SLOVENSKI STANDARD
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Toplotnoizolacijski proizvodi za opremo stavb in industrijske inštalacije - Ugotavljanje toplotne upornosti z zaščiteno vročo ploščo - 1. del: Meritve pri povišani temperaturi od 100 °C do 850 °C

Thermal insulation products for building equipment and industrial installations - Determination of thermal resistance by means of the guarded hot plate method - Part 1: Measurements at elevated temperatures from 100 °C to 850 °C

Wärmedämmstoffe für betriebstechnische Anlagen in der Industrie und in der technischen Gebäudeausrüstung - Bestimmung des Wärmedurchlasswiderstandes nach dem Verfahren mit dem Plattengerät - Teil 1: Messungen bei erhöhten Temperaturen von 100 °C bis 850 °C

Produits isolants thermiques pour l’équipement du bâtiment et les installations industrielles - Détermination de la résistance thermique par la méthode de la plaque chaude gardée - Partie 1: Mesurages a températures élevées comprises entre 100 °C et 850 °C

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91.100.60	Materiali za toplotno in zvočno izolacijo	Thermal and sound insulating materials

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Thermal insulation products for building equipment and industrial installations - Determination of thermal resistance by means of the guarded hot plate method - Part 1: Measurements at elevated temperatures from 100 °C to 850 °C

Produits isolants thermiques pour les équipements de bâtiments et les installations industrielles - Détermination de la résistance thermique par la méthode de la plaque chaude gardée - Partie 1 : Mesurages à haute témperature entre 100 °C et 850 °C

Wärmedämmstoffe für die Haustechnik und für betriebstechnische Anlagen - Bestimmung des Wärmedurchlasswiderstandes nach dem Verfahren mit dem Plattengerät - Teil 1: Messungen bei erhöhten Temperaturen von 100 °C bis 850 °C

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Management Centre: Avenue Marnix 17, B-1000 Brussels

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Foreword

This document (CEN/TS 15548-1:2011) has been prepared by Technical Committee CEN/TC 89 “Thermal performance of buildings and building components”, the secretariat of which is held by SIS.

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Introduction

This technical specification is an interim solution to the need for a standard to complement EN 12667:2001 in the approximate temperature range 100 °C to 850 °C.

The technical specification is chosen to publish the knowledge gained in the field of measuring thermal conductivity at elevated temperature now, as the finalisation of a standard is a complex matter requiring further investigations.

Among existing apparatus for steady state thermal testing, the guarded hot plate can be operated at selected mean temperatures over the temperature range -100 °C to 850 °C. In general, these apparatus exist in three forms covering roughly the following temperature ranges -100 °C to ambient, ambient to 100 °C and above 100 °C. However, it has been found that it is not possible to achieve the uncertainties of ± 2 % claimed as achievable for the low and ambient temperature forms when using the high temperature version in accordance with ISO 8302. More realistic figures adopting the method and procedures detailed in this document are ± 5 % up to 450 °C and ± 7 % at temperatures above 450 °C.

Many issues are more difficult at high temperatures. There are design issues due to apparatus material stability, the level of temperature measurement uncertainty is higher than at ambient temperatures and there is also greater degradation in the performance of temperature sensors when operated at high temperatures, requiring calibration checks to be more frequent. At high temperatures, it is more likely to get hot spots on a plate due to non-uniformity of a heater; these could be near temperature sensors and give false readings. Any air gaps will have greater heat flow across them due to radiation heat exchange and finally provisions for specimen expansion or shrinkage are needed.

Due to the above considerations the following clauses of EN 12667:2001 have been expanded and detailed:

5 Apparatus

5.1 General

5.2.4 Heating Unit

5.2.5 Metering Area

5.2.6 Edge insulation and auxiliary guards

5.2.7 Cooling units

5.3.5 Accuracy and repeatability

6 Test specimens

6.2 Selection and size

7 Testing procedure

7.3.8 Settling time and measurement interval

Annex A

Annex B.2

1 Scope

This document provides the additional information to that given in EN 12667, EN 12664, EN 12939 and ISO 8302 on the design of apparatus and operational procedures required to determine the thermal resistance of thermal insulation products in the temperature range 100 °C to 850 °C using the guarded hot plate method.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1946-2, *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*

EN 12664, *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*

EN 12667:2001, *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*

EN 12939, *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 resistance*

EN ISO 7345, *Thermal insulation – Physical quantities and definitions (ISO 7345:1997)*

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

ISO 8302:1991, *Thermal insulation – Determination of steady state thermal resistance and related properties – Guarded hot plate apparatus*

3 Terms and definitions, symbols and units

3.1 Terms and definitions

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

3.2
Symbols and units

Symbol	Quantity	Unit
A	metering area measured on a selected isothermal surface	m^2
d	thickness; average thickness of specimen	m
e	edge number ratio	-
m	mass (of the specimen)	kg
Δm	mass change	kg
q	density of heat flow rate	W/m^2
R	thermal resistance	m^2·K/W
ΔR	increment of thermal resistance	m^2·K/W
r	thermal resistivity	m·K/W
T_1	temperature of the warm surface of the specimen	K
T_2	temperature of the cold surface of the specimen	K
T_3	specimen edge temperature	K
T_{m}	mean test temperature (usually $(T_1 + T_2)/2$)	K
ΔT	temperature difference (usually $T_1 - T_2$)	K
Δt	time interval	s
$\mathcal{T}$	transfer factor	W/(m·K)
V	volume	m^3
Φ	heat flow rate	W
λ	thermal conductivity	W/(m·K)
λ_{t}	thermal transmissivity	W/(m·K)
ρ	density	kg/m^3

4 Principle

4.1 Apparatus

The principle of the guarded hot plate method is as described in 1.6 of ISO 8302:1991.The guarded hot plate apparatus is intended to establish a unidirectional constant and uniform density of heat flow rate within homogeneous specimens, in the form of slabs with flat parallel faces. The part of the apparatus where this takes place with acceptable accuracy is around its centre; the apparatus is therefore divided in a central metering section in which measurements are taken, and a surrounding guard section.

NOTE Specimen homogeneity is discussed in A.3.2 of EN 12667:2001.

4.2 Measuring the density of heat flow rate

Following 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 crosses.

4.3 Measuring the temperature difference

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

4.4 Deriving the thermal resistance or transfer factor

The thermal resistance, R, is calculated from q, A and ΔT. From the additional knowledge of the thickness, d, of the specimen, the transfer factor, $\mathcal{T}$, is computed; see A.2.8 of EN 12667:2001.

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 of EN 12667:2001 are realised

4.6 Apparatus limits

The application of the method is limited by the capability of the apparatus to maintain an 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 description and design requirement

5.1 General

A guarded hot plate apparatus used for measurements according to this document shall comply with the limits on equipment performance and test conditions given in Annex A and shall conform with the requirements concerning the assessment of equipment accuracy given in EN 1946-2; this requires that the equipment design, error analysis and performance check be according to Section 2 of ISO 8302.

A guarded hot plate design for high temperature measurement needs detailed modelling of heater plates, gap, imbalance sensors, guard plates, edge insulation and auxiliary guards and requires much more careful design than its ambient temperature counterpart for the following reasons:

- The heater plate material needs to retain its mechanical properties to the higher operating temperatures. Suitable materials with the higher strength requirements usually have a lower thermal conductivity than pure copper and aluminium alloys that are normally used at ambient temperatures. This can mean that the heater plates have to be thicker to ensure uniform temperature distribution across the plate, which in turn can lead to higher heat losses or gains from the edges of the plate.

- Extra precautions have to be taken to electrically insulate heater wires and temperature sensors from the metal heater plate. One solution is to use sheathed wires but this raises the problem of accurately locating the voltage probes on the heater wire in the centre of the guard centre gap.

- The use of sheathed temperature sensors to limit the degradation of temperature sensors due to oxidation can also create additional problems because of the increased area of metal that crosses the guard centre gap compared to a 0,2 mm diameter thermocouple.

- Despite the use of materials with high strength at high temperatures, there could still be problems with plate distortion at higher temperatures due to residual stresses introduced by machining. This could result in non-parallelism and unacceptable air gaps between the specimen and the heater plates.

In a guarded hot plate apparatus, the heat flow rate is obtained from the measurement of the electrical power input to the heating unit in the metering section. The general features of the apparatus with specimens installed are shown in Figure 1. The apparatus can have an enclosure to exclude air exchange from enclosure to ambient and be provided with additional edge guard heaters or a temperature controlled environment around the specimen assembly.

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.

5.2 Two specimen apparatus

In the two specimen apparatus, (see Figure 1), 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, which may consist of either a heated “cold plate” with additional cooling plates separated by insulation slabs or separate cooling units.

5.3 Single specimen apparatus

In the single specimen apparatus (see Figure 2), one of the specimens and its cold plate is replaced by a combination of a piece of insulation and a guard plate. Zero temperature difference is then established across this combination. Providing all other applicable requirements of this document are fulfilled, accurate measurements and reporting according to this method can be achieved with this type of apparatus, but the test report shall state that a single specimen apparatus was used.

5.4 Plates

5.4.1 General

A guarded hot plate designed for high temperature measurements uses heated plates for both faces of the specimen, the “cold” plates may also be equipped for cooling or the cooling can be established by other means, e.g. separate cooling plates.

5.4.2 Plate material

The materials used in the construction of the heating unit must be chosen carefully to ensure adequate performance at the temperatures at which the heating unit is to be operated. At high temperatures the chosen material shall be

- resistant to further oxidation once an initial thin oxidation film has formed;
- able to withstand repeated cycling from room temperature to the highest design temperature without the heating unit distorting beyond the flatness requirements;
- of sufficiently high thermal conductivity in relation to the plate thickness and the separation of the wires or strips forming the heating element to ensure that uniform temperatures can be maintained across the working surfaces.

Suitable materials might be pure nickel, Inconel alloys (low conductivity), silver or pure alumina (high conductivity).

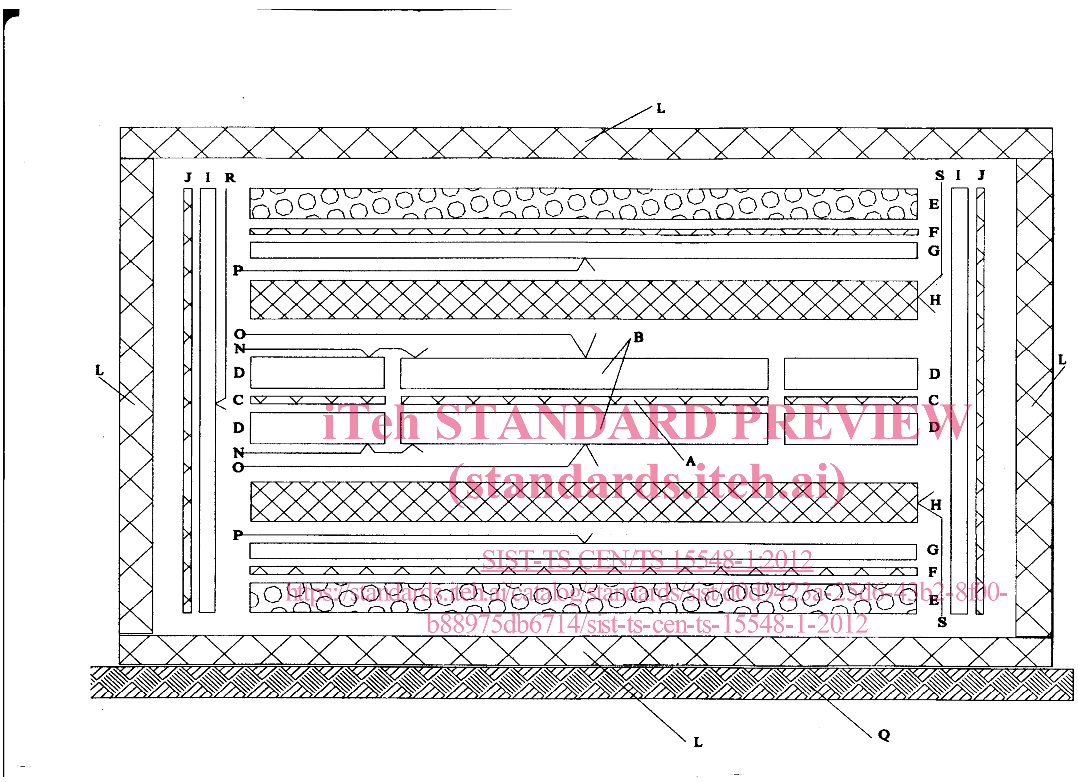
5.4.3 Plate geometry

Plates are either square or circular.

Round plates are simpler to model and design although greater care is required both in the assembly and to ensure uniform heating per area.

Square plates offer a simpler design but for high temperature operation additional heaters with control may be required in the corners of the guard area in order to maintain a uniform temperature across the plates.

The surface departure from plane shall not exceed 0,025 % as specified in Annex A, A.4.



Key

A metering section heater

B metering section surface plates

C guard section heater

D guard section surface plates

E cooling unit (optional)

F cold plate heater (optional)

G cold surface plate

H test specimen

I edge guard plate (optional)

J edge guard heater (optional)

L insulated enclosure (optional)

N differential temperature sensors

O metering section surface temperature sensors

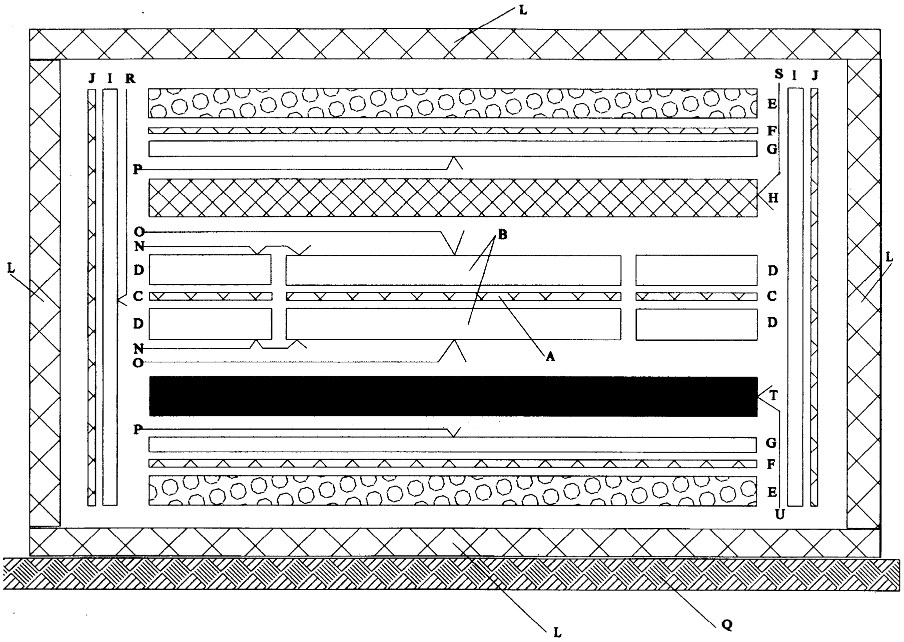
P cold surface plate temperature sensors

Q base plate

R edge guard temperature sensors (optional)

S specimen edge temperature sensors (optional)

Figure 1 —Schematic design of two specimen guarded hot plate apparatus



Key

A metering section heater

B metering section surface plates

C guard section heater

D guard section surface plates

E cooling unit (optional)

F cold plate heater (optional)

G cold surface plate

H test specimen

I edge guard plate (optional)

J edge guard heater (optional)

L insulated enclosure (optional)

N differential temperature sensors

O metering section surface temperature sensors

P cold surface plate temperature sensor

Q base plate

R edge guard temperature sensors

S specimen edge temperature sensors

T guard insulation

U guard insulation edge temperature sensor

Figure 2 —Schematic design of single specimen guarded hot plate apparatus