INTERNATIONAL STANDARD

# ISO 6781-1

First edition
2023-08

# Performance of buildings — Detection of heat, air and moisture irregularities in buildings by infrared methods —

## Part 1: General procedures

*Performance des bâtiments — Détection d'irrégularités de chaleur, air et humidité dans les bâtiments par des méthodes infrarouges —*

*Partie 1: Modes opératoires généraux*



Reference number
ISO 6781-1:2023(E)

# Contents

Page





# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for whom a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC1, *Test and measurement methods,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces ISO 6781:1983, which has been technically revised.

The main changes are as follows:

— now comprises the first part of the ISO 6781 series, which addresses the general user of thermography and provides general requirements pertinent to thermography;

NOTE Further parts of the ISO 6781 series provide specific thermographic requirements pertinent to thermographic practitioners, and the technical requirement for thermography of specific types of buildings.

— covers general requirements concerning detection of air leakage and moisture anomalies, using thermographic methods, in addition to thermal anomalies;

— thoroughly updates the thermographic requirements resulting from the vast technological upgrades in thermography since ISO 6781:1983 was published;

— provides general information and specific constraints concerning qualitative thermography and quantitative thermography;

— provides general information and requirements regarding the qualification of thermographic operators and report writers.

A list of all parts in the ISO 6781 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

Infrared building thermography provides a tool to qualitatively identify the presence of energy-wasting defects and anomalies within building structures. These defects and anomalies can include, for example, thermal insulation defects, moisture content, and / or unwanted air movement or leakage within the building enclosure.

Building thermography is carried out by means of an infrared thermography camera, which produces an image based on the apparent radiance temperature of the target surface area. The thermal radiation (infrared radiation density) from the target area is converted by the infrared thermography camera to produce a thermal image (thermogram). This image (thermogram) represents the relative intensity of thermal radiation from different parts of the surface. The radiation intensity indicated by the image is related directly to

a) the surface temperature distribution,

b) the characteristics of the surface,

c) the ambient conditions, and

d) the sensor itself.

As a result, surface temperature distribution can be a key parameter for monitoring the performance of building components, building enclosure and the diagnostics of problems. In use, via analysis of surface temperature distributions, irregularities in the heat and moisture properties of building enclosures and components, and air movement within the building enclosure, can be indicated. These irregularities can be due to, for example, thermal insulation defects, moisture content, air leakage within components or through assemblies, or incorrect installation of components which comprise the construction of the building.

To realize its full utility as an initial qualitative screening technique, or an in-depth diagnostic technique, thermography must often be supported and/or validated by other methods. These methods include, but are not limited to, infrared photosensitive tracer gas methods, fan pressurization of the building enclosure, heat-flow metres, smoke diffusion, anemometry, moisture metres and relative humidity (RH) sensors.

Infrared building thermography inspection methodologies can be used for either new-construction quality control applications or in existing buildings as ongoing condition monitoring for periodic or specific building-condition reporting. The latter applications may be accompanied with visual fault symptoms, while the former may not necessarily present symptoms via visual faults.

# Performance of buildings — Detection of heat, air and moisture irregularities in buildings by infrared methods —

# Part 1: General procedures



## 1 Scope

This document specifies requirements and methodologies for infrared thermographic services for detection of heat, air and moisture irregularities in buildings that help users to specify and understand

a) the extent of thermographic services required,

b) the type and condition of equipment available for use,

c) the qualifications of equipment operators, image analysts, and report authors and those making recommendations, and

d) the reporting of results.

It provides guidance to understanding and utilizing the final results stemming from provision of the thermographic services.

This document is applicable to the general procedures for infrared thermographic methods as can be applied to residential, commercial, and institutional and special use buildings.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6781-3, *Performance of buildings — Detection of heat, air and moisture irregularities in buildings by infrared methods — Part 3: Qualifications of equipment operators, data analysts and report writers*

ISO 7345, *Thermal performance of buildings and building components — Physical quantities and definitions*

ISO 9288, *Thermal insulation — Heat transfer by radiation — Vocabulary*

ISO 9869-1, *Thermal insulation — Building elements — In-situ measurement of thermal resistance and thermal transmittance — Part 1: Heat flow meter method*

ISO 9972, *Thermal performance of buildings — Determination of air permeability of buildings — Fan pressurization method*

ISO 10878, *Non-destructive testing — Infrared thermography — Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 9288, ISO 10878 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

## 3.1 General terms

**3.1.1**
**system**
regularly interacting or interdependent group of associated entities (e.g. components, factors, members, parts) forming an integrated whole and delineated by its spatial and temporal boundaries

Note 1 to entry: One or more of the associated entities define the boundary of the system.

**3.1.2**
**analysis**
careful scrutiny of constituent parts of a *system* (3.1.1) in order to thoroughly understand the whole

**3.1.3**
**function**
functional purpose of the building, building component or building *system* (3.1.1)

Note 1 to entry: The function is the activity assigned to, required of, or expected of the system.

**3.1.4**
**residential building**
building meeting the parameters defined in local building codes as small/residential building and as agreed with the customer receiving thermographic services

**3.1.5**
**parameter**
numerical or other measurable factor forming one of a set that sets the conditions for measurement, or defines the system and its operation

**3.1.6**
**performance**
behaviour, characteristics and efficiency of a building, building component or building *system* (3.1.1)

**3.1.7**
**sign**
characteristic parameter of a signal, which shows information about a state

**3.1.8**
**symptom**
perception, made by means of human observations and measurements (descriptors), which may indicate the presence of one or more *faults* (3.1.12) with a certain probability

**3.1.9**
**syndrome**
group of *signs* (3.1.7) or *symptoms* (3.1.8) that collectively indicate or characterize an abnormal condition

**3.1.10**
**anomaly**
something that deviates from what is standard, normal or expected, and an *irregularity* (3.1.12) or *abnormality* (3.1.11) in a *system* (3.1.1)

**3.1.11**
**abnormality**
deviation from a standard condition



**3.1.12**
**irregularity**
condition which significantly departs from the operational norm

**3.1.13**
**fault**
condition that occurs when a building or one of its components or assemblies degrades or exhibits abnormal behaviour, which may lead to the *failure* (3.1.14) to perform in accordance with its design intent

Note 1 to entry: A fault can be the result of a failure, but can exist without a failure.

Note 2 to entry: Planned actions or lack of external resources are not a fault.

**3.1.14**
**fault propogation**
characterization of the change in severity of a *fault* (3.1.12) over time

**3.1.15**
**failure**
termination of the ability of an item to perform a required *function* (3.1.4)

Note 1 to entry: Failure is an event as distinguished from *fault* (3.1.12), which is a state.

**3.1.16**
**failure mode**
effect by which a *failure* (3.1.14) is observed

**3.1.17**
**diagnostics**
examination of *symptoms* (3.1.8) and *syndromes* (3.1.9) to determine the nature of *faults* (3.1.12) or *failures* (3.1.14) (i.e. kind, situation, extent)

**3.1.18**
**root cause**
either a set of conditions or actions, or both, that occur at the beginning of a sequence of events and result in the initiation of a *failure mode* (3.1.15)

**3.1.19**
**root cause failure analysis**
**RCFA**
after a failure, the logical systematic examination of an item, its construction, application and documentation in order to identify the *failure mode* (3.1.15) and determine the failure mechanism and its basic cause

Note 1 to entry: Root cause failure analysis is often used to provide a solution to chronic problems.

**3.1.20**
**prognostics**
analysis of the symptoms of *faults* (3.1.12) to predict a future condition and remaining useful life

**3.1.21**
**prognosis**
result of the prognostics process

**3.1.22**
**qualitative**
relating to measuring, or measured by the quality of something, rather than its quantity

**3.1.23**
**quantitative**
relating to measuring, or measured by the quantity of something, rather than its general qualities

## 3.2 Thermography terms

**3.2.1**
**infrared**
**IR**
portion of the electromagnetic spectrum extending from the red visible wavelength, 0,75 µm to 1 mm

Note 1 to entry: Because of instrument design and infrared transmission characteristics of the atmosphere, most infrared measurements are made between 0,75 µm and 15 µm wavelengths.

**3.2.2**
**thermography**
representation of the temperature distribution of a surface, in a thermal image

**3.2.3**
**thermographic analysis**
interpretation and determination of the casual mechanisms producing variations and irregularities in the thermal image

**3.2.4**
**quantitative thermographic examination**
examination of whole buildings, structures or components using thermographic methods with the objective of providing *quantitative* (3.1.22) output

Note 1 to entry: Reporting requirements for both qualitative and quantitative examinations are specified in Clause 19.

**3.2.5**
**infrared thermography camera**
**IRT camera**
instrument that collects the infrared radiant energy from a target surface and produces a monochrome (black and white) or colour image, where the grey shades (monochrome) or colour hues are related to the target surface apparent temperature

**3.2.6**
**thermal image**
image which is produced by an infrared thermography camera and which represents the apparent radiance temperature distribution over the target surfaces

Note 1 to entry: Such images are sometimes called "infrared thermograms".

**3.2.7**
**temperature isotherm**
enhancement feature applied to an image, which marks an interval of equal apparent temperature

**3.2.8**
**radiation density isotherm**
region on an infrared (IR) (3.2.1) display consisting of points, lines or areas having the same infrared radiation density

**3.2.9**
**isotherm image**
output from an infrared thermography camera showing *temperature isotherms* (3.2.7) and *radiation density isotherms* (3.2.8)

**3.2.10**
**ironbow palette image**
image comprising a colour palette running from black through blue, magenta, orange, yellow to white that creates best contrast, in particular regarding edges and shapes

**3.2.11**
**image interpretation**
processing and comparing apparent surface temperatures and thermal patterns against those representative of the ideal design, construction, installation and maintenance criteria

Note 1 to entry: In the case of a thermal image or thermogram this can include temperature scaling, spot temperature measurements, thermal profiles, image manipulation, subtraction and storage.

**3.2.12**
**apparent temperature**
uncompensated reading from an infrared thermography camera containing all radiation incidents on the detector, regardless of its source

**3.2.13**
**attenuating media**
windows, filters, atmospheres, external optics, materials or other media that attenuate the infrared radiation emitted from a source

**3.2.14**
**black body**
ideal perfect emitter and absorber of thermal radiation at all wavelengths

Note 1 to entry: The *emissivity* (3.2.15) of a black body is 1... ε = 1.

Note 2 to entry: This is described by Planck's law.

**3.2.15**
**emissivity**
*ε*
ratio of a target surface's radiance to that of a *black body* (3.2.14) at the same temperature and over the same spectral interval

**3.2.16**
**total radiance**
radiant heat flow rate divided by the solid angle around the direction Δ and the projected area normal to this direction

Note 1 to entry: Radiance includes emitted radiation from a surface as well as reflected and transmitted radiation.

**3.2.17**
**apparent radiance temperature**
temperature determined from the measured total radiance

Note 1 to entry: This temperature is the equivalent *black body* (3.2.14) temperature which would produce the same total radiance.

**3.2.18**
**reflectivity**
*ρ*
ratio of the total reflected energy from a surface to total incident energy on that surface

Note 1 to entry: $\rho = 1 - \varepsilon - \tau$ ; for a mirror, reflectivity approaches 1,0; for a black body, $\rho = 0$.

Note 2 to entry: Technically, reflectivity is the ratio of the intensity of the reflected radiation to the total radiation; reflectance is the ratio of the reflected flux to the incident flux. In infrared thermography (IRT), the two terms are often used interchangeably.

**3.2.19**
**reflected apparent temperature**
$T_{refl}$
apparent temperature of other objects that are reflected by the target into the thermography camera

**3.2.20**
**repeatability**
capability of an instrument to repeat exactly a reading on a fixed target over a short- or long-term interval

Note 1 to entry: Repeatability is expressed in ± degrees or a percentage of full scale.

**3.2.21**
**spatial measurement resolution**
measurement-spot size in terms of working distance

EXAMPLE In an infrared radiation thermometer, this is expressed in milliradians or as a ratio of the target-spot size (containing 95 % of the radiant energy, according to common usage) to the working distance. In scanners, cameras and imagers it is most often expressed in milliradian.

**3.2.22**
**instantaneous field of view**
**IFOV**
measurement of a sensor's intrinsic field of view, as distinct from what the sensor can perceive when a scanning motion is incorporated into the imaging system

Note 1 to entry: The instantaneous field of view corresponds to the solid angle that admits light to a sensor at any given instant.

**3.2.23**
**target**
object surface to be measured

**3.2.24**
**working distance**
distance from the target to the instrument, usually to the primary optic

**3.2.25**
**diffuse surface**
surface from which light or other electromagnetic radiation is scattered, rather than reflected

**3.2.26**
**specular surface**
surface from which light or other electromagnetic radiation is strongly reflected, rather than randomly scattered

**3.2.27**
**transmissivity / transmittance**
$\tau$
proportion of infrared radiant energy impinging on an object surface, for any given spectral interval, that is transmitted through the object

Note 1 to entry: Transmissivity: $\tau = 1 - \varepsilon - \rho$

where

$\tau$ is transmissivity;

$\varepsilon$ is emissivity;

$\rho$ is reflectivity.

Note 2 to entry: For a black body, $\tau = 0$. Transmissivity is that fraction of incident radiation transmitted by matter.

**3.2.28**
**thermal index**
**TI**
ratio of temperature drop across the building enclosure, to the total temperature drop between inside and outside environmental temperatures

Note 1 to entry: Thermal index is calculated as follows: TI= [($T_{surface}$−$T_{outside}$) / ($T_{inside}$−$T_{outside}$)] × 100 %

where

| | |
|---|---|
| $T_{surface}$ | is the surface temperature of a part of the building enclosure; |
| $T_{outside}$ | is the localized outside air temperature measured by the user; |
| $T_{inside}$ | is the air temperature inside the structure measured by the user. |

Note 2 to entry: Example: $T_{surface}$ = 60 °C; $T_{inside}$ = 70 °C; $T_{outside}$ = 30 °C.

Therefore TI = [(60 – 30) / (70 – 30)] × 100 = 75 %.

## 4 Symbols and abbreviated terms

| | |
|---|---|
| $L_e$ | Radiance |
| $\varepsilon(\lambda)$ | Spectral emissivity |
| $\rho(\lambda)$ | Spectral reflectivity |
| $\tau(\lambda)$ | Spectral transmissivity |
| $\alpha(\lambda)$ | Spectral absorptivity |
| $\Delta T$ | Differential temperature |
| FOV | Field of view |
| Hz | Hertz |
| IFOV | Instantaneous field of view for detection (3.2.22) |
| IRT | Infrared Thermography |
| MDT | Minimum detectable temperature |
| MRTD | Minimum resolvable temperature difference |
| NETD | Noise equivalent temperature difference |
| NUC | Non-uniformity correction |
| MIFOV | Instantaneous field of view for measurement |
| mrad | milliradian |
| TI | Thermal index |

## 5 Example applications of use of thermography in building assessments

The following list gives examples of where thermography may be applied as an initial or screening tool in the context of building examinations. These examinations can be conducted from inside or outside of the building. The list given below is not exhaustive:

a) surface temperature variations;

b) uniformity of building component installation;

c) thermal anomalies, e.g. thermal bridges, thermal insulation deficiencies, variances, or misfits;

d) location(s) of air movement;

e) extent of air movement through (i) a wall (ii) single component (iii) inter-component (iv) interstitial space, and determination of volumes of air movement when pressure differentials are known;

f) moisture transport due to temperature or pressure differentials;

g) moisture ingress and egress;

h) the extent and phase of moisture present during inspection;

i) thermal comfort;

j) delaminating of coatings or renderings;

k) as a standard for training personnel;

l) provide a basis / set a performance standard / level of qualification for certifying thermographers;

m) energy efficient renovation of buildings;

n) location of under-floor heating;

o) building condition assessments of existing structures;

p) quality control assessments of renovations to existing buildings;

q) quality control assessments of new construction, part of building enclosure commissioning;

r) quality control assessment of repairs to new construction;

s) re-commissioning of building enclosure;

t) detection of structural components within masonry wall assemblies;

u) detection of structural reinforcing in poured concrete assemblies;

v) location of roof leaks, severity of leak and path of drainage through structural components;

w) moulds and fungus.

NOTE The presence of moisture in materials can lead to formation of surface or interstitial mould and fungus.

## 6 Customer preparation

The customer of an infrared thermography (IRT) service shall, as applicable:

a) provide access to the building / facility to be inspected;

b) provide the thermographer with details of any potential safety hazards related to the building / facility use;

c) disclose the history of any prior problems;

d) provide or help develop an inventory of building enclosure, architectural & structural assemblies, building components, etc., to be inspected, in a logical and efficient route with "line of sight" viewing;

e) make available any building, architectural and structural shop drawings;

f) make available any building equipment operating manuals and building "as built" drawings;

g) identify fire zones;

h) provide qualified guide(s) knowledgeable in the operation and maintenance history of the building / facility to be inspected. This person(s) shall accompany the infrared thermographer during the examination and shall be qualified and authorized to:

   — gain access to the inner and outer parts of the buildings to be inspected and to notify the building owner, occupants, operating and maintenance personnel, etc. of the IRT examination activities;

   — open and make accessible any requested areas immediately before examination by the infrared thermographer;

   — either close or secure these areas, or both, immediately after examination by the infrared thermographer;

   — operate, as possible, any building architectural, structural, mechanical and/or electrical equipment;

   — assure that building systems are operating normally, or placed in a state as requested by the infrared thermographer and allow sufficient time for stable thermal patterns to be attained

   — take full responsibility for consequences resulting from actions taken, or not taken, as a result of information provided by an infrared examination;

   — provide information on the results of follow up examination and repair activities.



# 7 Qualification of personnel

## 7.1 Personnel — General guidance

The requirements for operator competence and qualifications vary with the type of structure being investigated and methodologies employed. The building thermographer's qualification classification shall be agreed upon by the customer and service provider. The thermographer shall provide evidence of qualification to that classification prior to the commencement of any work. Building thermographers shall possess knowledge, skills and abilities assessed in accordance with the classification requirements of ISO 6781-3.

The following provides an outline summary of classification levels:

**Class I**: Conversant and capable in knowledge, skills and abilities regarding camera operation, heat transfer basics, infrared basics, applications basics, baseline imaging, thermal signatures, problem identification, recognition of special (atypical) problems, fundamental analysis and reporting, safety considerations, and the ability to think and conceptualize 'thermally'.

**Class II:** All Class I requirements plus knowledge, skills, abilities, baseline experience in building physics and technology, building materials and construction methods, thermographic methodologies, building thermographic procedures, infrared radiometrics, diagnostic imaging, thermographic infrared measurement, and basic Infrared thermography program management.

**Class III:** All Class II requirements plus knowledge, skills, abilities, experience and advanced knowledge in building physics, building technology, materials and construction methods plus advanced thermographic methodologies in thermographic program management, cost / benefit accounting, specialized diagnostics, advanced radiometry, technology planning, and training and certification.

## 7.2 Application specific requirements

### 7.2.1 Residential buildings — Qualification requirements

#### 7.2.1.1 Thermographic inspections

Personnel operating equipment performing thermographic inspections / investigations on residential buildings, where standard construction is employed, shall be qualified to building-thermography qualification Class I or higher in accordance with ISO 6781-3.

#### 7.2.1.2 Report author / Data analyst

Personnel analysing thermographic data / results or writing reports of thermographic inspections / investigations on residential buildings, where standard construction is employed, shall be qualified to building-thermography qualification Class I or higher in accordance with ISO 6781-3.

### 7.2.2 Commercial buildings — Qualification requirements

#### 7.2.2.1 Inspections — Wall assemblies

Personnel supervising or operating equipment performing thermographic inspections / investigations of wall assemblies, of conventional construction, on commercial buildings, shall be:

a) qualified to building-thermography qualification Class II (or higher) in accordance with ISO 6781-3.

b) Alternatively, a Class I thermographer may be the field investigator, but shall either be under the direct supervision of a Class II thermographer, or follow a written procedural methodology prepared by a Class II thermographer. The procedural methodology for the field investigation developed by the Class II thermographer shall be for the specific structure being investigated.

#### 7.2.2.2 Inspections — Roof assemblies

Personnel operating equipment performing thermographic inspections / investigations of low-slope roof assemblies, of conventional construction, on commercial buildings, shall be qualified to building-thermography qualification Class I (or higher) in accordance with ISO 6781-3.

#### 7.2.2.3 Report author / Data analyst — Wall assemblies

Personnel analysing thermographic data / results or writing reports of thermographic inspections / investigations on wall assemblies, of conventional construction of commercial buildings, shall be qualified to building-thermography qualification Class II (or higher) in accordance with ISO 6781-3.

#### 7.2.2.4 Report author / Data analyst — Roof assemblies

Personnel analysing thermographic data / results or writing reports of thermographic inspections / investigations on roof assemblies, of conventional construction, of commercial buildings, shall be qualified to building-thermography qualification Class I (or higher) in accordance with ISO 6781-3.

### 7.2.3 Institutional / Industrial buildings — Qualification requirements

#### 7.2.3.1 Inspections — Wall assemblies

Personnel supervising or operating equipment performing thermographic inspections / investigations of wall assemblies, of conventional construction, on institutional / industrial buildings, shall be qualified to building-thermography qualification Class II (or higher) in accordance with Clause 7 of this document.

A Class I thermographer may be the field investigator in this case, but shall either be under the direct supervision of a Class II thermographer, or follow a written procedural methodology. The procedural methodology for the field investigation shall be developed by a Class II thermographer for the specific structure being investigated.

#### 7.2.3.2 Inspections — Roof assemblies

Personnel operating equipment performing thermographic inspections / investigations of low-slope roof assemblies, of conventional construction, on institutional / industrial buildings, shall be qualified to building-thermography qualification Class I (or higher) in accordance with Clause 7 of this document.

#### 7.2.3.3 Report author / Data analyst — Wall assemblies

Personnel analysing thermographic data / results or writing reports of thermographic inspections / investigations on wall assemblies, of conventional construction, of on institutional / industrial buildings, shall be qualified to building-thermography qualification Class II (or higher) in accordance with Clause 7 of this document.

#### 7.2.3.4 Report author / Data analyst — Roof assemblies

Personnel analysing thermographic data / results or writing reports of thermographic inspections / investigations on roof assemblies, of conventional construction, of on institutional / industrial buildings, shall be qualified to building-thermography qualification Class I (or higher) in accordance with Clause 7 of this document.



## 8 Equipment requirements for thermographic examination of residential, commercial and institutional buildings

### 8.1 Equipment — General requirements

Infrared cameras vary widely. Performance factors to be considered shall include variance in thermal performance, spatial detection capabilities, measurement capabilities, and field of view (FOV).

For basic interior thermographic investigations related to heat and air-leakage detection, a camera with minimum specifications of 3 mrad, 20 ° minimum fixed lens FOV and 0,08 °C sensitivity at 30°C can be suitable given appropriate environmental conditions. For detection of moisture in the same situation, a higher sensitivity such as 0,05 °C sensitivity at 30 °C can be required.

For thermographic investigators examining a broad range of residential, commercial and institutional applications for detection of heat, air and moisture irregularities, the following shall be the minimum equipment requirements:

- thermal sensitivity of 0,05 °C at 30 °C object temperature;
- interchangeable or optical zoom lens with IFOV capability ranging from approximately 10 ° FOV to 45 ° FOV;
- corresponding IFOV spatial detection capabilities as great as 0,5 mrad;
- resolvable thermal, air and / or moisture anomaly size of 10 mm × 10 mm with a minimum resolution of 300 pixels × 300 pixels;
- for visible resolution in building enclosure examinations: the minimum digital image size for visible spatial resolution of defects due to air leakage or thermal or structural irregularities shall be a minimum of 1 pixel per 150 mm$^2$ of wall or surface area;

— for visible moisture in roof examinations: the minimum digital image size for visible spatial resolution of defects due to moisture shall be a minimum of 1 pixel per 645 $mm^2$ of roof area.

For outdoor investigation of building enclosures of large commercial buildings at cold temperatures, the spatial and thermal characteristics demands will be significantly higher.

### 8.2 Calibration and checking of equipment

— Calibrations: Thermographers shall have IRT cameras calibrated to original equipment manufacturers' established specifications, using traceable standards. Records of calibration shall be maintained.

— Equipment check: Quick equipment checks are recommended prior to each examination or survey.

NOTE A quick check can be made by using the human face tear duct, melting ice, or a target of known temperature and emissivity.

— Documented equipment checks shall be carried out using a traceable blackbody reference in accordance with manufacturer's recommendations or any agreed upon applicable industry standard.

## 9 Safety

Prior to the commencement of work, minimum safety rules and guidelines shall be reviewed and established where hazardous environments can exist. Minimum safety rules and guidelines are contained in Annex A.

The thermographer shall immediately report any unsafe conditions encountered during the course of thermographic examinations.

## 10 Thermography techniques

### 10.1 General

Consideration shall be given to the technique(s) selected for use. There are three separate skills within the scope of building thermography:

a) data collection;

b) data processing and analysis;

c) data reporting.

Personnel exercising these skills shall be qualified in accordance with ISO 6781-3.

### 10.2 Comparative thermography

#### 10.2.1 General

Thermography provides a representation of the temperature distribution of a surface by means of a thermal image. Illustrative thermograms and examples of surface-temperature distribution and thermal anomalies are presented in Annex C of this document.

Thermography can be either quantitative or qualitative. Evaluation criteria for each should be based on building physics.

Comparative thermography is commonly used to provide the best available information in lieu of ideal or absolute thermal measurements. It provides useful information for detection of heat, air and moisture irregularities under sometimes less-than-ideal field circumstances. Comparative thermography relies on comparing data from building surfaces with suspect performance against buildings surfaces with known good performance.

An application of comparative quantitative thermography would entail two or more similar building surfaces, components or assemblies operating in the same environment, under the same conditions, but one is exhibiting a dissimilar surface temperature. This can indicate a potential deteriorating condition.

The subsequent quantitative determination of surface temperature difference(s) assists in establishing the severity of the condition. Good thermographic judgment is required to assess if the temperature differentials are to be considered minor, or to be considered as critical.

While qualitative measurements can detect deficiencies, quantitative measurements have the capability of determining severity.

In applications where close quantitative data are not required for monitoring or diagnosing a building assembly or building component problem, qualitative techniques can be more than adequate.

### 10.2.2 Technique

The comparative measurement technique relies on emissivity estimates, reflected apparent temperature and target distance measurements. Emissivity estimates of materials are obtained through experience or via assigning default emissivity values from the most commonly encountered building materials.

In either instance, the ability to perform emissivity estimates and to distinguish emissivity differences in building surfaces under changing conditions is key to assessing suspected failure conditions and root cause failure analysis.

The confidence level of the information obtained will therefore be dependent on the infrared thermography equipment used, the training, knowledge, skills and abilities of the thermographer, and the detection methods applied. These factors shall be considered in subsequent data assessment, decision making, conclusions and assignment of priorities.

## 10.3 Comparative qualitative thermography

Qualitative thermographic examination is the examination of whole buildings, structures or components using thermographic methods with the objective of providing qualitative information only.

When it is not practical to determine the exact temperatures or emissivity's of each building, structure or component surface, the use of comparative qualitative thermography becomes the practical approach.

Comparative qualitative thermographic assessment compares the thermal pattern or profile of one building surface or component, to an identical or similar building surface / component operating under the same environmental conditions (e.g. wind, solar load, temperature and pressure differentials).

Heat, air and moisture anomalies are identifiable by the variation in resulting radiant thermographic patterns between any two or more similar objects operating in the same environment. It is not necessary to assign temperature values to the thermal patterns to discern potential anomalies. This technique does not require any adjustments to the infrared instrument to compensate for atmospheric or environmental conditions, or surface emissivities.

Comparative qualitative thermography is particularly effective when a significant change to a single operating or environmental parameter can be made. Examples would be examination of a residential building for air leakage when neutral or positive pressure is first maintained on the structure, then the pressure quickly changed to a negative pressure. Comparative thermograms with the neutral or positive pressure condition versus the negative pressure condition would reveal the thermal response to the changing pressure condition in the structure, indicating air leakage pathways.

A further example highlights detection of interstitial moisture: Interior temperature is raised to a higher temperature than normal for an extended period of time. The temperature is then dropped quickly creating a transient condition. The presence of moisture is detected through the difference in thermal capacitance of water-laden materials versus dry materials (see 13.2).

## 10.4 Comparative quantitative thermography

### 10.4.1 General

Quantitative thermographic examination is the examination of whole buildings, structures or components using thermographic methods with the objective of providing quantitative output.

Comparative quantitative thermography is used for evaluating the condition of a building, component or assembly by determining approximate surface temperatures '$T$' over an area, then determining differential temperature values, $\Delta T$. These values are used as the basis to discern either faults or failure-condition severity, or both.

To deploy this approach, emissivity values, $\varepsilon_{\text{default}}$, are determined compared with surfaces of similar emissivity in a building operating under the same or similar environmental conditions (e.g. wind, solar loading, temperature and pressure differentials).

Surface temperatures '$T$' are determined using $\varepsilon_{\text{default.}}$ Differential temperature values, $\Delta T$, are determined by comparing the target's temperature to a similar surface of known status or known baseline data.

For high emissivity surfaces, values of both temperature $T$, and temperature difference $\Delta T$, are regarded as reliable provided good measurement techniques are followed.

With these parameters considered, estimated emissivity, distances, and reflected apparent temperatures shall be entered into the IRT camera to indicate a building surface approximate temperature. This, when interpreted, is usually sufficient to determine the severity of a fault condition in a building surface, building assembly or building component.

This approach is effective when surveying many building components or surface locations and provides useful information for determining the severity of faults.

### 10.4.2 Comparative quantitative thermography — Limitations

Limitations of quantitative thermography include:

— Difficulty in precise determination of actual temperature(s) $T$ of a surface, component or assembly under actual IRT field conditions. This is attributable to the physics of IRT, and the multiple variable parameters (emissivity, reflectivity and transmissivity) required to allow a true absolute temperature measurement to be determined.

— Low-emissivity-surface observed temperature ($T$), and differential temperature ($\Delta T$) values are unreliable due to surface and environmental variations.

The measurement uncertainty of thermography in determining in-situ thermal resistance, transmittance and anomalies is approximately +/− 25 %.

If exact determination of thermal resistance and transmittance are required, then it shall be according to ISO 9869-1.



## 11 Non-contact infrared radiometry (spot radiometry) using infrared thermography cameras

Non-contact, spot radiometry measurements shall be made only by Class II or higher qualified thermographers, or Class I thermographers following a documented procedural methodology developed for the particular application by a Class II qualified thermographer.

Absolute infrared thermography IRT measurements shall only be performed if very precise temperature values, or small temperature differentials, are deemed critical. These determinations shall be made under controlled environmental conditions.

NOTE The determination of the corrected temperature of a target using infrared thermography, to arrive at an absolute temperature, can be difficult because of the many technical and environmental factors involved.

## 12 Air leakage and mass transfer

### 12.1 Air leakage

Illustrative thermograms and examples of air leakage and mass transfer anomalies detected by thermography are presented in Annex C of this document.

Testing for air leakage shall be undertaken with a minimum of 10 °C differential temperature and a minimum of 10 Pa differential pressure across the building enclosure.

Differential pressure shall be created using either

a) blower door equipment in accordance with ISO 9972, or

b) operation and manipulation of the building mechanical systems.

Testing for air leakage shall include a means to vary the differential pressure under the two separate conditions of positive and negative pressure.

Calibrated instrumentation shall be available to measure pressures, pressure differentials air flow, temperatures, moisture and RH.

NOTE Thermography will not calculate infiltration leakage flow.

### 12.2 Mass transfer — Moisture

Leakage of warm air through a wall structure is coupled to mass transfer of the air-entrained water vapour along the leakage path. In instances where the exterior temperature and humidity is lower than the interior space, moisture condensation will occur within the wall and is discernible by thermographic techniques described in Clause 13.

The driving forces for exfiltration air leakage can include building pressurization due to mechanical ventilation, wind direction and speed, and 'stack effect' in multi-storey buildings.

These conditions can be simulated by air leakage testing techniques and shall be undertaken in accordance with 12.1.

Unexplainable thermal anomalies not attributable to conductive sources or air movement shall be considered as possible moisture anomalies warranting further investigation.

There are no easily definable physical environmental conditions for conducting moisture evaluations. If moisture evaluations are to be conducted by a thermographer, evaluations shall require the competence level of a Class II thermographer or higher with a background in building physics and technology.

Three techniques are available for detection of moisture anomalies: conductive, capacitive and phase change. Optimized environmental and operating conditions are not the same for each of these techniques. Also, a clear distinction shall be made between interstitial moisture within a building enclosure, and surface moisture.

## 13 Moisture detection

### 13.1 Conductivity test method — Moisture detection

Illustrative thermograms and examples of air leakage and moisture anomalies detected by thermography are presented in Annex C of this document.

Moisture-saturated hydroscopic building materials exhibit significantly increased thermal conductivity over dry materials.

Increased thermal conductivity in similar enclosure assemblies, where consistent full insulation / building material thickness has been determined to exist, shall be regarded as a possible moisture anomaly.

Moisture detection can be determined in interior finish assemblies, interstitial insulation layers, and hydroscopic cladding assemblies through conductive thermographic inspections.

Conductive thermographic testing for moisture shall be performed once steady state heat transfer has been established, and with a minimum differential temperature ($\Delta T$) of 15 °C across the building enclosure. Steady state conditions shall be judged by the responsible thermographer. Given a constant indoor temperature, steady state conditions are generally indicated when the temperature differential between the outdoor surface temperature and outdoor ambient temperature remain constant over several readings under no-wind conditions with absence of solar loading.

### 13.2 Capacitance test method — Moisture detection

Fully moisture-saturated hydroscopic building materials will exhibit a significant increase in thermal capacitance (the ability to retain heat) of up to 1 000 times more than dry materials.

A noticeable increase in thermal capacitance of building assemblies shall be regarded as possible moisture anomalies warranting further investigation.

Capacitive thermographic testing for moisture requires the test area be in a state of transient heat transfer. Compared to dry materials, water-laden areas will lag in time to response to changes in detection surrounding heat transfer.

NOTE The capacitance test method works best on horizontal surfaces where the moisture content remains static and is not subject to drainage movements.

### 13.3 Phase change test method — Moisture detection

As water changes state, latent heat is absorbed or released due to vaporization, condensation, freezing, melting or sublimation.

Condensation and freezing phase changes release (latent) heat. These are exothermic processes.

Vaporization, melting and sublimation phase changes absorb (latent) heat. These are endothermic processes.

Areas of building enclosures, building assemblies or building components exhibiting suspected latent endothermic or exothermic characteristics shall be regarded as possible moisture anomalies warranting further investigation.

Each of the five phase-changes phenomena are driven by specific environmental conditions. The thermographer shall develop and report on the individual test method procedures applicable to each situation.



Detection of moisture via a phase-change method is extremely transient in nature and requires constant monitoring of environmental conditions during inspections. Phase-change induced thermal patterns can also be present with capacitance or conductive induced thermal patterns.

NOTE There can be more than one phase change phenomenon occurring at the same time in the same building assembly.

## 14 Baseline measurements for building maintenance and condition monitoring

For both comparative and absolute thermographic techniques, baseline initial measurements of facilitates are recommended for future diagnostic and prognostic reference. This allows comparison of subsequent IRT surveys with previous thermograms of building structures operating under the same or similar environmental conditions. This assists in monitoring of unstable or deteriorating conditions and identifies developing problems early preventing major maintenance operations or catastrophic failures.

## 15 Data collection

Data collection shall be carried out in accordance with the following parameters:

a) Infrared inspections shall be performed when environmental and physical conditions such as solar, wind, surface and atmospheric conditions and heat transfer are favourable to gathering accurate data.

b) The operating and environmental conditions under which data are acquired shall be noted so that the tests may be repeatable.

c) The thermographer shall ensure that all emissivity and reflected apparent temperature determinations are carried out in accordance with Annex B.

d) For qualitative investigative work, the thermographer and data analyst shall ensure the target size is within the spatial resolution of the camera. The thermographer shall ensure that the minimum spot size for all investigative work shall not be less than 150 mm$^2$ (0.25 in$^2$) unless otherwise specified in a written procedural methodology developed for the task by a Class II thermographer.

   — The minimum digital image size for visible resolution of defects due to air leakage, thermal or structural irregularities; for building enclosure examinations shall be a minimum of 1 pixel per 150 mm$^2$ of target surface area.

   — The minimum digital image size for visible spatial resolution of moisture for roof inspections shall be a minimum of 1 pixel per 645 mm$^2$ of roof area.

e) The thermographer and data analyst shall have sufficient knowledge, skills and abilities concerning building materials, assemblies, finishes and technology. Sufficient knowledge will encompass the ability to interpret data associated with building materials and finishes and building technology, and resulting thermal anomalies represented by the observed patterns of radiation.

f) For qualitative investigative work, the thermographer shall use infrared thermography and measurement equipment with sufficient capability to meet the building examination requirements.

g) Following repair, or when requested by the end user, it is recommended that each anomaly be re-inspected to ensure that the resultant thermal patterns are normal and the assessed problem corrected.

h) The thermographer shall ensure that all items of interest are within focus, and do not exceed the depth of field limitations of the camera and lens. Where imagery is taken at an angle to an examined surface, or where part of the area under examination is in focus, and part out of focus due to lens depth of field, multiple images shall be taken such that all areas are within focus.

i) All image data shall be recorded using a ‘high-bit’ depth (e.g. 12 bit, 14 bit or 16 bit) to allow the imagery to be manipulated and adjusted with post-analysis software. Data shall be preserved in a form that allows independent review.

## 16 Field measurements of reflected temperature and emissivity, and attenuating media

In many instances, field measurements of reflected apparent temperature and emissivity need to be carried out in order to obtain estimated absolute temperatures. These measurements shall be carried out in accordance with Annex B as well as in accordance with established industry standards and practices, normative references and manufacturers’ guidelines.

Reflected temperatures and emissivity are also relevant in qualitative inspections and shall be noted to validate possible thermal anomalies created by these factors.



## 17 Comparative assessment criteria — Severity

Comparative assessment is a process of comparing temperature differences and patterns across a surface. As in any severity assessment process the absolute and differential temperatures and condition profiles need to be determined under two key longitudinal conditions, one being the “as new”, or “known status”, and the “failed” conditions. Typical instances of these conditions include:

— before occupancy condition survey;

— annual post-occupancy condition survey;

— before renovation survey;

— post renovation survey;

— pre-sale audits and inspections;

— reclamations warranty survey;

— known other ‘typical’ conditions.

Severity assessment is the subsequent process of determining the condition of the building components and assemblies between any two or more previously determined conditions.

The key areas of profile assessment are temperature gradients, changes in profile, historical changes, localized differences, absolute temperatures, thermal pattern configurations, and location of anomalies or profile characteristic relative to the item.

## 18 Diagnosis and prognosis

### 18.1 Survey intervals

Survey intervals shall be determined. The determination of survey interval is necessary for confirming prognosis accuracy rather than fault identification.

Determine building survey intervals accounting for perceived rate of deterioration and spread of potential faults (from perceived variances in thermal patterns) over time as indicators of fault propagation.

### 18.2 Image interpretation

Image interpretation is a process of comparing apparent surface temperatures and thermal patterns against those representative of the ideal design, construction, installation and maintenance criteria.

When using IRT for building monitoring, the environmental conditions at the time of each survey shall be determined in detail. Many changes in thermal patterns occur when measured under varying prevailing environmental conditions. These are not just limited to temperature, but RH, wind speed and direction, building pressurization, and solar loading also.

The design of a building and its enclosure assemblies and structural systems is essential to understanding the thermal performance of a building and any faults present during thermographic examination. When using IRT to assess a building, the building and its enclosure assemblies and structural systems shall be considered as a whole. Each image shall be analysed as part of a series rather than an individual representation of a localized condition.

### 18.3 Fault identification process

A typical fault identification process is as follows:

a) determine temperature and thermographic patterns expected when the building is operating under "as-designed" normal conditions;

b) develop severity assessment criteria associated with the building design, and that of its structures, enclosure assemblies and components;

c) perform thermographic survey;

d) assess severity criteria associated with anomalies and faults discovered in the "as-found" operating condition" versus comparative previous "as new" or previous "as known" condition;

e) determine whether the temperature and pattern anomalies are caused by the operating condition or a fault condition;

f) develop fault diagnosis;

g) develop prognosis if required;

h) issue report with recommendations.



## 19 Test report

### 19.1 General information

The thermographer shall provide reports for infrared inspections unless otherwise agreed with the customer. The report and format shall contain, but not be limited to, the following information:

a) the name, address and contact information of the customer;

b) the name, address and contact information of the organization providing the thermographic services;

c) the name and qualifications of each thermographer, data analyst, and person making recommendations and writing the report;

d) the name of each guide or assistant accompanying the infrared thermographer during examination;

e) the type, model and serial number, lens FOV; the range of distances to target surfaces the equipment will be operated at, and verification that they comply with IFOV requirements for spatial resolution of captured IRT images;

f) date of calibration for the infrared equipment used;

g) the objective(s) of the thermographic investigation / tests and any exclusions;

h) a list of all building, building assembly and building components planned to be inspected and subsequently inspected. Also, notations on the same list of those buildings, building assemblies and components not inspected;

i) details of the operating and environmental conditions for each building, building assembly and building component at and prior to the time of examination;

j) sketches or photographs identifying the parts of the building, building enclosure assemblies and / or building components examined;

k) sketches, photographs or camera data of the building showing the positions of thermograms obtained during the thermographic examination;

l) details of any methods employed to support thermographic measurements and results / measurements obtained from the methods;

m) the date(s) and time(s) of the thermographic examination(s);

n) if quantitative thermographic methods are used, a statement of the measurement uncertainty / possible causes of error shall be included. Statistical measurement uncertainty shall be estimated using standard statistical techniques such as ANOVA in conjunction with the published measurement accuracies of the equipment used;

o) the date when the report was prepared.

## 19.2 Building-specific information

The report shall include the following building-specific information if applicable:

a) A brief description of the construction of the building based on field observations.

NOTE This can be supported by drawings or other construction documents when available.

b) Type(s) of surface material(s) used in the structure and the estimated value(s) of emissivity of this (these) material(s).

c) Geographical orientation of the building with respect to the points of the compass (plan), distance to and description of the surrounding (e.g. buildings, vegetation, landscape).

d) The operational status of the building mechanical systems according to building occupancy and other considerations.

e) The pressure differential profiles of the building during

— all times of the IRT inspection, and

— the duration of time each pressure differential was present prior to and during inspection.

f) Outside environmental conditions including as a minimum:

— air temperature at the start of the examination and during the thermographic examination;

— RH;

— Any precipitation events prior to and during the thermographic examination;

— Direction of the wind, and wind velocity during the thermographic examination;

— General information about sky conditions including, clear sky or cloud conditions observed during the 12 h period prior to commencement and during the thermographic investigation;

— Minimum and maximum air-temperature values observed during the 24 h period prior to the commencement of the thermographic examination;

— General information about solar radiation conditions observed during the 12 h period prior to commencement and during the thermographic examination.

NOTE General information concerning prevailing weather conditions prior to the thermographic inspection can be obtained from local weather stations and internet sources.

g) Inside environmental conditions, including air temperature, RH, dew point.

h) Where reasonably practicable, air pressure differential over the leeward and windward side of the building or structure, and for each applicable storey.

i) Quantitative statement of building pressure at points of moisture leakage.

j) RH, where moisture detection is encountered.



### 19.3 Qualitative inspections

When performing a qualitative infrared examination, the thermographer shall provide the following information for each anomaly identified:

a) the exact location and description of each anomaly;

b) the spot size resolution based on the distance to the object and spatial resolution of the IRT cameras used in the specific inspection;

c) copies of thermograms of the anomalies and corresponding visible-light image(s) identifying the locations of the thermograms and details of any attenuating media;

d) details of any filters or external optics used;

e) thermograms obtained from the thermographic examination with a detailed analysis and an explanation of the causal mechanisms of the anomaly, Class II or III thermographers, qualified according to ISO 6781-3, capable of determining the causes of anomalies;

f) an evaluation rating, or a statement of the importance of the anomaly vis-à-vis the durability of the structural or architectural assembly;

g) reference to, or statement of, any assessment criteria used;

h) notation of any unsafe conditions or practices observed during the course of thermographic investigations.

### 19.4 Quantitative inspections

When performing a quantitative infrared examination, the thermographer shall provide the following additional information:

a) the distance from the IRT camera to the anomaly;

b) the emissivity, reflected apparent temperature and transmission values used to calculate temperatures;

c) the spot size resolution based on the distance to object and spatial resolution of IRT camera used in the specific inspection;

d) note of unsteady environmental conditions, both inside and outside of the building, e.g. large temperature swings, differences in solar loading, variations in wind speed, pressure differential changes, precipitation;

e) any other information / conditions that can affect the results, repeatability or interpretation of the anomaly.

### 19.5 Reporting of unsafe conditions

The thermographer shall immediately report any unsafe conditions encountered during the course of thermographic investigations.

# Annex A
(normative)

# Pro-forma safety rules and guidelines

## A.1 General

This annex gives pro-forma safety rules and guidelines that shall be observed by all parties concerned (see Clause 9).

## A.2 Requirements for safety

The thermographer shall take into consideration the safety guidelines, rules and regulations of the customer at all times.

Prior to commencement of work, the following minimum safety guidelines and rules should be followed:

a) a site safety induction shall be completed where deemed appropriate by the customer;

b) personal protective equipment (PPE) shall be worn to site standards;

c) carrying out a job hazard risk assessment shall be completed;

d) ensure a site standby person shall be present at all times, within clear sight, where appropriate by the customer;

e) if an injury occurs, the standby person shall notify the site safety response services;

f) any incidents shall be reported via an appropriate incident report system.

**IMPORTANT — Unless the necessary qualifications, licenses, or other training is held, or dispensation by the customer granted, the thermographer shall not perform any tasks that are normally done by qualified personnel including:**

— **operating of any building equipment;**

— **opening or closing cabinets containing electrical or mechanical equipment.**

The thermographer shall not alter or modify any building system, guards, enclosures or barriers, or defeat any safety devices, or building or equipment interlock systems in any way. Modifications carried out by the building operational staff or their qualified contractors shall be noted and recorded as part of the operational procedures prior to and during the IRT examinations.

# Annex B
(normative)

# Field measurements of reflected apparent temperature and emissivity

## B.1 How to measure reflected apparent temperature

### B.1.1 Equipment requirements

To measure target reflected apparent temperature a calibrated quantitative IRT camera is required which allows the thermographer to input reflected apparent temperature, $T_{refl}$, and emissivity, $\varepsilon$, values.

### B.1.2 Surface texture considerations

The technique for obtaining reflected apparent temperature varies with the type of surface being examined: specular or diffuse.

On examining a diffuse surface, the background is essentially the area-weighted average of the entire hemisphere facing the surface. Small hot surface areas make only a very small contribution to the overall area weighted average.

Conversely, small, hot areas reflecting from smooth and specular surfaces at an equal and opposite angle potentially make a significant contribution to the IR signal from the surface. This is an important consideration if undertaking spot radiometric measurements local to that area.

### B.1.3 Direct method

The procedure for determining the reflected apparent temperature, $T_{refl}$, using the direct method shall be as follows.

a) Set the IRT camera's emissivity control to 1,00.

b) Place the IRT camera at the desired location and distance from the target. Estimate the angle of reflection, $\alpha$, and the angle of incidence, $\beta$, when viewing the target with the camera from this location (see Figure B.1).

c) Position the IRT camera so that it is at the angle of reflection from the target. View the sources reflected by the target (see Figure B.2).

d) Measure the average apparent temperature of these sources with the camera. Use any camera features available (such as area averaging) which average these reflected apparent temperatures. Record this temperature. It is the reflected apparent temperature, $T_{refl}$, of the target.

   Highly diffuse surface: Observe and measure the average entire hemispherical background with extreme out of focus.

   Semi-diffuse surfaces: At an approximate equal and opposite angle to the angle created between the surface and the lens centreline, observe and measure the average temperature of a limited hemispherical background; ~ 2 times lens-angle FOV with lens slightly out of focus.

   Specular surfaces: Obtain area average by moving so the background is uniform within the lens angle. If warmer/cooler area reflection cannot be obtained from the surface(s), change angle and make precise in-focus measurement of the reflecting background which is in the area of interest.

For optimal measurement, the background should be shielded and measurement angle moved to avoid intense or extreme backgrounds, e.g. extremely cold or warm window surfaces, stoves, furnaces, incandescent lights.

e) For greater accuracy, repeat procedures b) to d) a minimum of three times and average the temperatures.

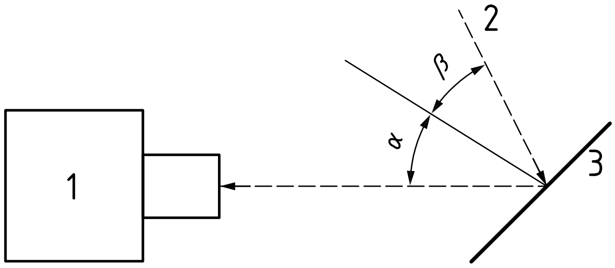
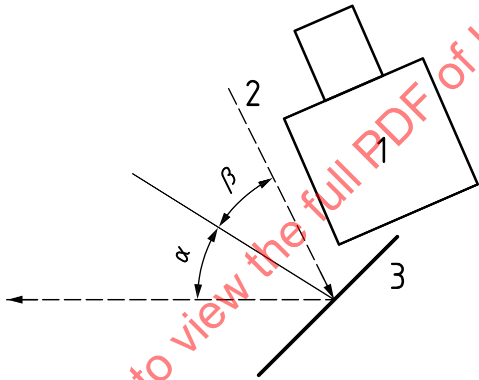



**Figure B.1 — Direct method step b)**




**Key**

1 IRT camera
2 reflected heat source
3 target
$\alpha$ angle of reflection
$\beta$ angle of incidence
$\alpha = \beta$

**Figure B.2 — Direct method step c)**

Compensation for the reflected apparent temperature can be made by entering the averaged reflected apparent temperature in the IRT camera under the $T_{\text{refl}}$ input (sometimes referred to as “TAM”, “amb. temp.”, “reflected apparent temperature”, or “background temperature”).

Thermographers shall test for the significance of reflected apparent temperatures by shielding the target from various angles and observing any visual or temperature changes shown in the thermal image. Errors caused by hot or cold sources of reflected radiation shall also be reduced by shielding the target from these sources.

Reflections produced by a point source (such as the sun) can be avoided by moving the camera position and angle relative to the target. Take into consideration also that reflected apparent temperatures can be lower than ambient temperatures.

Thermographers should be aware that the direct method usually does not include the heat from the thermographer's body as a source of reflected radiation. In some cases, this can create a significant error.



## B.2 How to measure the emissivity of a target

### B.2.1 Equipment requirements

In order to measure target emissivity, the following equipment is required:

a) a calibrated quantitative IRT camera that allows the thermographer to input reflected apparent temperature, $T_{refl}$, and emissivity, $\varepsilon$, values; and

b) a natural or induced means of heating the target at least 10 °C above the reflected apparent temperature such that the target temperature is stable and close to the temperature of the target(s) to be measured; and

c) a calibrated contact or mirrored thermometer; or

d) a surface-modifying material such as paint or tape with a known high emissivity in the waveband of the IRT camera being used and at a temperature close to that of the target

### B.2.2 Contact method

The procedure for determining the emissivity, $\varepsilon$, using the contact method shall be as follows:

a) Place the IRT camera at the desired location and distance from the target to be measured.

b) Measure and compensate for the target's reflected apparent temperature.

c) Aim and focus the IRT camera on the target and, if possible, freeze the image.

d) Use an appropriate camera measurement function (such as spot temperature, cross hairs or isotherms) to define a measurement point or area in the centre of the camera's image.

e) Use a contact or mirrored thermometer to measure the temperature of the point or area just defined by the camera's measurement function. Note this temperature.

f) Without moving the camera, adjust the emissivity control until the indicated temperature is the same as the contact temperature just taken. The indicated emissivity value is the emissivity of this temperature target measured with this waveband camera.

g) For greater accuracy, repeat procedures b) to f) a minimum of three times and average the emissivity values.

h) Compensate for emissivity by entering the averaged emissivity value in the IRT camera under the emissivity input (commonly referred to as "$\varepsilon$", "emissivity").

### B.2.3 Reference emissivity material method

The reference emissivity material method is as follows:

a) Place the IRT camera at the desired location and distance from the target to be measured. Aim and focus the IRT camera on the target.

b) Measure and compensate for the target's reflected apparent temperature.

c) Apply the surface-modifying material on or immediately adjacent to the target you are measuring. Make sure the surface modifying material is either dry or in good contact with the target, or both.

d) Enter the known emissivity of the surface-modifying material in the emissivity input.

e) Aim and focus the IRT camera on the surface-modifying material. Allow enough time for the temperatures to stabilize, freeze the image, and measure and note the indicated temperature.

f) Aim and focus the IRT camera on the target immediately adjacent to the surface-modifying material, or remove the surface-modifying material and aim and focus the camera on the previously modified surface.

   Be sure to allow enough time for the temperature to stabilize, freeze the image, and measure and note the indicated temperature.

g) Using the frozen image, adjust the emissivity control until the indicated temperature is the same as the just taken, non-contact temperature of the surface-modifying material. The indicated emissivity value is the emissivity of this temperature target measured with this waveband camera.

h) For greater accuracy, repeat procedures b) to g) a minimum of three times and average the emissivity values.

i) Compensate for emissivity by entering the averaged emissivity value in the IRT camera under the emissivity input (commonly referred to as "ε", "emissivity").

## B.3 General

Both methods of measuring emissivity require contact with the target surface.

Whenever possible, temperature measurements shall be verified with other thermometers.

These methods are valid only for opaque target surfaces within the waveband of the IRT camera.



# Annex C
(informative)

# Examples of buildings heat, air and moisture faults, failures and anomalies detected by infrared thermography (IRT)

## C.1 Heat and thermal transmittance faults, failures and anomalies detected by IRT

The thermograms in Figures C.1 to C.5 provide qualitative illustrations of thermal heat loss and gain and the importance of utilizing adequate temperature differentials across walls and ceilings in order for clear thermograms to be obtained.

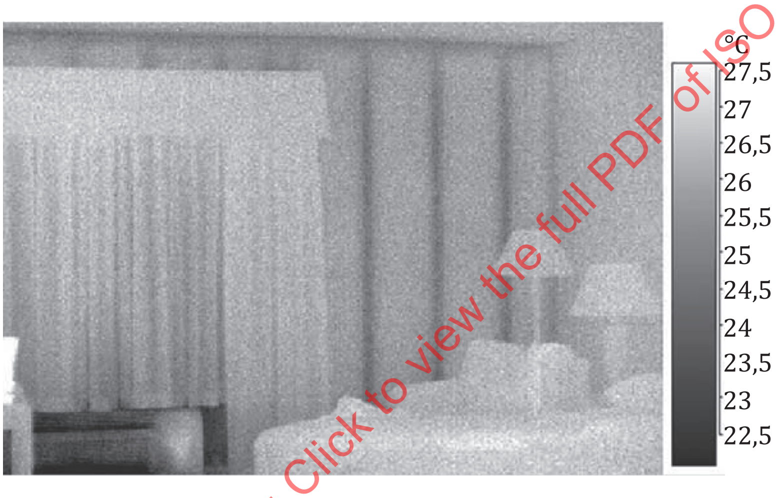



**Figure C.1 — Wall — Insulated stud wall with good construction — Qualitative illustration of heat loss**

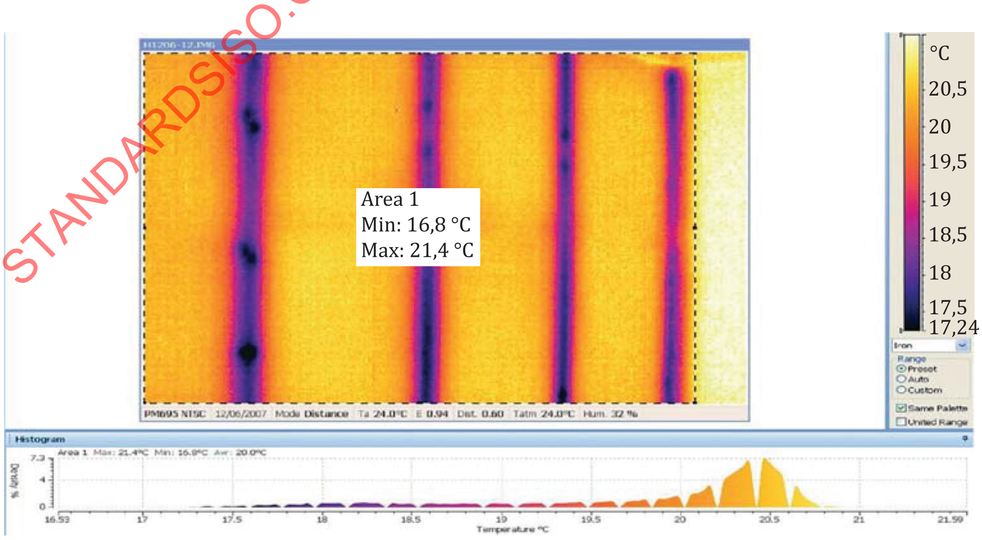



**Figure C.2 — Wall — Insulated stud wall with good construction — Qualitative illustration of heat loss with histogram**

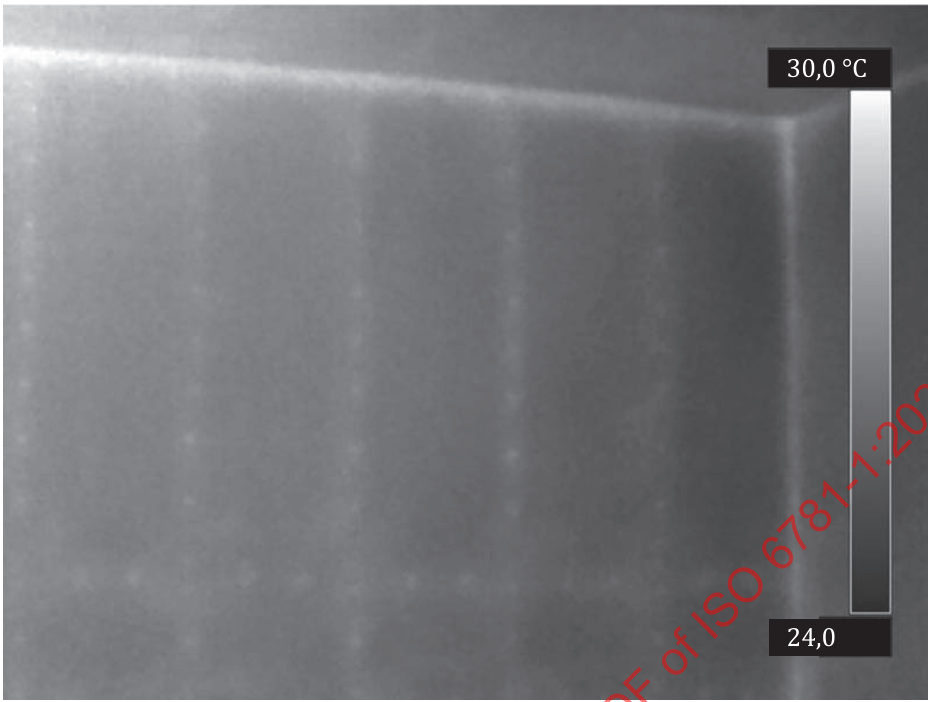



**Figure C.3 — Wall — Insulated stud wall with good construction — Qualitative illustration of thermal heat gain**

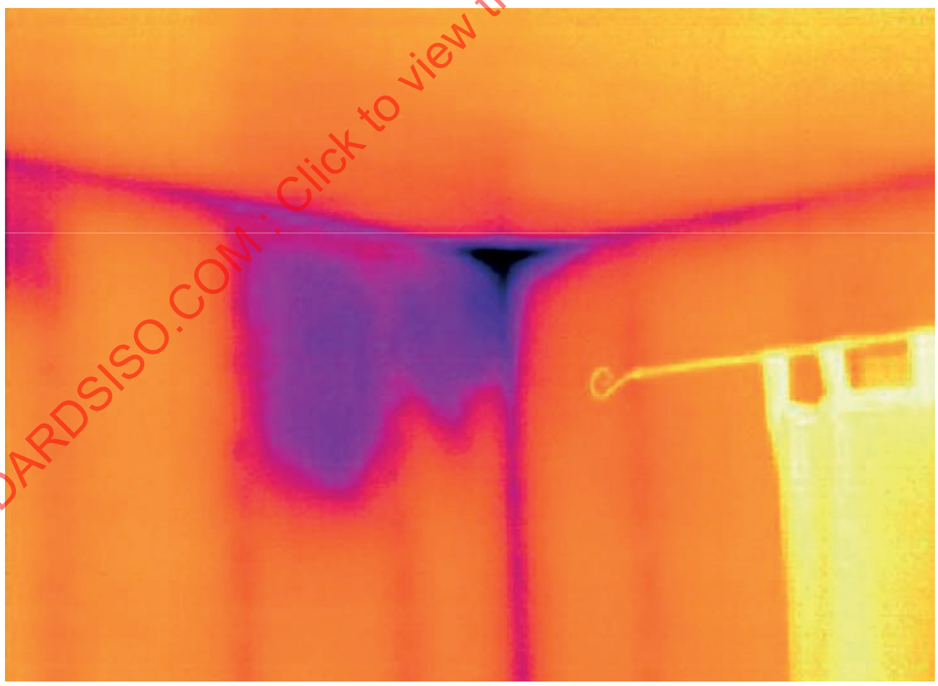


**Figure C.4 — Wall — Insulated stud wall — Qualitative illustration of thermal insulation fault**

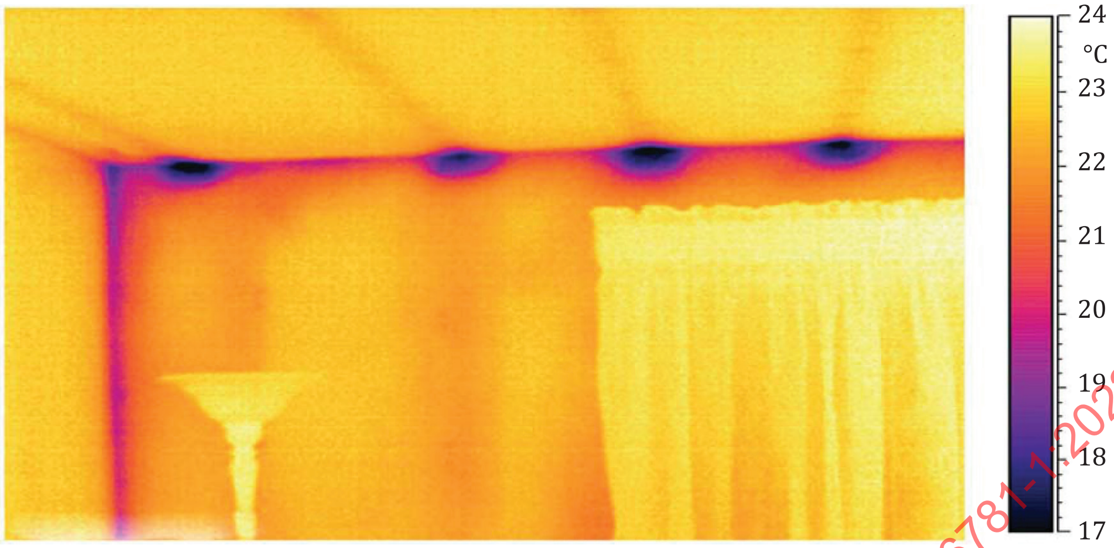



**Figure C.5 — Insulated stud wall / ceiling — Qualitative illustration of joist thermal bridging and air infiltration**

## C.2 Heat and air infiltration faults, failures and anomalies detected by infrared thermography (IRT)

**C.2.1 Wall penetrations -** The thermograms in Figures C.6 to C.9 provide a qualitative illustration of detecting air infiltration anomalies at wall penetrations, and the importance of utilizing

a) adequate pressure differentials (e.g. by blower door) across the wall,

b) temperature differential across the wall, and

c) sufficient time lapse for air infiltration to be established in order for clear thermograms to be obtained.

Note the flared pattern of air leakage (infiltration) at 3 Pa negative pressure following application of 50 Pa negative pressure for 15 min.


**Figure C.6 — Greyscale palette image — Insulated stud wall with 5 °C temperature differential and 3 Pa negative pressure — Qualitative illustration of air infiltration**