International Standard ISO 6781

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Thermal insulation — Qualitative detection of thermal irregularities in building envelopes — Infrared method

Isolation thermique — Détection qualitative d'irrégularités thermiques dans des enveloppes de bâtiments — Méthode infrarouge

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

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It has been approved by the member bodies of the following countries:

Australia	Egypt, Arab Rep. of	Norway
Austria	Finland	Spain
Belgium	France	Sweden
Canada	Italy	USA
Denmark	Japan	

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Germany, F.R.
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Thermal insulation — Qualitative detection of thermal irregularities in building envelopes — Infrared method

0 Introduction

Irregularities in the thermal properties of the components constituting the external envelope of a building result in temperature variations over the surfaces of the structure. The surface temperature is also influenced by air flow within and/or through the envelope of the building. The surface temperature distribution can thus be used to detect thermal irregularities due, for example, to insulation defects, moisture content and/or air leakage, in the components constituting the external envelope of the building.

Thermography is a method of indicating and representing the temperature distribution over a part of a building envelope. In the context of this International Standard, thermography is carried out by means of an infrared radiation sensing system which produces an image based on the apparent radiance temperature. The thermal radiation (infrared radiation density), which depends on the surface temperature, is converted by the infrared radiation sensing system to produce a thermal image representing the relative intensity of thermal radiation from different parts of the surface. The radiation intensity is a function of the surface temperature, the characteristics of the surface and the sensor, and the ambient conditions. The procedure also involves interpretation of the thermal images (thermograms).

Valuable information for the application of this International Standard will be given in a Technical Report. This information, which was not regarded as suitable for inclusion in this International Standard, will cover the practical application of building thermography and the problems involved, instrumentation, test reports, educational requirements and certification, together with a bibliography.

1 Scope and field of application

This International Standard specifies a qualitative method, by thermographic examination, for detecting thermal irregularities in building envelopes. The method is used initially to identify wide variations in the thermal properties, including air tightness, of the components constituting the external envelopes of buildings.

The results obtained by means of this method have to be interpreted and assessed by persons who are specially trained for this purpose. (See annex D.)

This International Standard does not apply to the determination of the degree of thermal insulation and air tightness of a structure. For such determinations, examinations by other methods are required.

2 Definitions[1)]

For the purposes of this International Standard, the following definitions apply.

2.1 thermography: Determination and representation of surface temperature distribution by measuring the infrared radiation density from a surface, including interpretation of thermal images.

2.2 thermal image: Image which is given by an infrared radiation sensing system and which represents the apparent radiance temperature distribution over a surface.

2.3 thermogram: A recording of a thermal image.

2.4 radiance: Total amount of energy emanating from a surface per unit solid angle and unit projected area.

Radiance includes emitted radiation from a surface as well as reflected and transmitted radiation.

2.5 apparent radiance temperature: Temperature determined from the measured radiance.

This temperature is the equivalent black body temperature which would produce the radiance.

2.6 isotherm image: Thermal image with isotherms.

2.7 isotherm: A region of points having the same temperature.

In this context, an isotherm may refer to a feature used to outline, on the display, the points, lines or areas having the same infrared radiation density.

1) A vocabulary relating to thermal insulation will form the subject of ISO 7345.

3 Principle

Thermographic examination of parts of buildings comprises:

a) determination of the surface temperature distribution, over a part of a building envelope, from the apparent radiance temperature distribution obtained by means of an infrared radiation sensing system;

b) ascertainment of whether this surface temperature distribution is 'abnormal', i.e. if it is due, for example, to insulation defects, moisture content and/or air leakage;

c) estimation of the type and the extent of defects.

In order to determine whether the observed variations in the thermal insulation properties are abnormal, the thermograms obtained are compared with the anticipated temperature distribution over the surface, determined by the design characteristics of the building envelope and by the environment at the time of examination. The anticipated temperature distributions can be determined by means of 'reference thermograms' (see 5.3 and annexes A, B and C), calculations or other investigations. This determination is based on drawings and other construction documents relating to the external envelope and to the installations of the building under investigation.

The general procedure for the interpretation of thermal images is represented schematically in figure 1.

Additional information on thermography is given in annex D.

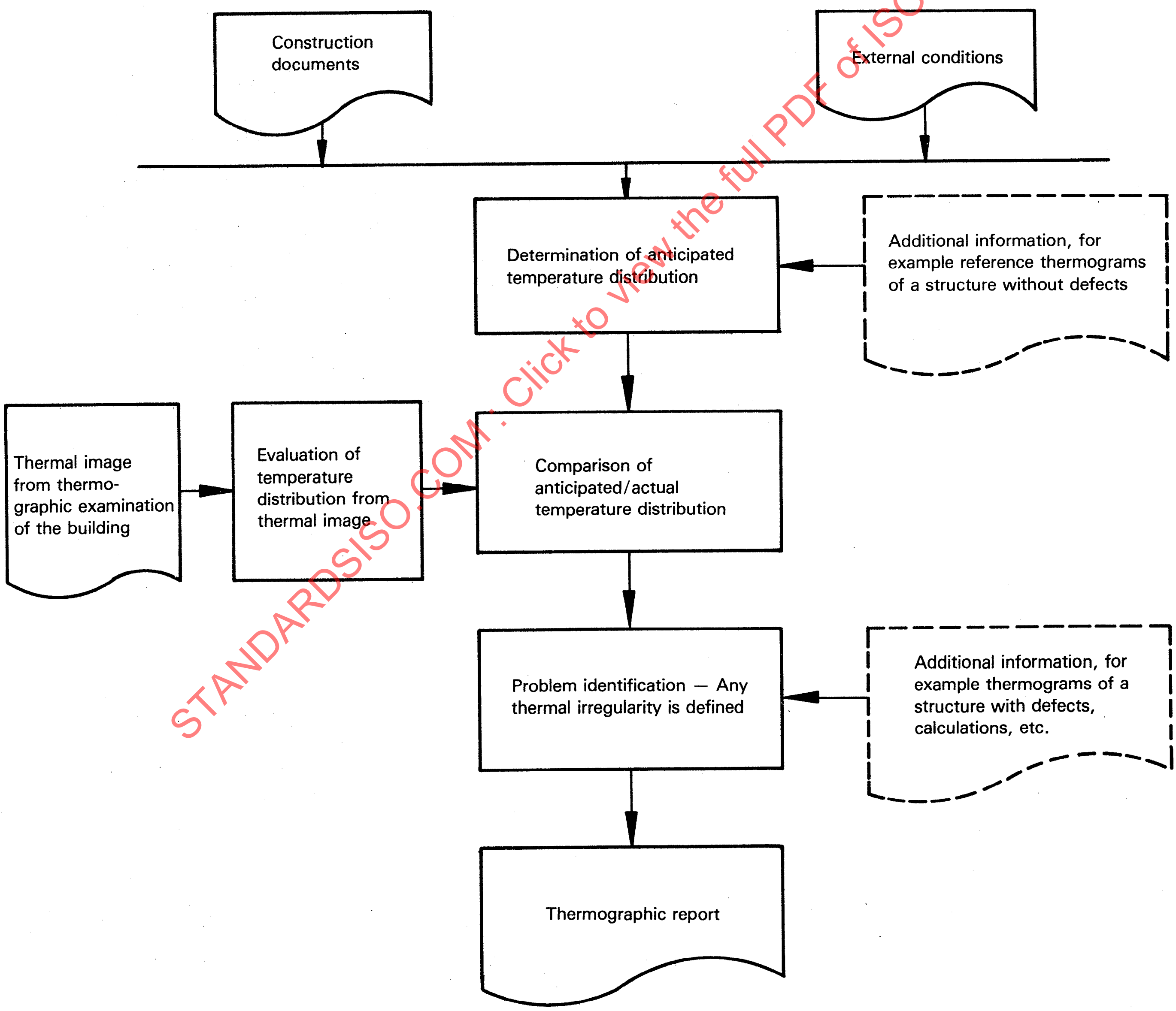


Figure 1 — General procedure for the interpretation of thermal images in thermographic examinations
(Dotted boxes indicate suggested use of additional information)

4 Infrared radiation sensing system

The infrared radiation sensing system shall comprise

a) infrared radiation sensor(s), operating at a wavelength greater than 2 µm, and which can sense apparent radiance temperatures of interest with sufficient resolution; [1)]

b) a device which renders visible and displays, in the form of a thermal image, the apparent radiance temperature over the surface being examined;

c) a device which makes it possible to record the thermal image;

d) means of establishing temperature levels on the surface under examination.

During the test period, no significant drift in the infrared radiation sensing system shall occur.

5 Thermographic examination

5.1 General test requirements

In order to define the actual test requirements, and in particular the side of the building envelope (outdoors or indoors) from which the thermographic examination is to be performed, the following factors need to be considered:

- the specifications and capabilities of the thermographic equipment;
- the characteristics of the building envelope, i.e. the respective locations of structural and insulating layers;
- the radiative properties of the cladding materials;
- climatic factors;
- accessibility for easy inspection;
- influences of the environment;
- other factors of importance.

The temperature drop across the envelope shall be sufficiently large to permit the detection of thermal irregularities. For ease of interpretation, the thermographic examination should preferably be carried out with constant temperature- and pressure drops across the envelope. (The interpretation of thermograms taken under non-steady state conditions requires a higher degree of expertise and knowledge of building physics.) This implies, among other things, that the test shall not be carried out when the outside or inside air temperature is liable to vary considerably, or when the structure is exposed to direct solar radiation, or when the wind varies markedly.

These general requirements shall be considered when a thermographic examination is carried out. The actual requirements may be varied according to the thermal properties of the building envelope under examination and the characteristics of the infrared radiation sensing system used. They may also be varied to take account of the local climate. The conditions shall be taken into account when carrying out the examination and when evaluating the thermograms, and shall be carefully recorded in the thermographic report (see clause 6).

Example of an actual set of test requirements taken from Scandinavian conditions. These test requirements must be adapted to meet the specific climatic conditions of a particular geographic region. For Scandinavian conditions, the following test requirements are likely to ensure approximate steady state conditions for a lightweight building structure [2)], when the thermographic examination is to be carried out from the inside:

a) For at least 24 h before the start of the examination, and during the examination, the air temperature drop across the building envelope shall be at least 10 °C. During the same period, the air temperature drop shall not vary more than ± 30 % from its value at the start of the examination. During the examination, the indoor air temperature shall not vary by more than ± 2 °C.

b) For at least 12 h before the start of the examination, and during the examination, the surfaces of the envelope under examination shall not be exposed to direct solar radiation.

c) The minimum and maximum temperatures at the place of examination shall be known for a period of 24 h before the start of the thermographic examination, for example by means of a maximum/minimum thermometer or by information from a weather station. The solar radiation conditions at the place of examination shall be known for a period of 12 h before the start of the thermographic examination.

5.2 Procedure

When available, drawings and other construction documents relating to the building envelope to be examined shall be consulted. The emissivity of the surface materials shall be evaluated from appropriate tables.

Information concerning outside air temperature, cloudiness, precipitation and any moisture on the outside of the building, together with wind conditions, shall be recorded. The geographical orientation of the building with respect to the points of the compass shall also be recorded.

Whenever necessary, a pressure drop shall be produced across the building envelope, or the examination shall be carried out at an appropriate time. The thermographic examination shall be carried out from the low pressure side.

1) Experience in field tests has shown that a minimum resolvable temperature difference of 0,3 °C at a surface temperature of 20 °C and at a spatial frequency of 0,052 cycle/mm would be sufficient for the purposes of this International Standard.

2) The time to reach nearly steady state conditions varies with the characteristics of the external envelope of the building. For a heavy masonry structure, this time may be several days. Alternatively, it may be advantageous to perform the survey under non-steady state conditions.

The effects produced by ventilated air layers, for example in walls or by heat sources (if any) installed in the building (embedded pipes, smoke ducts, etc.), on the temperature of the envelope under examination shall be estimated. If possible, heat sources that might interfere with the examination shall be shut off before the start of the examination. Furniture, pictures, etc., that might influence the result, shall be removed so that the test areas are free. The changes required shall be made in a way that avoids transient effects.

Immediately before the start of the examination, the inside and outside air temperatures shall be determined to an accuracy of ± 1 °C. When the pressure drop across the envelope is to be determined, it is recommended that this be measured to an accuracy of ± 5 Pa (for a low pressure drop ± 2 Pa) over the leeward and windward side for each storey. The observed values shall be recorded. It is especially important to identify the direction of the pressure difference across the section of the building envelope and the position of the neutral plane, if any.

Anticipated temperature distributions for the envelope under investigation shall be selected, taking into consideration the conditions for the examination.

The infrared radiation sensing system shall be set and adjusted in accordance with the directions for its use. The sensitivity, the range and the aperture, as appropriate, shall be set to cover the temperature range of the surface being studied.

The apparent radiance temperature differences within the thermal image on the surface of the building envelope shall be measured with an accuracy of ± 10 % or ± 0,5 °C, whichever is the greater. When a reference surface temperature is needed, it is recommended that it be determined to an accuracy of ± 0,5 °C.

The examination shall be started by performing a preliminary test over the surface of the envelope. Parts of the surface of special interest, or parts exhibiting anomalies, shall be studied in detail. Thermograms shall be taken of selected parts of the envelope under investigation (parts which are free from defects as well as parts where it is suspected that construction defects are present).

In order to decide whether a variation in radiation from the surface concerned is due to reflection from another surface, it is best to study the surface from different positions. The reflection will then change its position.

The positions of the parts represented on the thermograms shall be indicated on a plan/sketch of the building.

The apparent radiance temperature pattern shall be calculated according to the directions for use of the infrared radiation sensing system. In particular, emissivity and reflection effects shall be considered when these patterns are to be evaluated to yield actual surface temperature variations.

If the thermograms indicate air leakage, this shall be verified by measurements of the air velocity, if possible.

If required, the factors which influence the coefficient of heat transfer at the inside surface of the envelope (air flow, thermal radiation, moisture condensation) shall be estimated.

5.3 Evaluation of thermograms

The anticipated temperature distribution for tested parts shall be determined using drawings and other construction documents relating to the external envelope and the installations in the building under examination. For this purpose, calculations, experience, laboratory tests or reference thermograms of building envelopes without defects may be used.

NOTE — The reference thermograms may either be produced in a laboratory, or may be obtained from field tests made on actual buildings. Reference thermograms should be selected so as to ensure that the structure represented by the reference thermogram and the corresponding conditions of examination are as similar as possible to the structure under examination and to the environment at the time of examination. See annexes A, B and C.

The temperature distribution shall be evaluated from the thermograms. If this temperature distribution differs from that expected, this shall be noted. If the irregularities cannot be explained on the basis of the design of the envelope in accordance with the drawings, or effects of heat sources, or cannot be attributed to variations in emissivity or in the value of the coefficient of heat transfer, then the irregularity shall be stated as a defect.

NOTE — Irregularities in the thermal insulation, the air tightness and the building structure will produce various surface temperature patterns. Certain types of defects have a characteristic shape in a thermal image. In evaluating thermograms, the following pattern characteristics should be considered:

a) uniformity of density of the thermogram relating to sections of the surface where there are no thermal bridges;

b) the regularity and incidence of colder or warmer sections, for instance over studs and corners;

c) the contours and characteristic shape of the colder or warmer sections;

d) the measured difference between the 'normal' surface temperature of the construction and the temperature of the selected colder or warmer sections;

e) the continuity and uniformity of the constant temperature region over the surface of the construction.

Deviations and irregularities in the appearance of a thermogram often indicate a defect in the building envelope. The appearance of a thermogram relating to a construction with a defect may vary considerably.

Examples of pattern characteristics:

Air leakage (often at joints and junctions) in the building envelope often produces irregular shapes with uneven boundaries and large temperature variations.

Missing insulation produces regular and well defined shapes not associated with building structure features. The defect area has a relatively even temperature distribution.

Moisture present in the structure normally produces a mottled and diffuse pattern. Temperature variations are not extreme within the pattern.

The type of defect shall be determined. This may be done by calculation, by other investigations, from experience or by comparing the actual thermograms with reference thermograms for structures with known thermal insulation defects and air leakages of various kinds. Such determinations shall be thoroughly substantiated in the thermographic report.

For those parts of the building envelope in which the presence of thermal insulation defects and air leakages have been detected, the type and the extent of each defect shall be subject to a brief analysis. This may include a statement of whether these defects require any measures to be taken, or whether they can be accepted.

6 Thermographic report

The thermographic report shall include, *inter alia*, the following information:

a) Brief description of the construction of the building. (This information shall be based on 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), and description of the surrounding (buildings, vegetation, landscape, etc.).

d) Specification of the equipment used, including model and serial number.

e) Date and hour of test.

f) Outside air temperature. (Give at least the minimum and maximum values observed during the 24 h prior to the start of the examination and during the examination.)[1]

g) General information about solar radiation conditions (observed during the 12 h prior to the start of the examination and during the examination).[1]

h) Precipitation, direction of the wind, and velocity of the wind during the test.

j) Inside air temperature and air temperature drop across the envelope.

k) Difference in air pressure over the leeward and windward side for each storey.

m) Other important factors influencing the results, for example rapid variations in weather conditions.

n) Statement of the actual test conditions as described in 5.1.

p) Sketches/photographs of the building showing the positions of the thermograms.

q) Thermograms obtained from the test with indications of their respective positions, and with comments on the appearance of the thermal images.

r) Identification of the parts of the building examined.

s) Results of the analysis dealing with the type and the extent of each construction defect which has been observed.[2]

t) Results of supplementary measurements and investigations.

1) The information within brackets refers to the example in 5.1.

2) This analysis may include a statement of whether these defects require any measures to be taken, or whether they can be accepted.

Annex A

Reference thermograms

A.1 Reference thermograms obtained from field measurements on actual buildings

Thermograms produced by field measurements on actual buildings can be used as reference thermograms, provided that the characteristics of the buildings under examination, the workmanship, and the test conditions at the time of examination are well known and documented.

A.2 Reference thermograms produced in a laboratory

Reference thermograms can be produced in an air-conditioned installation where a building envelope can be constructed between a cold space and a warm space. The air temperature and the air pressure shall be controlled in both these spaces. The surface temperature and the emissivity of the walls of the warm space shall have values which are normally encountered in practice.

A number of typical building envelopes shall be used for the production of reference thermograms.

A typical envelope 'with no defects' shall be constructed to represent a design and construction free from defects.

Typical envelopes 'with deliberate defects' shall be provided with thermal insulation and air leakage defects which are encountered in practice. The type and the extent of the defects shall be carefully recorded.

The typical envelope shall comprise a representative part of the envelope under consideration, including adjacent parts.

To obtain typical thermograms, a number of combinations of temperature and pressure drops across the typical envelope shall be selected so as to correspond to the values which are encountered in practice.

The temperature drops may include 10 and 25 °C. The temperature in the warm space should be about 20 °C.

The pressure drops may include − 10, 0, and + 10 Pa.

A.3 Presentation of reference thermograms

Reference thermograms should be recorded and presented in two forms, i.e.

a) as a normal thermal image; and

b) as one or several isotherm images which clearly exhibit the temperature distribution that is characteristic of the defect under examination.

Examples of reference thermograms of a typical envelope (see figure 2) with no defects are shown in annex B.

Examples of reference thermograms of a typical envelope (see figure 2) with deliberate defects are shown in annex C.

The division of the typical envelope into frames is shown in figure 3 and the positions of the deliberate defects are shown in figure 4. (The types of defects are not described in detail.)

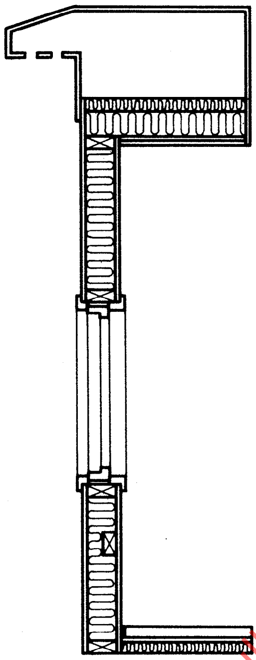


Figure 2 — Section of a typical envelope of the type used in the examples of reference thermograms shown in annexes B and C

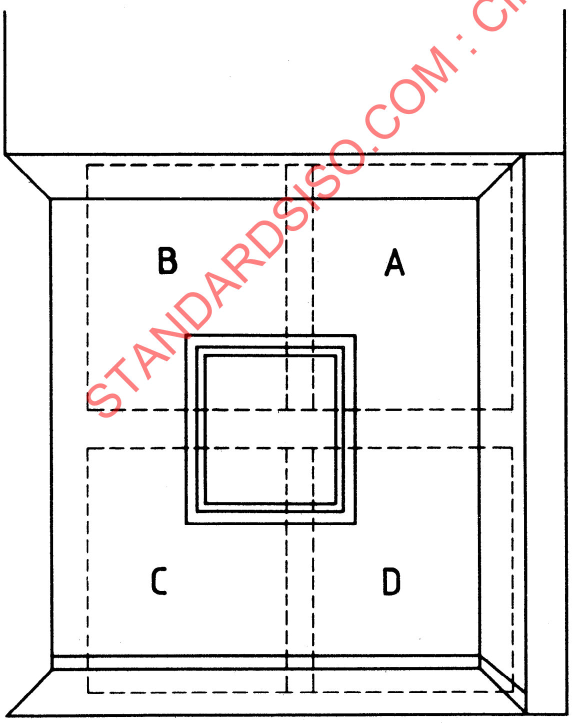


Figure 3 — Division of the typical envelope into frames as shown in annexes B and C

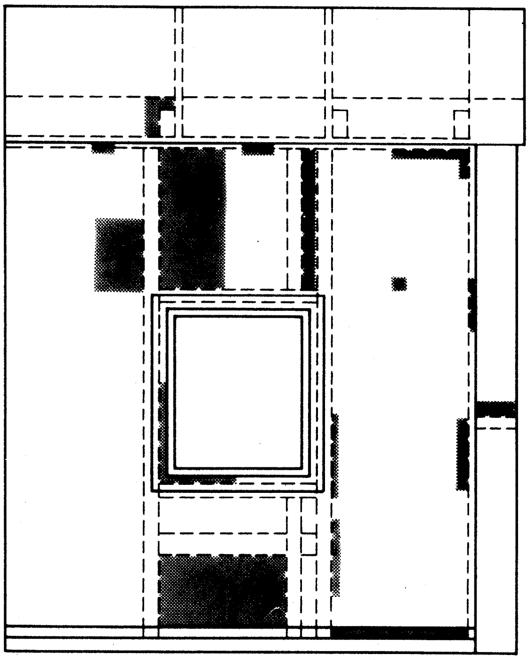


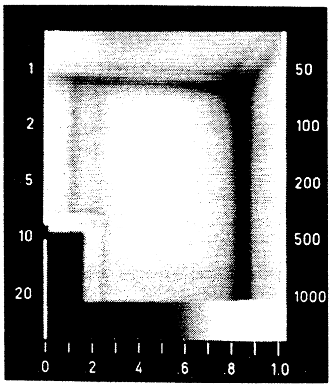
Figure 4 — Positions of deliberate defects shown on the thermograms in annex C

Annex B

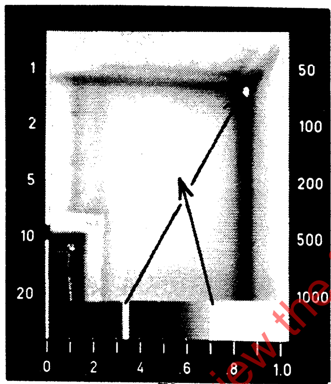
Examples of thermograms recorded on a stud wall 'with no defects'

Mineral wool, 120 mm thick. Temperature drop (inside-outside), $\theta_i - \theta_e$ = 26 °C. Pressure drop (inside-outside), $p_i - p_e$ = −50 Pa.

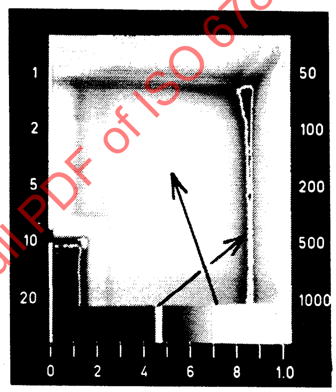
The arrows indicate the isotherms corresponding to the temperatures which are shown on the relative temperature scale in each image. Under each isotherm image, the difference in temperature ($\Delta\theta$) between the isotherms is stated in degrees Celsius.



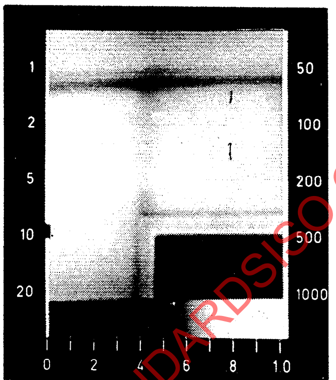
A1



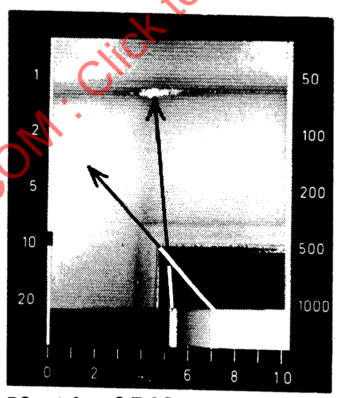
A2 $\Delta\theta$ = 6,2 °C



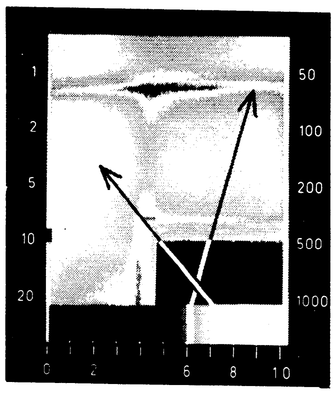
A3 $\Delta\theta$ = 3,8 °C



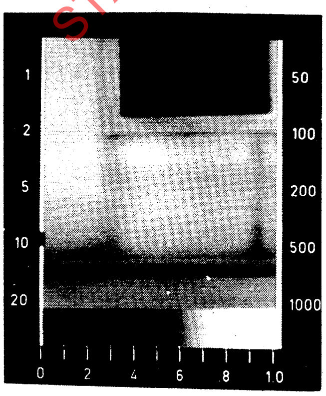
B1



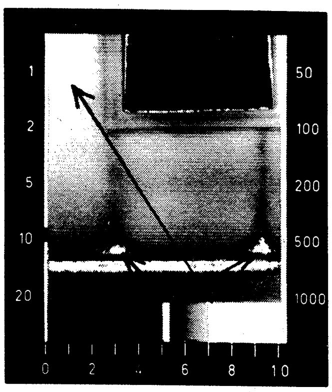
B2 $\Delta\theta$ = 2,7 °C



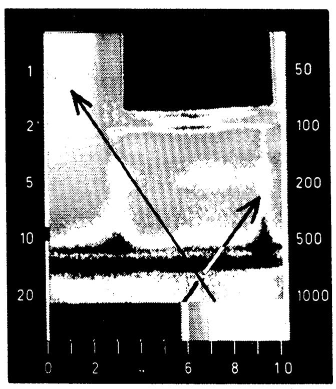
B3 $\Delta\theta$ = 1,5 °C



C1



C2 $\Delta\theta$ = 3,1 °C



C3 $\Delta\theta$ = 1,8 °C