology can play a powerful role in visualizing otherwise invisible building problems and conditions. Contractors and architects alike are both using thermography these days to assure the performance of their buildings. Building specialists count on thermography to help them diagnose tough problems that, left unsolved, are costly or dangerous. Owners rely

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on thermography as a tool for commissioning a new building. While a foundation of expertise must underlie the successful use of thermography for building diagnostics, getting started with most of the applications is often not difficult. An appropriate infrared system is required, with proper training and experience for the operator as well. Having supplementary knowledge of building sciences or access to that information is also vital. The primary return on an investment in building thermography is gaining a higher level of assurance that buildings will perform as intended and occupants will be more comfortable, often at a lower cost.

The above guideline attempts to familiarize the stakeholder with several envelope possibilities based on the information TRAKHEES has collected from study materials referred in the guideline and those received from the stakeholders. This guideline should however not be construed as a scope that is specifically required by TRAKHEES towards compliance. It is strongly recommended that the stakeholders, while using the guideline for an objective understanding, take to the recourse of strong fundamental design integration and analysis to ascertain the true performance of the building and its energy systems. It is prudent to contact the specialists for validation of the performance characteristics.

We wish you good luck in this journey. Should you need any assistance please do not hesitate to contact the department.

Disclaimer

This Guideline for Thermal Imaging has been issued by Trakhees to assist the stakeholders in gaining an understanding of the concepts underlying the thermal imaging principles and the areas where such techniques can be effectively deployed for various applications and scenarios in the built environment As such, this is an

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attempt to disseminate the information TRAKHEES has gathered from the stakeholders and its limited research of the documents that it has reviewed in the course of its regulatory activities.

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