BRITISH STANDARD

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

(ISO 6781:1983 modified)

The European Standard EN 13187:1998 has the status of a British Standard

ICS 91.120.10

National foreword

This British Standard is the English language version of EN 13187:1998.

The UK participation in its preparation was entrusted by Technical Committee RHE/9, Thermal insulating materials, to Subcommittee RHE/9/2, Thermal properties of insulating materials, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Summary of pages

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(ISO 6781:1983 modified)

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Wärmetechnisches Verhalten von Gebäuden — Qualitativer Nachweis von Wärmebrücken in Gebäudehüllen — Infrarot-Verfahren (ISO 6781:1983 modifiziert)

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 89, Thermal performance of buildings and building components, the Secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 1999, and conflicting national standards shall be withdrawn at the latest by May 1999.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

It is based on International Standard ISO 6781:1983, *Thermal insulation — Qualitative detection of thermal irregularities in building envelopes — Infrared method*, which was modified to take account of the development of equipment performance and inspection practice. The main modification is the addition of a procedure for "Simplified testing with an IR camera".

This standard is one of a series of standards for the design and evaluation of thermal performance of buildings and building components.

Contents

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.

Building thermography is a method of indicating and representing the temperature distribution over a part of the surface of a building envelope. In the context of this standard, thermography is carried out by means of an infrared radiation sensing system which produces an image based on the apparent radiance temperature of the measured target area. The thermal radiation (infrared radiation density) from the target area 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 intensity of the image is a function of the surface temperature, the characteristics of the surface, the ambient conditions and the sensor itself. The measurement procedure also involves interpretation of the thermal images (thermograms).

1 Scope

This 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.

In this standard two forms of thermography are specified.

— Testing with an IR camera is primarily intended for the inspection of the overall performance of new buildings or the result after a rebuilding operation.

— Simplified testing with an IR camera is suitable when carrying out audits, e.g. at the site of a rebuilding project or at production control or other routine inspections.

These two adaptations differ mainly with regard to the reporting and the presentation of results.

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

This standard applies to the determination of the location of thermal irregularities and to the location of air leakage paths through the enclosure. This 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 Normative references

This standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN ISO 7345, *Thermal insulation — Physical quantities and definitions* (ISO 7345:1987).

EN ISO 9288:1996, *Thermal insulation — Heat transfer by radiation — Physical quantities and definitions* (ISO 9288:1989).

3 Definitions

For the purposes of this standard, the definitions in EN ISO 7345, EN ISO 9288 and the following definitions apply:

3.1

thermography

determination and representation of surface temperature distribution by measuring the infrared radiant density from a surface, including interpretation of casual mechanisms producing the irregularities in the thermal images

3.2

thermal image

image which is produced by an infrared radiation sensing system and which represents the apparent radiance temperature distribution over a surface

3.3

thermogram

a thermal image, documented by a photograph of the camera display, by a recording on a video tape or a digital data diskette or as a file on a computer or hard disk drive

3.4

total radiance

radiant heat flow rate divided by the solid angle around the direction $\vec{\Delta}$ and the projected area normal to this direction [EN ISO 9288:1996]

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

3.5

apparent radiance temperature

temperature determined from the measured total radiance

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

3.6

isotherm image

thermal image with isotherms

3.7

isotherm

a region on the display consisting of points, lines or areas having the same infrared radiation density

3.8

IR camera

an infrared radiation sensing system which produces a thermal image based on the apparent radiance temperature

4 Principle

Thermographic examination of parts of buildings comprises:

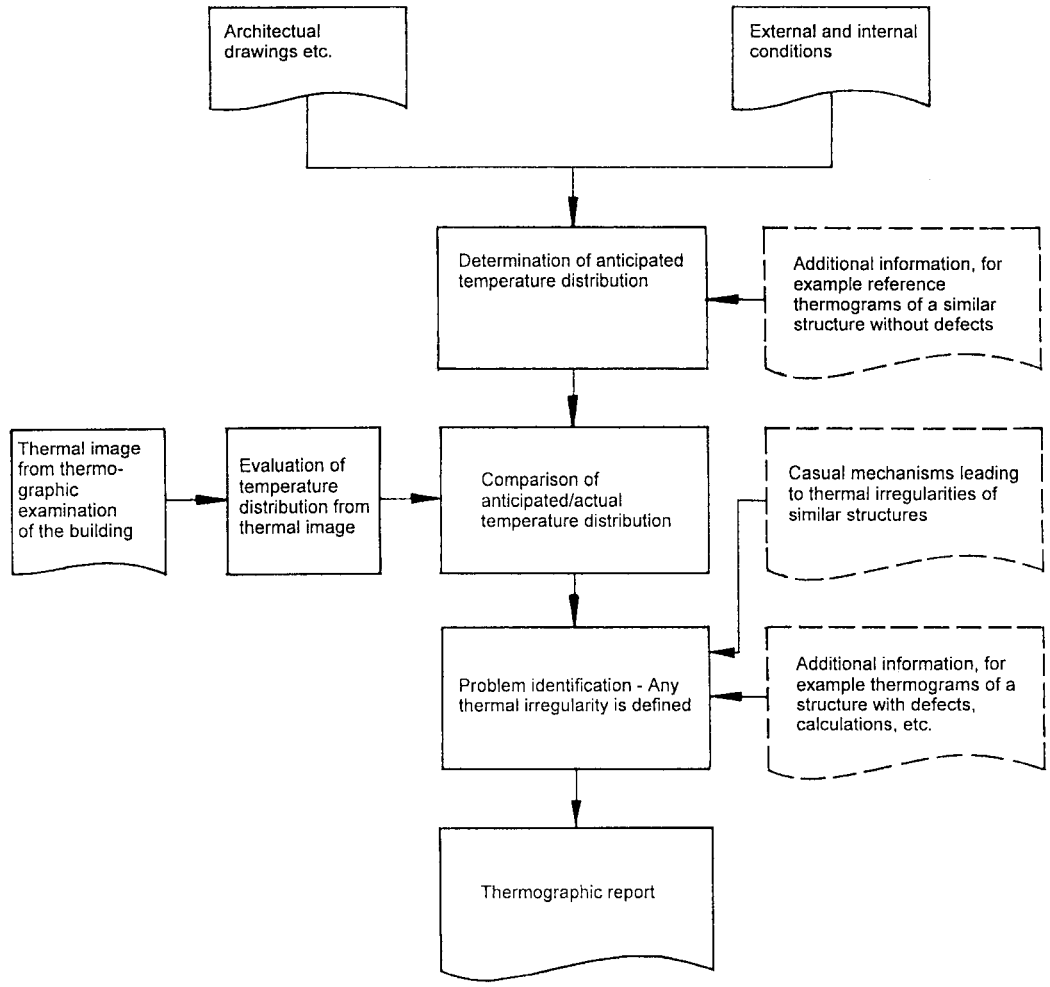
a) determination of the surface temperature distribution over a part of a building envelope, from the apparent radiance temperature distribution obtained by means of an infrared radiation sensing system;

b) ascertaining 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) if so, assessment 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 documents relating to the external envelope and to the heating and ventilation system of the building under investigation.

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



Dotted boxes indicate suggested use of additional information.

Figure 1 — General procedure for the interpretation of thermal images in thermographic examinations

5 Infrared radiation sensing system

The infrared radiation sensing system shall comprise:

a) an infrared radiation sensor, operating at a wavelength between 2 μm and 12 μm, 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 and, if relevant, measured digital data;

d) a 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.

6 Thermographic examination

6.1 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:

a) the specifications and capabilities of the thermographic equipment;

b) the characteristics of the building envelope, i.e. the respective types and locations of heating systems, structural elements and insulating layers;

c) the radiative properties of the surface, e.g. the cladding materials;

d) climatic factors;

e) accessibility for easy inspection;

f) influences of the environment;

g) other factors of importance.

The temperature difference 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 differences 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 **7**).

NOTE An example of an actual set of test requirements, applicable to Scandinavian conditions, is given in annex D. Special national conditions may justify other sets of test requirements to ensure approximate steady state conditions.

6.2 Procedure

When available, drawings and other documents relating to the building envelope to be examined shall be consulted. The emissivity of the surface materials shall be estimated 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 orientation of the building with respect to the points of the compass shall also be recorded.

If air leakages are relevant to the examination, a pressure difference shall be produced across the building envelope, or the examination shall be carried out at an appropriate time such that a pressure difference exists. If the main purpose of the thermographic examination is to locate air leakages, the pressure difference shall be at least 5 Pa at the location of the inspection. The thermographic examination shall be carried out from the low pressure side.

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 unobstructed. 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 difference across the envelope is to be determined, it is recommended that this be measured to an accuracy of ± 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.

[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 standard.

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 variations in apparent radiance temperature within the thermal image on the surface of the building envelope shall be measured with an accuracy of $\pm 10\,\%$ or $\pm 0{,}5\,^{\circ}C$, whichever is the greater. When a reference surface temperature is needed, it is recommended that it be determined to an accuracy of $\pm 0{,}5\,^{\circ}C$.

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 because, in general, the reflection will change with position.

The positions of the parts represented on the thermograms shall be indicated on a plan or 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, it is essential that emissivity and reflection effects be considered or compensated for when these patterns are used to calculate 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.

6.3 Evaluation of thermograms

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

NOTE 1 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 to the value of the coefficient of heat transfer, then the irregularity shall be stated as a defect.

NOTE 2 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 apparent radiance temperature relating to sections of the surfaces of similar structures where there are no thermal bridges;

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

c) the location of 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;

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.

6.4 Examples of pattern characteristics

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

b) Missing insulation produces regular and well defined shapes not associated with features of the building structure. The defect area has a relatively even temperature variation.

c) 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.

NOTE The results of the test can be checked by disassembling the part of the building envelope suspected to be defective, and by subjecting it to visual examination. Other supplementary investigations may include heat flow measurements and pressurization tests.

7 Thermographic report

7.1 Report on testing with an IR camera

The report shall include:

a) a description of the test with reference to this standard and a statement, that testing with an IR camera has been performed, name of the client and full address of the object;

b) brief description of the construction of the building (this information shall be based on drawings or other available documentation);

c) type(s) of surface material(s) used in the structure and the estimated value(s) of emissivity of this (these) material(s);

d) orientation of the building with respect to the points of the compass shown in a plan, and description of the surroundings (buildings, vegetation, landscape, etc.);

e) specification of the equipment used, including make, model and serial number;

f) date and hour of test;

g) outside air temperature. Give at least the minimum and maximum values observed, i) during the 24 h prior to the start of the examination and, ii) during the examination;

h) general information about solar radiation conditions, observed during the 12 h prior to the start of the examination and during the examination;

j) precipitation, direction of the wind, and velocity of the wind during the examination;

k) inside air temperature and air temperature difference across the envelope during the examination;

l) difference in air pressure over the leeward and windward side, whenever necessary for each storey;

m) other important factors influencing the results, for example rapid variations in weather conditions;

n) statement of any deviations from relevant test requirements;

o) sketches and/or photographs of the building showing the positions of the thermograms;

p) thermograms indicating temperature levels obtained from the test, showing parts of the building where defects have been detected, with indications of their respective positions, and the position of the IR camera with respect to the measurement target, and with comments on the appearance of the thermal images; if possible with reference to parts of the building envelope with acceptable performance;

q) identification of the parts of the building examined;

r) results of the analysis dealing with the type and the extent of each construction defect which has been observed[2)]. Relative extent of the defect by a comparison of the defective part of the envelope to similar parts throughout the building;

s) results of supplementary measurements and investigations;

t) date and signature.

7.2 Report on simplified testing with an IR camera

The report shall include:

a) a description of the test with reference to this standard and a statement, that simplified testing with an IR camera has been performed, name of the client and full address of the object;

b) brief description of the construction of the building. (This information shall be based on drawings or other available documentation.);

c) —

d) —

e) —

f) date and hour of test;

g) —

h) —

j) —

k) inside air temperature and air temperature difference across the envelope during the examination;

l) difference in air pressure over the leeward and windward side, whenever necessary for each storey;

m) other important factors influencing the results, for example rapid variations in weather conditions;

n) statement of any deviations from relevant test requirements;

o) —

p) —

q) identification of the parts of the building examined;

r) type, extent and position of each observed defect[3)];

s) results of supplementary measurements and investigations;

t) date and signature.

[2)] According to **5.4.3** of EN 45001: 1989, this item shall not include any statement of whether these defects require measures to be taken, or whether they can be accepted. Such statements may be given in a separate letter.

[3)] According to **5.4.3** of EN 45001: 1989, this item shall not include any statement of whether these defects require measures to be taken, or whether they can be accepted. Such statements may be given in a separate letter.

Annex A (informative)
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 component can be constructed between a cold space and a warm space. The air temperature and the air pressure should be controlled in both these spaces. The surface temperature and the emissivity of the walls of the warm space should have values which are normally encountered in practice.

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

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

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

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

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

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

The pressure differences may include −10 Pa, 0 Pa 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 with no defects (see Figure A.1) are shown in annex B.

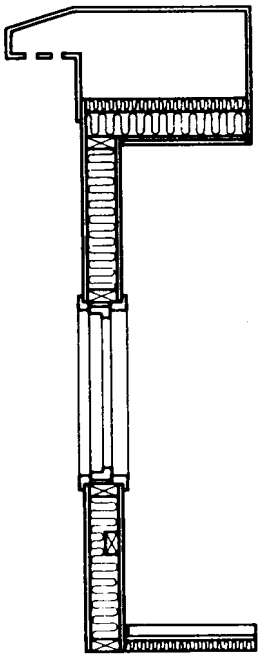


Figure A.1 — Section of a typical envelope of the type used in the examples of reference thermograms shown in annexes B and C

Examples of reference thermograms of a typical envelope (see Figure A.1) with deliberate defects are shown in annex C.

The division of the typical envelope into frames is shown in Figure A.2 and the positions of the deliberate defects are shown in Figure A.3. (The types of defects are not described in detail.)

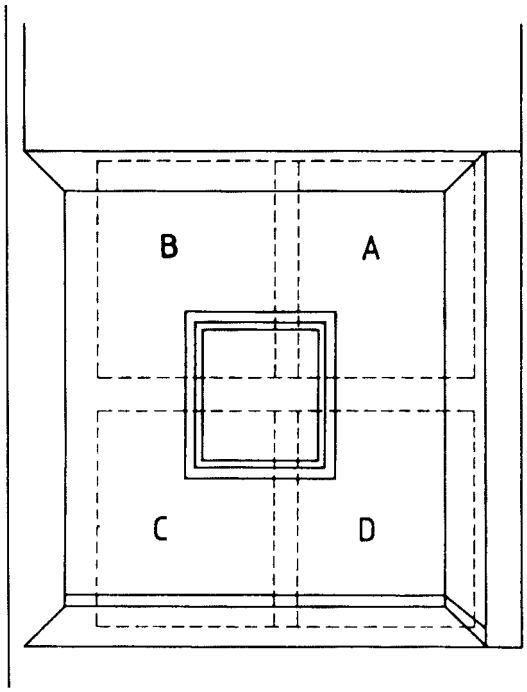


Figure A.2 — Division of the typical envelope into frames as shown in annexes B and C

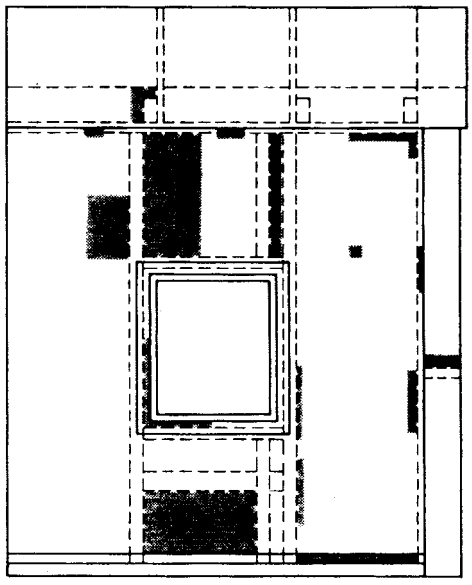


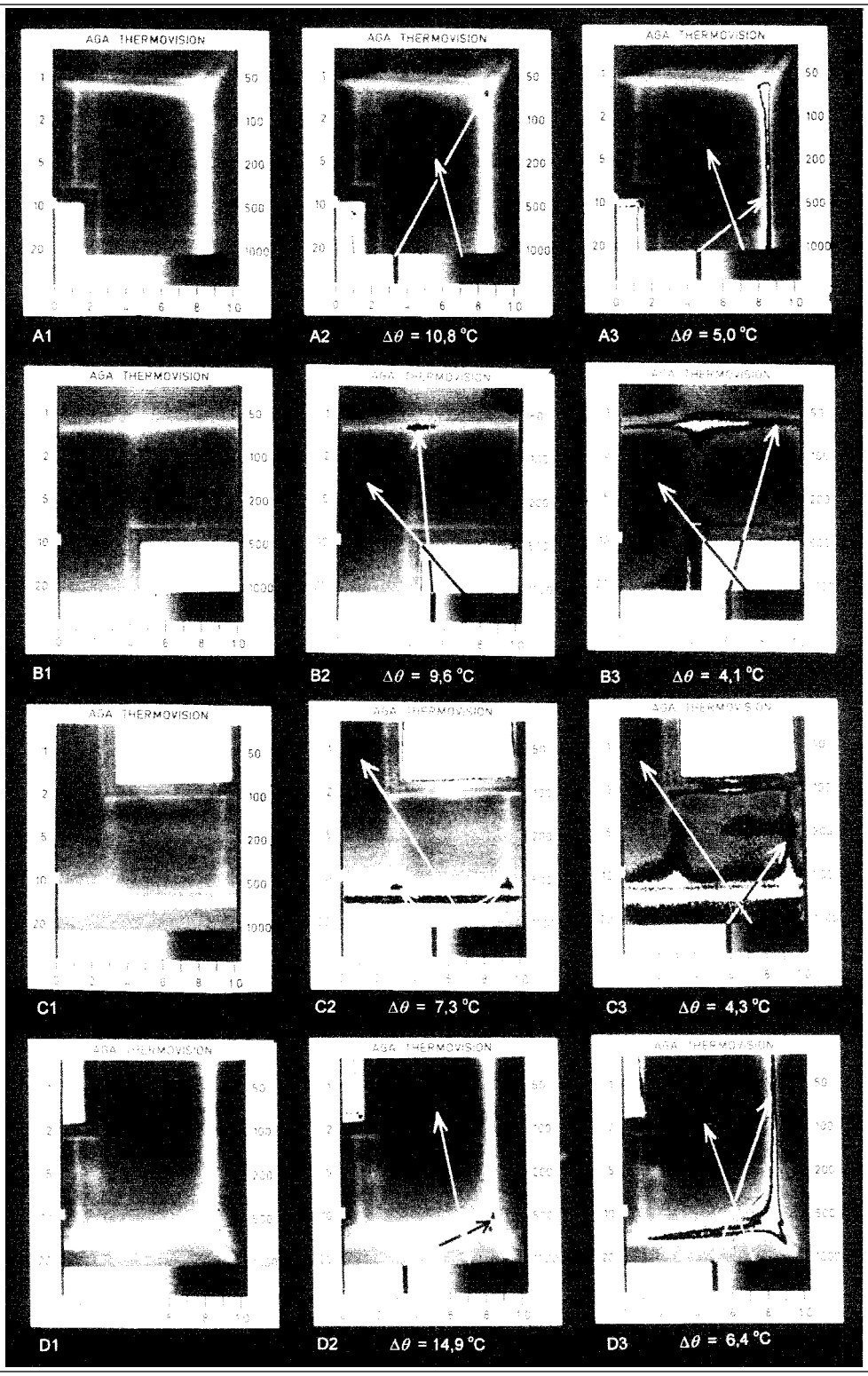
Figure A.3 — Positions of deliberate defects shown on the thermograms in annex C

Annex B (informative)

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

Mineral wool, 120 mm thick. Temperature difference (inside-outside), $\theta_i - \theta_e = 26$ °C. Pressure difference (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.

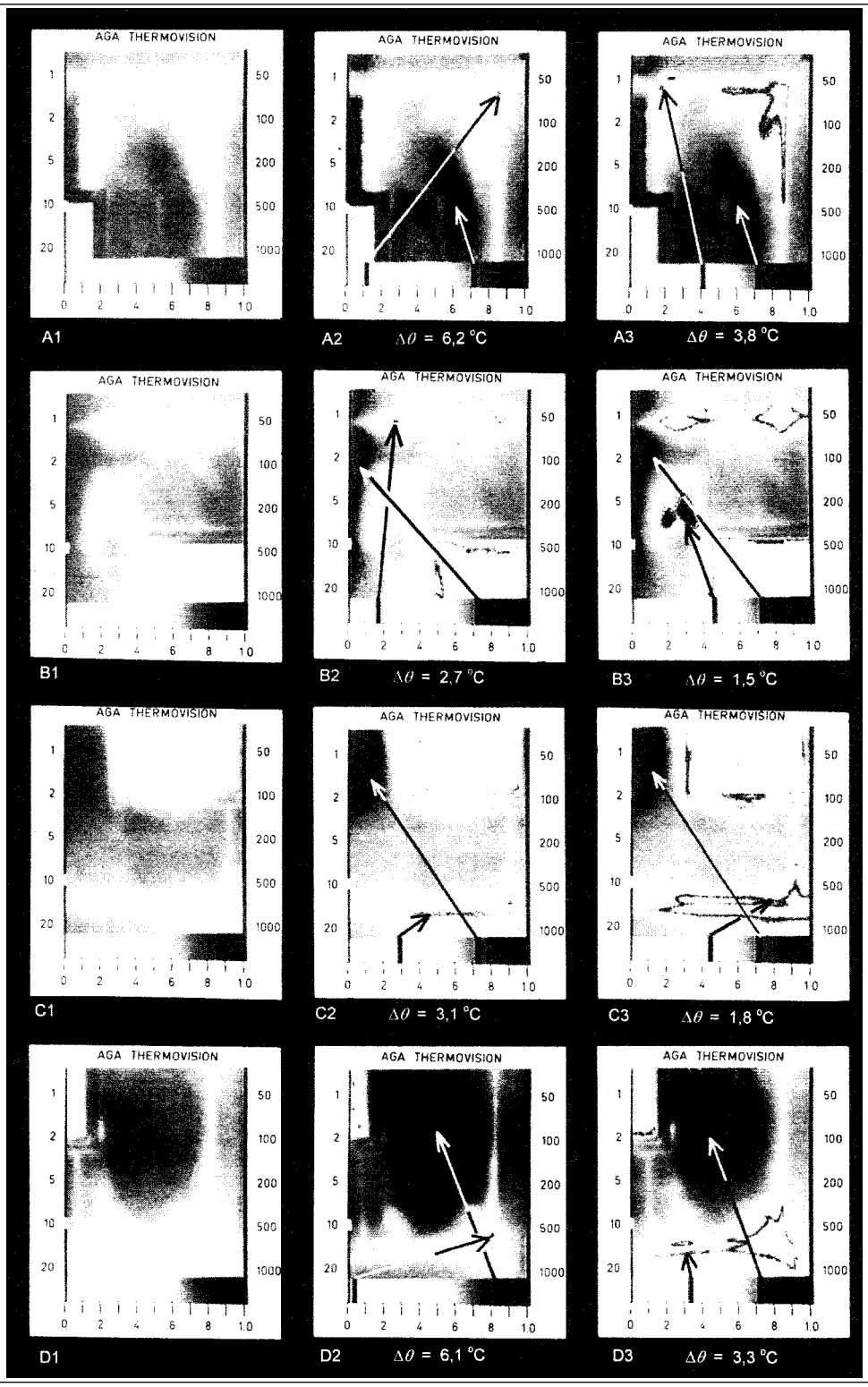


Annex C (informative)

Examples of thermograms recorded on a stud wall containing deliberate defects

Mineral wool, 120 mm thick. Temperature difference (inside-outside), $\theta_i - \theta_e = 26$ °C. Pressure difference (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.



Annex D (informative)

Example of a set of test requirements

The test requirements in this annex are adapted to meet the specific climatic conditions and building technology of Scandinavia. Special national conditions may justify other sets of test requirements in other regions.

For Scandinavian conditions, the following test requirements are likely to ensure approximate steady state conditions for a lightweight building structure[4)], when the thermographic examination is to be carried out from the inside.

a) For at least 24 h before the start of the examination, the external air temperature shall not vary by more than ± 10 °C from the temperature at the start of the examination.

For heavy structures with a large thermal mass, special consideration has to be given to the effects of heat storage.

b) For at least 24 h before the start of the examination, and during the examination, the air temperature difference across the building envelope shall not be less than the numerical value of $3/U$, where U is the theoretical value of the thermal transmittance of the building element in $W/(m^2 \cdot K)$, but never less than 5 °C.

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

d) During the examination, the external air temperature shall not vary more than ± 5 °C and the internal air temperature not more than ± 2 °C from their respective values at the start of the examination. The effects of variations in temperature during the examination may be checked by overlapping the final scan with the initial scan. If there is less than 1 °C or 2 °C change, then the test requirements should be considered fulfilled.

If the infrared radiation sensing system has a minimum resolution of 0,3 °C, this set of test requirements would imply the following. At an internal surface resistance $R_{si} = 0{,}10\ m^2 \cdot °C/W$, a change in the U-value of 50 % can be detected and with an internal surface resistance $R_{si} = 0{,}20\ m^2 \cdot °C/W$, a change in the U-value of 25 % can be detected.

If the examination is carried out despite of deviations from these test requirements, this should be borne in mind at the examination and evaluation of the results and should be pointed out in the thermographic report.

[4)] 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 conditions.

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