

Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Products of high and medium thermal resistance

The European Standard EN 12667:2001 has the status of a
British Standard

ICS 91.100.01; 91.120.10

National foreword

This British Standard is the official English language version of EN 12667:2001. This British Standard together with BS EN 12664 and BS EN 12939 supersedes BS 874-2.1:1986 and BS 874-2.2:1988.

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 subcommittee can be obtained on request to its secretary.

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Thermal performance of building materials and products -
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Performance thermique des matériaux et produits pour le
bâtiment — Détermination de la résistance thermique par la
méthode de la plaque chaude gardée et la méthode
fluxmétrique — Produits de haute et moyenne résistance
thermique

Wärmetechnisches Verhalten von Baustoffen und
Bauprodukten — Bestimmung des
Wärmedurchlasswiderstandes nach dem Verfahren mit
dem Plattengerät und dem Wärmestrommessplatten-Gerät
— Produkte mit hohem und mittlerem
Wärmedurchlasswiderstand

This European Standard was approved by CEN on 25 June 2000.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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Management Centre: 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 July 2001, and conflicting national standards shall be withdrawn at the latest by December 2001.

This document is one of a series of standards on thermal test methods that support product standards for building materials.

The annexes A, B, C and D are normative.

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.

Introduction

Steady state heat transfer properties may be measured by a number of standardized test methods: the choice of the most appropriate method depends on specimen characteristics. This standard covers the guarded hot plate and the heat flow meter methods only.

For routine testing, the operator of these two methods needs only this standard and the relevant product standard, which may impose additional requirements related to specimen preparation or testing conditions.

Detailed requirements for measurements in any testing condition of thermal resistance of any compatible plane specimen are given:

- for the guarded hot plate method, in ISO 8302:1991 and EN 1946-2:1999;
- for the heat flow meter method, in ISO 8301:1991 and EN 1946-3:1999.

This standard provides general information on the apparatus, all mandatory limits for the equipment design and operation, and the specification of testing procedure, for specimens, with high and medium thermal resistance, described in relevant technical specifications (e.g. a European product standard or a European technical approval). The information given is technically equivalent to that in ISO 8301:1991 and ISO 8302:1991, for both these methods. It is only intended for the routine testing of specimens (within the limitations of thickness and inhomogeneity, etc. given in annex A) using equipment which has been constructed according to 5.1 and which has already been validated according to EN 1946-3:1999 or EN 1946-2:1999.

It also includes examples of equipment designs that meet the requirements of 5.1, so that the assessment of the accuracy of equipment designed accordingly does not need an error analysis but only the equipment performance check.

Measurements on products of medium and low thermal resistance and on moist products of any thermal resistance are covered in EN 12664. Measurements on thick products of high and medium thermal resistance are covered in EN 12939.

1 Scope

This standard specifies principles and testing procedures for determining, by means of the guarded hot plate or heat flow meter methods, the thermal resistance of test specimens having a thermal resistance of not less than $0,5 \text{ m}^2 \cdot \text{K/W}$

NOTE 1 The above limit is due to the effect of contact thermal resistances. An upper limit for measurable thermal resistance depends upon a number of factors described in this standard, but a unique figure cannot be assigned.

It applies in principle to any mean test temperature, but the equipment design in annex D is essentially intended to operate between a minimum cooling unit temperature of -100°C and maximum heating unit temperature of $+100^\circ\text{C}$.

NOTE 2 Limits to the mean test temperature are only imposed by the materials used in the apparatus construction and by ancillary equipment.

It supplies additional limits for equipment performance and test conditions.

It does not supply general equipment design procedures, equipment error analysis, equipment performance check or the assessment of equipment accuracy.

It supplies example designs of equipment complying with the requirements set down in this standard.

This standard does not supply general guidance and background information (e.g. the heat transfer property to be reported, product-dependent specimen preparations, procedures requiring multiple measurements, such as those to assess the effect of specimen non-homogeneities, those to test specimens whose thickness exceeds the apparatus capabilities, and those to assess the relevance of the thickness effect). Due to these limitations, this standard should be used in conjunction with the product standard relevant to the product to be tested.

Although intended primarily for building materials, it can also be used for specimens of any material that conforms to the requirements specified.

This standard does not cover measurements on moist products of any thermal resistance or measurements on thick products of high and medium thermal resistance.

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 applies (including amendments).

NOTE References to ISO 8301:1991 and ISO 8302:1991 do not cover the complete test methods, but are limited to such items as equipment design and performance check, not covered by European Standards or parts of them; references to ISO 8301:1991 or ISO 8302:1991 are not needed for routine testing according to this standard.

- | | |
|----------------|---|
| EN 1946-2:1999 | <i>Thermal performance of building products and components — Specific criteria for the assessment of laboratories measuring heat transfer properties — Part 2: Measurements by guarded hot plate method</i> |
| EN 1946-3:1999 | <i>Thermal performance of building products and components — Specific criteria for the assessment of laboratories measuring heat transfer properties — Part 3: Measurements by heat flow meter method</i> |

EN 12664	<i>Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Dry and moist products of medium and low thermal resistance</i>
EN 12939	<i>Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Thick products of high and medium thermal resistance</i>
EN ISO 7345	<i>Thermal insulation — Physical quantities and definitions (ISO 7345:1987)</i>
ISO 8301:1991	<i>Thermal insulation — Determination of steady-state thermal resistance and related properties — Heat flow meter apparatus</i>
ISO 8302:1991	<i>Thermal insulation — Determination of steady-state thermal resistance and related properties — Guarded hot plate apparatus</i>

3 Definitions, symbols and units

3.1 Terms and definitions

For the purposes of this standard, the terms and definitions in EN ISO 7345 apply. Most relevant definitions for the measurement of heat transfer properties on high and medium thermal resistance products are to be found in A.2.

3.2 Symbols and units

Symbol	Quantity	Unit
A	metering area measured on a selected isothermal surface	m^2
A_d	area of the defect	m^2
A_m	area of the metering section	m^2
R	thermal resistance	$\text{m}^2 \cdot \text{K} / \text{W}$
T	transfer factor	$\text{W} / (\text{m} \cdot \text{K})$
T_1	temperature of the warm surface of the specimen	K
T_2	temperature of the cold surface of the specimen	K
T_m	mean test temperature (usually $(T_1 + T_2)/2$)	K
V	volume	m^3
c	specific heat capacity	$\text{J} / (\text{kg} \cdot \text{K})$
d	thickness; average thickness of a specimen	m
e	edge number ratio	-
e_h	heat flow meter output voltage	mV
f	calibration factor of the heat flow meter	$\text{W} / (\text{mV} \cdot \text{m}^2)$

Symbol	Quantity	Unit
m	mass (of the specimen)	kg
q	density of heat flow rate	W/m ²
r	thermal resistivity	K·m/W
ΔR	increments of thermal resistance	m ² ·K/W
ΔT	temperature difference (usually $T_1 - T_2$)	K
Δd	increments of thickness	m
Δm	relative mass change	-
Δt	time interval	s
Φ	heat flow rate	W
λ	thermal conductivity	W/(m·K)
λ_t	thermal transmissivity	W/(m·K)
ξ	porosity	-
ξ_p	local porosity	-
ρ	density	kg/m ³

NOTE The meaning of some additional subscripts is specified in the text.

4 Principle

4.1 Apparatus

Both the guarded hot plate apparatus and the heat flow meter apparatus are intended to establish within homogeneous specimens with flat parallel faces, in the form of slabs, a unidirectional constant and uniform density of heat flow rate. The part of the apparatus where this takes place with acceptable accuracy is around its centre; the apparatus is therefore divided into a central metering section in which measurements are taken, and a surrounding guard section.

4.2 Measuring the density of heat flow rate

With the establishment of steady state in the metering section, the density of heat flow rate, q , is determined from measurement of the heat flow rate, Φ , and the metering area, A , that the heat flow rate crosses.

4.3 Measuring the temperature difference

The temperature difference across the specimens, ΔT , is measured by temperature sensors fixed at the surfaces of the apparatus in contact with the specimen and/or those of the specimens themselves, where appropriate.

4.4 Deriving the thermal resistance or transfer factor

The thermal resistance, R , is calculated from a knowledge of q , A and ΔT if the appropriate conditions given in A.3.2 are realized. From the additional knowledge of the thickness, d , of the specimen, the transfer factor, T , is computed.

4.5 Computing thermal conductivity or thermal transmissivity

The mean thermal conductivity, λ , or thermal transmissivity, λ_t , of the specimen may also be computed if the appropriate conditions to identify them and those given in A.4.3 are realized.

4.6 Apparatus limits

The application of the method is limited by the capability of the apparatus to maintain a unidirectional, constant and uniform density of heat flow rate in the specimen, coupled with the ability to measure power, temperature and dimensions to the limit of accuracy required, see annex A.

4.7 Specimen limits

The application of the method is also limited by the shape of the specimen(s) and the degree to which they are identical in thickness and uniformity of structure (in the case of two specimen apparatus) and whether their surfaces are flat or parallel, see annex A.

5 Apparatus

5.1 General

A guarded hot plate apparatus or a heat flow meter apparatus used for measurements according to this standard shall comply with the limits on equipment performance and test conditions given in annex B or annex C of this standard and shall conform with the requirements concerning the assessment of equipment accuracy given in EN 1946-2:1999 or EN 1946-3:1999: this requires that the equipment design, error analysis and performance check be according to section 2 of ISO 8302:1991 or ISO 8301:1991 respectively.

Annex D gives designs of equipment which conform with these requirements. If the equipment used is designed precisely in accordance with one of these, an error analysis need not be carried out, even though in all cases a performance check according to EN 1946-2:1999 or EN 1946-3:1999 shall be undertaken for the initial assessment of the equipment.

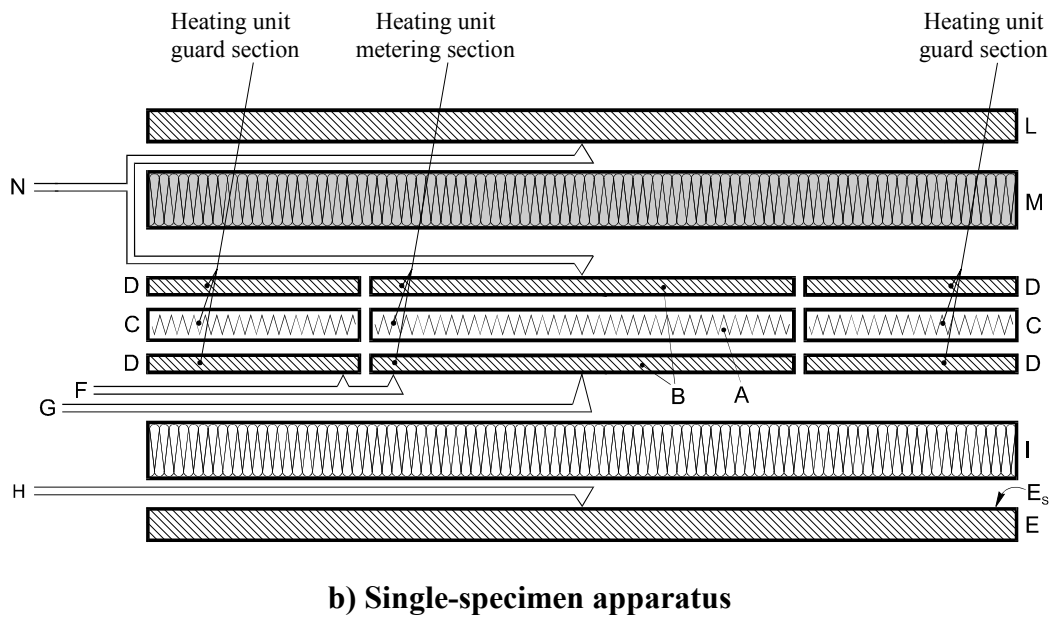
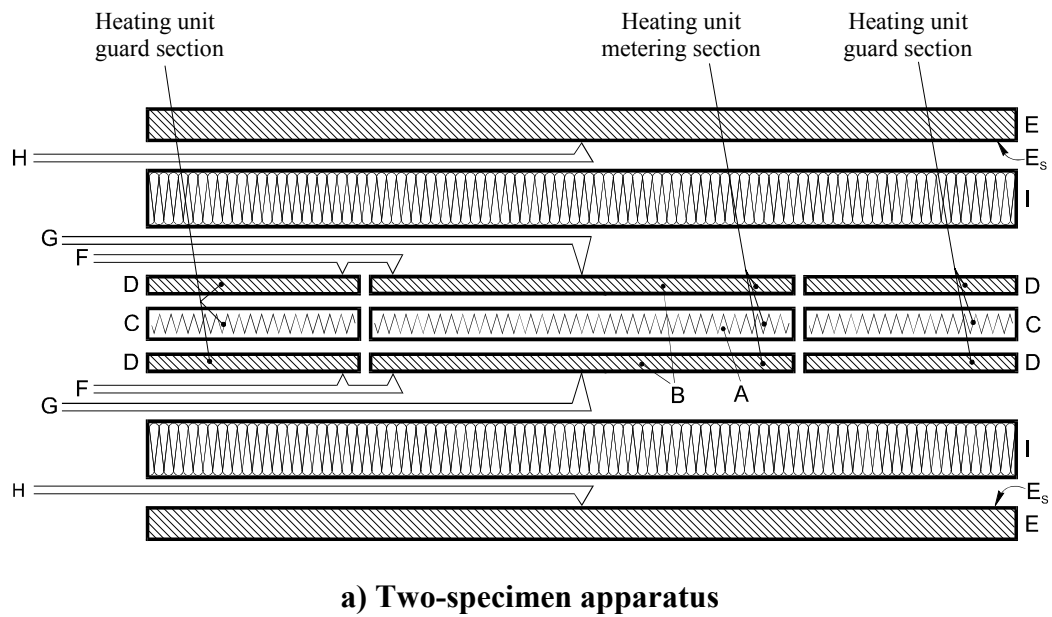
5.2 Guarded hot plate apparatus

5.2.1 General

In a guarded hot plate apparatus the heat flow rate is obtained from the measurement of the power input to the heating unit in the metering section. The general features of the apparatus with specimens installed are shown in Figure 1.

There exist two types of guarded hot plate apparatus, which conform to the basic principle outlined in clause 4:

- a) with two specimens (and a central heating unit);
- b) with a single specimen.



Key

A	Metering section heater	G	Heating unit surface thermocouples
B	Metering section surface plates	H	Cooling unit surface thermocouples
C	Guard section heater	I	Test specimen
D	Guard section surface plates	L	Guard plate
E	Cooling unit	M	Guard plate insulation
E _s	Cooling unit surface plate	N	Guard plate differential thermocouples
F	Differential thermocouples		

The gap is the separation between metering section (see A and B) and the guard section (see C and D)

Figure 1 — General features of two-specimen and single specimen guarded hot plate apparatus

5.2.2 Two specimen apparatus

In the two specimen apparatus [see Figure 1a)], a central round or square flat plate assembly, consisting of a heater and metal surface plates, called the heating unit, is sandwiched between two nearly identical specimens. The heat flow rate is transferred through the specimens to separate round or square isothermal flat assemblies, called the cooling units.

5.2.3 Single specimen apparatus

In the single specimen apparatus [see Figure 1b)], one of the specimens is replaced by a combination of a piece of insulation and a guard plate. A zero temperature-difference is then established across this combination. Providing all other applicable requirements of this standard are fulfilled, accurate measurements and reporting according to this method may be accomplished with this type of apparatus, but particular reference to the modification of the normal hot plate with two specimens should be made in the test report.

5.2.4 Heating unit

The heating unit consists of a separate central metering section, where the unidirectional constant and uniform density of heat flow rate can be established, surrounded by a guard section separated by a narrow gap.

5.2.5 Metering area

The metering area is the central area of the specimen delimited by the centre line of the gap of the heating unit.

This definition, which applies in principle to thick specimens only, has been retained for all the specimens to be tested according to this standard: due to this approximation, the thickness of the specimen shall be at least ten times the width of the gap.

5.2.6 Edge insulation and auxiliary guards

Additional edge insulation and/or auxiliary guard sections are required especially when operating above or below room temperature, see annex B of EN 1946-2:1999.

5.2.7 Cooling units

The cooling units shall have dimensions at least as large as those of the heating unit, including the guard heater(s). They shall consist of metal plates maintained at a constant and uniform temperature.

5.2.8 Accuracy and repeatability

Accuracy and repeatability depend both on the equipment and on testing conditions. The complete assessment of testing errors in a guarded hot plate apparatus in any specific testing condition shall be carried out in accordance with EN 1946-2:1999. The following is rough information applicable for tests correctly executed when the mean temperature of the test is near the room temperature.

Equipment constructed and operated in accordance with this standard (see also annex B) is capable of measuring thermal properties of high and medium thermal resistance products accurate to within $\pm 2\%$.

The repeatability of subsequent measurements made by the equipment on a specimen maintained within the apparatus without changes in testing conditions is typically better than $\pm 0,5\%$.

When measurements are made on the same reference specimen removed and then mounted again, the repeatability of measurements is normally better than $\pm 1\%$. This larger figure is due to minor changes in testing conditions, like the pressure of the plates on the specimen (which affects contact resistances), the relative humidity of the air around the specimen (which affects its moisture content), etc.

5.3 Heat flow meter apparatus

5.3.1 General

In the heat flow meter apparatus the density of heat flow rate is measured by means of one or two heat flow meter(s) placed against the specimen(s).

The general features of heat flow meter apparatus are shown in Figure 2; they consist of a heating unit, one or two heat flow meters, one or two specimens and a cooling unit. In configuration a), which is called “single-specimen asymmetrical”, the heat flow meter may be placed against either unit; the configuration b) is called “single-specimen symmetrical”; in configuration c), which is called “two-specimen symmetrical”, the specimens should be substantially identical. Each configuration yields equivalent results if used within the limitations stated in this standard.

NOTE There are distinct advantages for each configuration in practice; brief discussion is included in annex B of ISO 8301:1991.

5.3.2 Heat flow meters

The heat flow meter is an assembly that measures the density of heat flow rate through the specimen(s) by a temperature difference generated by this density of heat flow rate crossing the specimen(s) and the heat flow meter itself. Most commonly it consists of a homogeneous core, a surface temperature difference detector (a multi-junction thermopile) and a surface temperature detector(s). The heat flow meter region occupied by the core, where temperature difference detectors are placed, is called the metering area.

A density of heat flow rate, q , through the metering area of the device results in an output, e_h :

$$q = f e_h$$

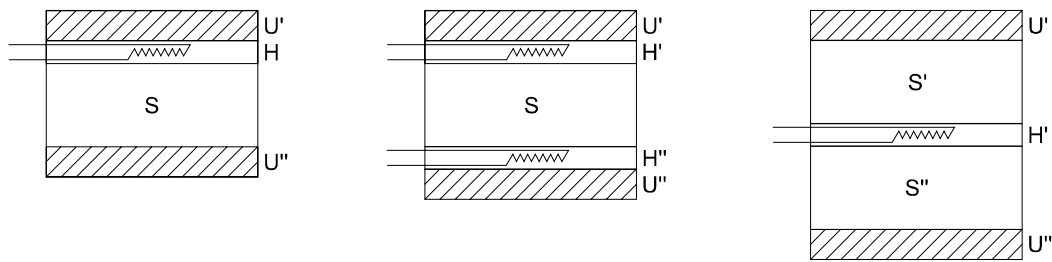
The calibration factor, f , which correlates e_h and q , is not a constant in all cases, but may depend upon temperature and, to a more limited extent, upon the density of heat flow rate.

5.3.3 Calibration principle

This is a secondary or relative method, since the ratio of the thermal resistance of the specimens(s) to that of a standard specimen(s) is measured. From the measurement of the heat flow rate, Φ_s , with the standard specimen(s) and Φ_u with the unknown specimen(s) to be measured, the assumption of a constant density of heat flow rate of the metering section and the assumption of the stability of the temperature difference, ΔT , and the mean temperature, T_m , gives the ratio between the thermal resistance, R_s , of the standard specimen(s) and R_u of the unknown specimen as follows:

$$R_u/R_s = \Phi_s/\Phi_u$$

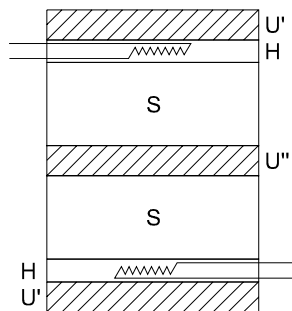
Calibration procedures are given in ISO 8301:1991.



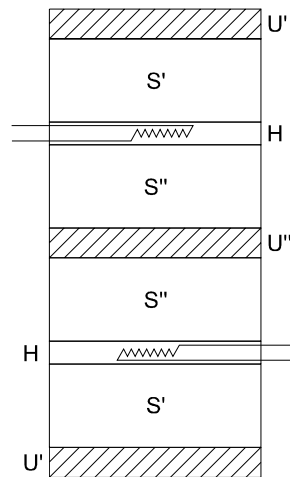
a) Single-specimen asymmetrical configuration

b) Single-specimen symmetrical configuration

c) Two-specimen symmetrical configuration



d) Double apparatus



e) Double apparatus

Key

U', U''	Cooling and heating units
H, H', H''	Heat flow meters
S, S', S''	Specimens

Figure 2 — Typical layouts of heat flow meter apparatus configurations

5.3.4 Limitations due to the calibration

The calibration factor, f , is a function of the mean heat flow meter temperature. If a calibration curve has been established in a temperature range, extrapolation is not allowed.

The calibration factor at a given mean heat flow meter temperature may also be a function of the density of heat flow rate. The apparatus shall only be used for densities of heat flow rate within the range covered by the calibration.

5.3.5 Accuracy and repeatability

Accuracy and repeatability depend both on the equipment and on testing conditions. The complete assessment of testing errors in a heat flow meter apparatus in any specific testing condition shall be carried out in accordance with EN 1946-3:1999. The following is rough information applicable for tests correctly executed when the mean temperature of the test is near the room temperature.

The repeatability of subsequent measurements made by the equipment on a specimen maintained within the apparatus without changes in testing conditions is typically better than $\pm 0,5\%$.

When measurements are made on the same reference specimen removed and then mounted again after large time intervals, the repeatability of measurements is normally better than $\pm 1\%$. This larger figure is due to minor changes in testing conditions, like the pressure of the plates and heat flow meter on the specimen (that affect contact resistances) and the relative humidity of the air around the specimen (that affects its moisture content), etc.

The accuracy of the calibration of the heat flow meter apparatus depends on the accuracy of the reference material and is normally within $\pm 2\%$.

NOTE The accuracy of the calibration is mainly due to the accuracy of the guarded hot plate method when measuring the properties of reference specimens.

When the limits specified in annex C are met, the heat flow meter method is capable of determining the heat transfer properties within $\pm 3\%$ when the mean temperature of the test is near the room temperature.

5.4 Error analysis and equipment performance check

The error analysis (not needed if equipment design conforms with one of the ones in annex D), the equipment performance check and the consequent assessment of the equipment accuracy in the range of testing conditions given in relevant product specifications shall be made according to 5.1.

6 Test specimens

6.1 General

Testing may be split into specimen handling, see below, and actual measurements, see clause 7. Some decisions about measurable heat transfer properties, specimen handling and testing conditions shall be taken when starting testing, see A.5. Directions on these decisions shall only be sought in this standard and/or in the relevant product standard applicable to the specimen to be tested.

6.2 Selection and size

One or two specimens shall be selected (from each sample) according to the type of apparatus (see 5.2.2 or 5.2.3 for guarded hot plate apparatus and 5.3.1 for heat flow meter apparatus). The specimen or specimens shall meet the general requirements outlined in A.3 and A.4. When two specimens are required they shall be as identical as possible with thicknesses differing by less than 2 %. The specimen or specimens shall be of such size as to cover the heating unit surfaces completely (including the guard section), without exceeding the overall linear dimension of the heating unit or heat flow meter by more than 3 %. They shall have a thickness according to the relevant product standard and additionally the relationship between the thickness of the test specimen used and the dimensions of the heating unit shall be restricted so as to limit the sum of the imbalance error (guarded hot plate apparatus only) and edge heat loss errors to 0,5 %, see thickness limits of Table A.1 in A.3. For the minimum specimen thickness see A.3.4 and Tables A.1 and A.2.

6.3 Specimen preparation

6.3.1 Conformity with product standards

The preparation of the specimens shall be in accordance with the appropriate product standard; unless otherwise specified in product standards, the general criteria in 6.3.2 and 6.3.3 should be fulfilled.

6.3.2 All specimens except loose-fills

The surface of the test specimens shall be made plane by appropriate means (sandpapering, face-cutting in a lathe, and grinding are often used), so that close contact between the specimens and apparatus or interposed sheets can be effected.

For rigid materials, the faces of the specimens shall be parallel over the total surface area within 2 % of the specimen thickness and shall be made as flat as the apparatus surfaces and so that the accuracy in the measurement of the specimen thickness be within 0,5 % (see A.3.6 and Table A.2).

The planeness of the surfaces can be checked with, for example, a good quality engineer's straightedge (straight to 0,01 mm) held against the surface and viewing at grazing incidence with a light behind the straightedge. Departures as small as 25 μm are readily visible. Large departures can be measured using feeler gauges and the straightedge as follows. The straightedge should be supported on a gauge block of known thickness, say 1 mm, at each end of the surface to be checked. Positive and negative deviations can be measured using feeler gauges along a straight line. Eight straight lines should be investigated as follows: the four edges of the surface, the two diagonals and a central cross (two lines parallel to the edges of the surface). When this procedure, applicable to both apparatus and specimen surfaces, is applied to specimen checking, it should be repeated for each face of the specimen.

Scratches, chips or similar defects over and above the naturally occurring surface irregularities in the finished surfaces of cellular or aggregate materials are accepted provided that the total of their surface areas is an acceptable fraction of the metering area and that their maximum depth is an acceptable fraction of the specimen thickness, so as to keep the added thermal resistance due to the corresponding air pockets low. For the purpose of this standard:

- if $(A_d/A_m)(R_a/R) < 0,0005$ the effect may be ignored;
- if $0,0005 \leq (A_d/A_m)(R_a/R) \leq 0,005$ the test may be undertaken, but the presence of the defects shall be mentioned in the test report;

where:

- A_d is the overall cross-sectional area of the defects;
- A_m is the area of the metering section;
- R_a is the thermal resistance of an air layer of thickness equal to the maximum depth of any defect;
- R is the thermal resistance of the specimen.

If contact sheets are used or thermocouples are mounted on the surface of the specimen, then the relevant product standards and EN 12664 shall be consulted.

6.3.3 Loose-fill materials

When testing loose-fill materials, the thickness of the specimen shall be at least 10 times the mean dimension of the beads, grains, flakes, etc. of the loose-fill material. The specimen(s) shall be prepared according to procedures appropriate to the material, in conformity with relevant product standards.

NOTE These product standard procedures cover such matters as mounting frames, covering sheets, specific precautions on specimen mounting, handling and conditioning, on how to get one (two) specimen(s) of the desired density during the test and how to check it, and on how to get a mass before and after conditioning, where applicable.

7 Testing procedure

7.1 General

A testing procedure is the complete set of operations to determine the desired heat transfer property performed on the specimen prepared as indicated in 6.3. These may be split into the conditioning, described in 7.2, and the remaining operations to run a test with the guarded hot plate or heat flow meter apparatus, as described in 7.3

7.2 Conditioning

After the determination of the mass of the specimen(s), they shall be conditioned to constant mass according to relevant product standards.

NOTE Conditioning is e.g. drying in a ventilated oven or drying and then bringing into equilibrium with the laboratory air; to prevent moisture migration to or from the specimen during the test, the specimen itself may be enclosed in a vapour-tight envelope.

A relative loss of mass is calculated from the mass determined before and after the drying.

To reduce testing time, the specimen(s) may be conditioned to the mean test temperature immediately prior to being placed in the apparatus.

7.3 Measurements

7.3.1 Mass

Just before mounting the specimen(s) in the apparatus, determine its mass with an accuracy better than 0,5 %.

7.3.2 Thickness and density

The specimen thickness is either the thickness imposed by positioning the heating and the cooling unit or the thickness of the specimen(s) as measured at the beginning of the test, as stated by relevant product standards.

NOTE For roll- or mat-type materials, product standards usually specify the thickness to be used for testing.

Specimen(s) thickness can be measured either in the apparatus at the existing test temperature and compression conditions or outside the apparatus with instrumentation that will reproduce the pressure on the specimen during the test, as stated by relevant product standards.

For thickness measurements in the apparatus, gauging points, or measuring studs mounted on purpose at the outer four corners of the cooling unit (or the heating and cooling units for a single specimen apparatus) or along the axes perpendicular to the units, at their centres, shall be used. The specimen thickness is determined from the average difference in the distance between the gauging points when the specimen(s) is (are) in place in the apparatus and when it is not in place, and the same force is used to press the apparatus units towards each other.

From the specimen dimensions, the thickness measured as above and the mass of the conditioned specimen determined as in 7.3.1 the as-tested density can be computed.

7.3.3 Temperature difference selection

Select the temperature difference to be in accordance with A.3.8 and the relevant product standard.

7.3.4 Ambient conditions

When heat transfer properties are desired for the situation in which the specimen is surrounded by air (or some other gas), adjust the humidity of the atmosphere surrounding the apparatus units during a test to a dew-point temperature at least 5 K below the cooling unit temperature.

When enclosing the specimen in a vapour-tight envelope to prevent moisture migration to or from the specimen, the testing conditions shall be such that no water condensation will take place on the portion of the envelope in contact with the cold side of the specimen.

7.3.5 Heat flow rate measurements

7.3.5.1 Heat flow rate in the guarded hot plate apparatus

Measure the average electrical power supplied to the metering area to within $\pm 0,1$ %.

Fluctuations or changes in the temperatures of the heating unit surfaces during the test period, due to random fluctuations or changes in their input power, shall not exceed 0,3 % of the temperature difference between the heating and cooling units.

Adjust and maintain the power input to the guard section, preferably by automatic control, to obtain the degree of temperature balance between the metering and guard section that is required to keep the sum of the imbalance and edge heat loss errors within 0,5 % (see 6.2).

7.3.5.2 Heat flow rate in the heat flow meter apparatus

Observe the mean temperature and the electromotive force output of the heat flow meter, the mean temperature and the temperature drop across the specimen(s) to check when they are stabilized.

Ensure that the temperature fluctuations (as a function of time) at the surface of the heat flow meter do not cause fluctuations in its electrical output greater than 2 % during the test period.

Ensure that the density of heat flow rate is in a range such that the accuracy of the calibration factor, f , and of the electrical instrumentation to read the heat flow meter output are in accordance with 5.3.5 and relevant requirements given in annex C.

7.3.6 Cold surface control (for two-specimen guarded hot plate apparatus)

When a two specimen apparatus is used, adjust the cooling units or cold surface heaters so that the temperature differences through the two specimens do not differ by more than 2 %.

7.3.7 Temperature difference detection

Determine the heating and cooling unit temperatures and the centre-to-guard temperature balance (for guarded hot plate apparatus only) by methods having sufficient repeatability and accuracy to meet all relevant requirements given in annex B for guarded hot plate apparatus, or relevant requirements given in annex C for heat flow meter apparatus.