INTERNATIONAL STANDARD

ISO 8990

First edition
1994-09-01

Thermal insulation — Determination of steady-state thermal transmission properties — Calibrated and guarded hot box

Isolation thermique — Détermination des propriétés de transmission thermique en régime stationnaire — Méthodes à la boîte chaude gardée et calibrée

Reference number
ISO 8990:1994(E)

Contents

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Annexes

Foreword

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

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8990 was prepared by Technical Committee ISO/TC 163, *Thermal insulation*, Subcommittee SC 1, *Test and measurement methods*.

Annex A forms an integral part of this International Standard. Annex B is for information only.

Introduction

Data on the thermal transmission properties of insulants and insulated structures are needed for various purposes including judging compliance with regulations and specifications, for design guidance, for research into the performance of materials and constructions and for verification of simulation models.

Many thermal insulating materials and systems are such that the heat transfer through them is a complex combination of conduction, convection and radiation. The methods described in this International Standard measure the total amount of heat transferred from one side of the specimen to the other for a given temperature difference, irrespective of the individual modes of heat transfer, and the test results can therefore be applied to situations when that is the property required. However, the thermal transmission properties often depend on the specimen itself and on the boundary conditions, specimen dimensions, direction of heat transfer, temperatures, temperature differences, air velocities, and relative humidity. In consequence, the test conditions must replicate those of the intended application, or be evaluated if the result is to be meaningful.

It should also be borne in mind that a property can only be assessed as useful to characterize a material, product or system if the measurement of the steady-state thermal transmission properties of the specimen and the calculation or interpretation of the thermal transmission characteristics represent the actual performance of the product or system.

Further, a property can only be characteristic of a material, product or system if the results of a series of measurements on a number of specimens from several samples provide sufficient reproducibility.

The design and operation of the guarded or calibrated hot box is a complex subject. It is essential that the designer and user of such apparatus has a thorough background knowledge of heat transfer, and has experience of precision measurement techniques.

Many different designs of the calibrated and the guarded hot box exist worldwide conforming to national standards. Continuing research and development is in progress to improve apparatus and measurement techniques. Also the variation of structures to be tested may be so great, and the requirements for test conditions so different, that it would be a mistake to restrict the test method unnecessarily and to confine all measurements to a single arrangement. Thus it is not practical to mandate a specific design or size of apparatus.

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Thermal insulation — Determination of steady-state thermal transmission properties — Calibrated and guarded hot box

Section 1: General

1.1 Scope

This International Standard lays down the principles for the design of the apparatus and minimum requirement that shall be met for determination of the laboratory steady-state thermal transmission properties of building components and similar components for industrial use. It does not, however, specify a particular design since requirements vary, particularly in terms of size, and also to a lesser extent in terms of operating conditions.

This International Standard describes also the apparatus, measurement technique and necessary data reporting. Special components, for example windows, need additional procedures which are not included in this International Standard. Also excluded are measurements of the effect on heat flow of moisture transfer or redistribution but consideration shall be given in the design and operation of the equipment as to the possible effect of moisture transfer on the accuracy and the relevance of test results. The properties which can be measured are thermal transmittance and thermal resistance. Two alternative methods are included: the calibrated hot box method and the guarded hot box method. Both are suitable for vertical specimens such as walls and for horizontal specimens such as ceilings and floors. The apparatus can be sufficiently large to study full-scale components.

The methods are primarily intended for laboratory measurements of large, inhomogeneous specimens, although homogeneous specimens can, of course, also be tested, and these are necessary for calibration and validation.

When testing homogeneous specimens in accordance with this International Standard, experience has shown that an accuracy within ± 5 % can generally be achieved. However, the accuracy of each individual apparatus shall be estimated with reference homogeneous specimens of thermal conductance extending over the range to be measured using the apparatus.

The estimation of accuracy for nonhomogeneous specimens will be more complex and involve an analysis of the heat flow mechanism in the particular types of inhomogeneous specimens being tested. Such analyses are not covered by this International Standard.

The method does not provide for measurements where there is mass transfer through the specimen during the test.

1.2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

1.3 Definitions

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

1.3.1 mean radiant temperature, T_r: Appropriate weighting of the temperatures of surfaces "seen" by the specimen for the purpose of determining the radiant heat flow rate to the surface of the specimen (see annex A).

1.3.2 environmental temperature, T_n: Appropriate weighting of air and radiant temperatures, for the purpose of determining the heat flow rate to the surface of the specimen (see annex A).

1.4 Symbols, units and relationships

The following recommended symbols are used:

i	Interior, usually hot side	
e	Exterior, usually cold side	
s	Surface	
n	Environmental	
λ	Thermal conductivity	[W/(m·K)]
R	Thermal resistance	[(m²·K)/W]
U	Thermal transmittance	[W/(m²·K)]
h	Surface coefficient of heat transfer	[W/(m²·K)]
Φ	Heat flow rate	[W]
Φ_p	Total power input, heating or cooling	[W]
Φ_1	Heat flow rate through specimen	[W]
Φ_2	Imbalance, heat flow rate parallel to specimen	[W]
Φ_3	Heat flow rate through metering box walls	[W]
Φ_4	Flanking loss, heat flow rate flanking specimen	[W]
Φ_5	Peripheral loss, heat flow rate, parallel to specimen surface at the edges of the specimen	[W]
A	Area perpendicular to heat flow	[m²]
q	Density of heat flow rate	[W/m²]
d	Specimen thickness	[m]
T_a	Air temperature	[K]
T_r	Mean radiant temperature	[K]
T_n	Environmental temperature	[K]
T_s	Surface temperature	[K]

$R_s = A(T_{si} - T_{se})/\Phi_1$

$R_s = 1/h$

$R_{si} = A(T_{ni} - T_{si})/\Phi_1$

$R_{se} = A(T_{se} - T_{ne})/\Phi_1$

$R_u = 1/U$

$U = \Phi_1/A(T_{ni} - T_{ne})$

$\Phi_1 = \Phi_p - \Phi_3 - \Phi_2$ [for guarded hot box]

$\Phi_1 = \Phi_p - \Phi_3 - \Phi_4$ [for calibrated hot box]

NOTE 1 This method does not directly measure the thermal conductivity although it can be derived in case of opaque, homogeneous, flat specimens using the relationship $\lambda = d/R_s$.

1.5 Principle

1.5.1 General

Both types of apparatus, the guarded hot box (GHB) and the calibrated hot box (CHB), are intended to reproduce conventional boundary conditions of a specimen between two fluids, usually atmospheric air, each at uniform temperature.

The specimen is placed between a hot and a cold chamber in which environmental temperatures are known.

Measurements are made at steady-state of air and surface temperatures and of the power input to the hot side chamber. From these measurements the thermal transfer properties of the specimen are calculated. Heat exchange at the surfaces of the test specimen involves both convective and radiative components. The former depends upon air temperature and air velocity, and the latter depends upon the temperatures and the total hemispherical emittances of specimen surfaces and of surfaces "seen" by the test specimen surface. The effects of the heat transfer by convection and radiation are combined in the concept of an "environmental temperature" and a surface heat transfer coefficient.

Thermal transmittance is defined between two environmental temperatures, and therefore suitable temperature measurements are required to enable these to be determined. This is particularly important with test specimens of low thermal resistance for which the surface coefficients of heat transfer form a significant fraction of the total resistance. In case of test specimens with a moderate to high thermal resistance, it may be sufficient to record air temperatures only during a test, if it can be shown that the difference in air and radiant temperatures on either side of the test specimen is so small that the accuracy requirements are met.

A special situation arises when the hot box has a radiant panel, close to the warm side of the specimen, as heat supply. In this case the radiant component will be more dominant in the heat transfer to the specimen surface. This method with radiant panel can be used to measure the thermal resistance of the specimen but is not suitable for direct measurements of the thermal transmittance, at conventional surface coefficients.

1.5.2 Guarded hot box

In the guarded hot box (see figure 1), the metering box is surrounded by a guard box in which the environment is controlled to minimize lateral heat flow in the specimen, Φ_2, and heat flow through the metering box walls, Φ_3. Ideally, when a homogeneous specimen is mounted in the apparatus and when both inside and outside the metering box the temperatures are uniform and furthermore when cold side temperatures and surface coefficients of heat transfer are uniform, a temperature balance for air both inside and outside the metering box would imply a balance on the specimen surface and vice versa, i.e. $\Phi_2 = \Phi_3 = 0$. The total heat flow through the specimen will then be equal to the heat input to the metering box.

In practice, for each equipment and each specimen under test, there will be a limit in detecting imbalance (imbalance resolution, see 1.6.1.1).

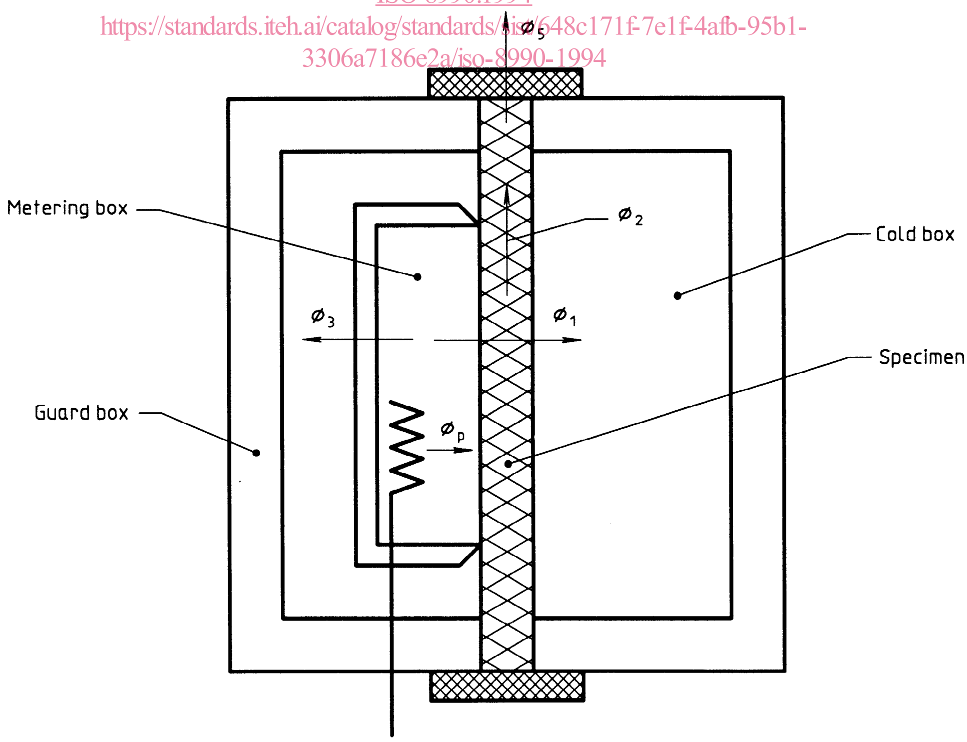

Figure 1 — Guarded hot box

1.5.3 Calibrated hot box

The calibrated hot box (see figure 2) is surrounded by a temperature-controlled space not necessarily at the same air temperature as that inside the metering box. The heat losses through the box walls, Φ_3, are kept low by using a construction of high thermal resistance. The total power input, Φ_p, shall be corrected for the wall losses, Φ_3, and for the flanking losses, Φ_4. The flanking heat flow path is illustrated in figure 3, which shows details of the specimen and specimen frame with the adjacent hot and cold side box walls. The correction for box wall losses and flanking losses are determined by tests on calibration specimens of known thermal resistance. For flanking loss calibration, the calibration specimens should cover the same thickness and thermal resistance range as the specimens to be measured and the temperature range of intended use.

1.6 Limitations and sources of errors

The operation of the apparatus, to a certain desired accuracy, is limited by a number of factors related to equipment design, calibration and operation and specimen properties, e.g. thickness, thermal resistance and homogeneity.

1.6.1 Limitations and errors due to apparatus

1.6.1.1 Limitations in imbalance resolution in a guarded hot box

In practice, even with homogeneous specimens, local surface coefficients of heat transfer are not uniform, especially close to the borders of the metering box. As a consequence, neither the specimen surface-temperature nor the air temperature are uniform close to the periphery of the metering box both inside and outside. This has two consequences:

a) It can be impossible to reduce to zero at the same time both the lateral heat flow, Φ_2, through the specimen, and the heat flow, Φ_3, through the metering box walls;

b) The temperature nonuniformity close to the metering box, on the specimen surface, and in the air, respectively, define the corresponding best imbalance resolution.

The apparatus shall be designed and operated in such a way as to obtain optimum heat flow balance as indicated in a) above, i.e. apparatus geometry and guard air space and air flow speed so that Φ_3 does not exceed 10 % of Φ_p.

Inhomogeneities in the specimen will enhance nonuniformities in local surface coefficients and in specimen surface-temperatures. Heat flow imbalance through the metering box wall and in the specimen shall be evaluated, and when necessary corrected for. For this purpose the metering box walls shall be equipped to serve as a heat flowmeter. Additionally, a thermopile across the metering area periphery can be mounted on the specimen surfaces. In routine testing, imbalance detection can be simplified by calibration and calculation.

1.6.1.2 Size of metered area

The metering area is defined:

a) for a guarded hot box, as the centre-nose to centre-nose when the specimen is thicker or equal to the nose width, or if the specimen is thinner than the nose width, as the inner periphery of the nose;

b) for a calibrated hot box, as the inner periphery of the metering box.

The size of the metered area determines the maximum thickness of the specimen. The ratios of the metering area side to the specimen thickness and of the guard width to the specimen thickness are governed by principles similar to those for the guarded hot box.

The size of the specimen can also limit possibilities for a representative section of the construction to be tested and thus allow errors and difficulties in interpretation of the result.

Measurement errors in testing to the hot box methods are in part proportional to the length of the perimeter of the metering area. The relative influence of this diminishes as metering area is increased. In the guarded hot box, the minimum size of the metered area is 3 times specimen thickness or 1 m × 1 m, whichever is the greater.

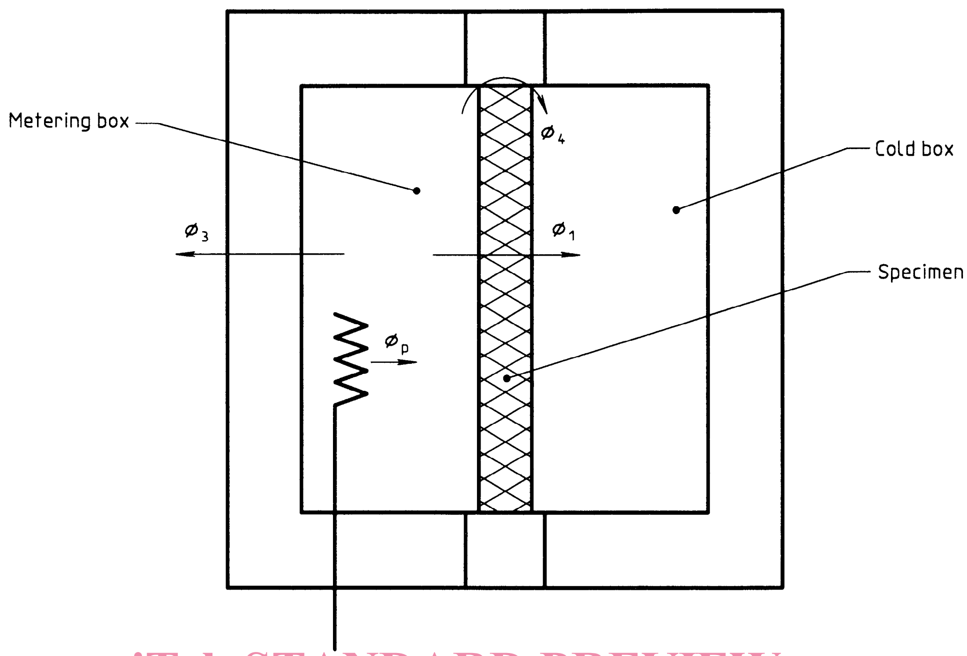

Figure 2 — Calibrated hot box

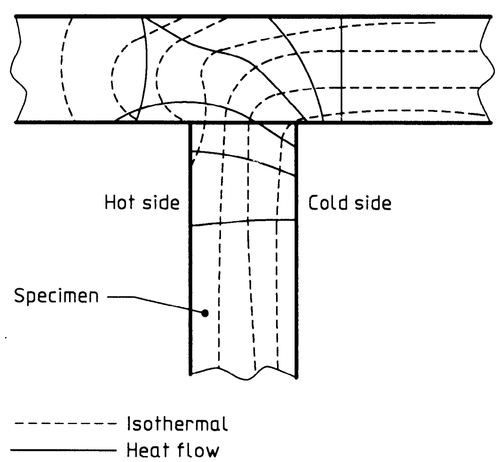

Figure 3 — Heat flow path in specimen and frame