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**Glass in building — Vacuum insulating  
glass —**

**Part 3:  
Test methods for evaluation of  
performance under temperature  
differences**

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*Verre dans la construction — Vitrage isolant à lame de vide —*

*Partie 3: Méthodes d'essai pour l'évaluation des performances en cas  
de différences de température*

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## 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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 1, *Product considerations*.

A list of all parts in the ISO 19916 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

# Glass in building — Vacuum insulating glass —

## Part 3: Test methods for evaluation of performance under temperature differences

### 1 Scope

This document specifies test methods for evaluation of performance of vacuum insulating glass samples with rigid edge seal when subjected to temperature differences between the glass sheets.

This document is not applicable to vacuum insulating glass samples with flexible edge seal.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 19916-1, *Glass in building — Vacuum insulating glass — Part 1: Basic specification of products and evaluation methods for thermal and sound insulating performance*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19916-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1

##### **heat transfer control board**

board placed in a test chamber for reducing air flow around the vacuum insulating glass specimen

#### 3.2

##### **rigid edge seal**

edge seal that prevents lateral relative movement between the glass sheets at the edge of the sheets where the seal is formed, made from a rigid material such as glass or metal

#### 3.3

##### **flexible edge seal**

edge seal structure allowing lateral movement between the two glass sheets

## 4 Test method

### 4.1 Principle

The evaluation of performance of a vacuum insulating glass specimen when subjected to a temperature difference shall be performed in the following way:

- a) the test conditions should ensure that a well-defined and reproducible temperature is established in all regions of specimen;
- b) stresses in the vacuum insulating glass specimen induced by the testing procedure from sources other than the temperature difference should be as small as possible.

In order to satisfy these criteria:

- the specimen should be surrounded on each side by air at well-defined temperatures, and
- the specimen shall be oriented vertically; this effectively eliminates stresses due to bending under gravitational forces.

NOTE Heat transfer on the glass surfaces and the glass edge constraint can have a significant influence on the stress induced in the glass sheets of vacuum insulating glass under temperature differences. A detailed study of this is given in [Annex B](#).

### 4.2 Test specimens

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#### 4.2.1 Number of specimens

Three vacuum insulating glass specimens shall be submitted for testing.

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#### 4.2.2 Size of specimens

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Each test specimen shall measure no less than 300 mm in width and 300 mm in height and no more than 850 mm in width and 850 mm in height. Size of specimens shall be determined so that distance between edge of the test specimen and inside wall of chamber is no less than 100 mm.

#### 4.2.3 Design of specimens

In the following, a product range shall consist of specimens having the same edge seal structure and material.

The specimen design with the lowest *U*-value in the product range shall be selected for the test. If there are multiple designs with different thickness, one design shall be selected with the following process.

The specimen design with the minimum total nominal thickness in the product range shall be selected for the test. If the selected design has different nominal thicknesses for the two glass sheets, the thicker glass sheet shall face the hot side of the apparatus. If there is more than one specimen design of glass thickness in the product range with the minimum total nominal thickness, the specimen to be tested shall be the one for which the nominal thicknesses of the glass sheets differ the least.

EXAMPLE 1 For a product range with thickness in mm of 3 + 3, 3 + 5 and 5 + 5, only 3 + 3 is tested.

EXAMPLE 2 For a product range with thickness in mm of 3 + 5 and 5 + 5, only 3 + 5 is tested. The glass sheet with 5 mm thickness faces to the hot side of the apparatus.

EXAMPLE 3 For a product range with thickness in mm of 3 + 5, 4 + 4 and 5 + 5, only 4 + 4 is tested.

### 4.3 Apparatus

The usual laboratory apparatus and, in particular, the following.

**4.3.1 Temperature chamber**, in which air temperature in a room can be controlled [see [Figure 1, a](#)] or in which air temperature in two rooms divided by the specimen and the frame can be controlled [see [Figure 1, b](#)].

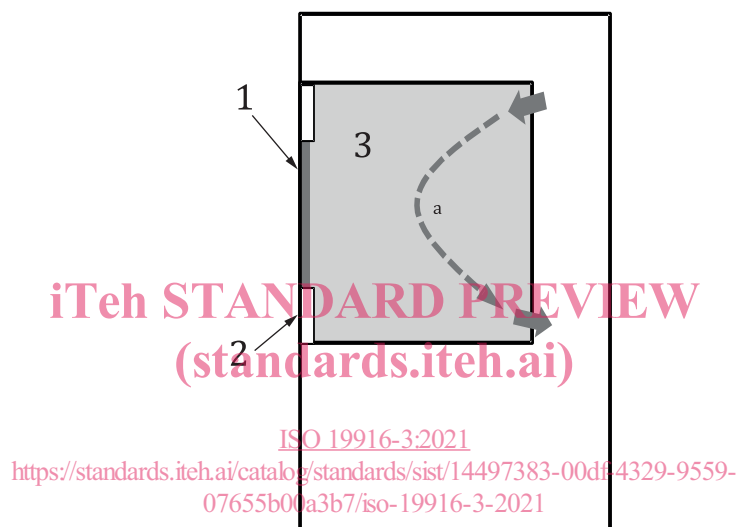
**4.3.2 Frame for specimen installation**, consisting of frame and insulating board [see [Figure 1, c](#)].

**4.3.3 Heat transfer control board**, consisting of flat metal plate.

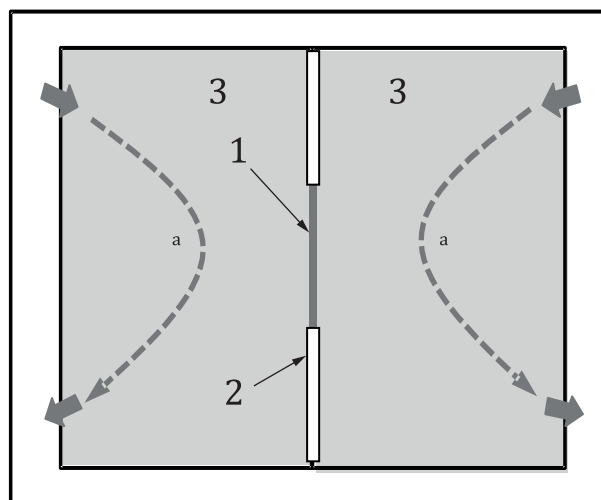
**4.3.4 Thermocouples**.

**4.3.5 Data recorder**.

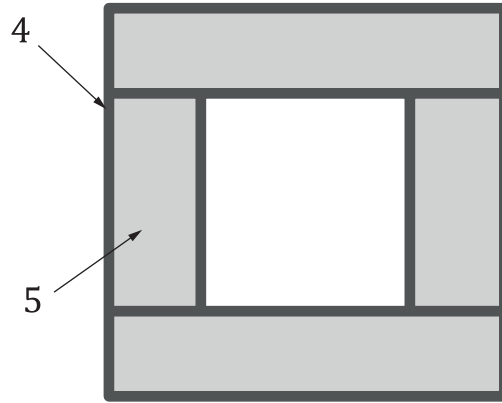
**4.3.6 Adhesive tape**.



**a) Temperature chamber having one room**



**b) Temperature chamber having two rooms**



c) Frame for specimen installation

**Key**

- 1 vacuum insulating glass specimen
- 2 frame for specimen installation
- 3 temperature controllable room
- 4 frame
- 5 insulating board
- <sup>a</sup> Air circulation.

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**Figure 1 — Examples of apparatus**  
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**4.4 Procedures**

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**4.4.1 General**

The *U*-value and the thermal resistance of each vacuum insulating glass specimen shall be determined with the method described in [4.4.2](#).

The specimen shall be prepared for the test by attaching thermocouples for temperature measurements to the surface, as shown in [4.4.3](#). The temperatures as measured by these thermocouples shall be continually recorded in a data recorder during the test.

The specimen shall be installed in the test apparatus as shown in [4.4.4](#). A heat transfer control board can be inserted between the circulating air and the surface of the specimen.

NOTE [Annex A](#) shows guidelines of the apparatus setup.

The test condition of the temperature difference to be applied to the specimen is described in [4.4.5](#).

The heat transfer coefficients on glass surfaces at the hot and cold sides shall be calculated from measured temperatures using the method described in [4.4.6](#).

If one or both of the calculated heat transfer coefficients is outside of the acceptable range defined in [4.4.7.1](#), the heat transfer control board and/or the cooling/heating system control shall be adjusted to correct the heat transfer coefficient(s) before continuing the test.

Failure criteria with the test shall be evaluated using measured temperatures as in [4.4.7.2](#).

The test procedure is shown in [Figure 2](#).



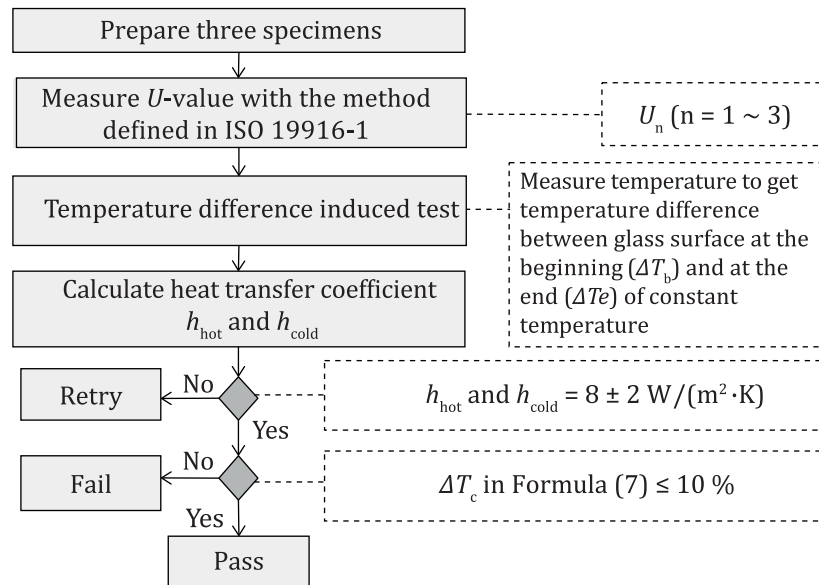


Figure 2 — Flow of test procedure

#### 4.4.2 Measurement of $U$ -value

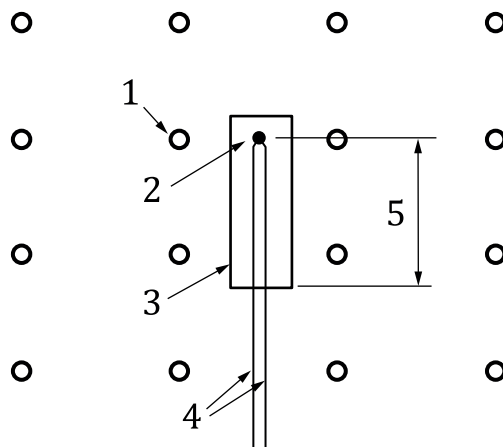
Before the specimen is installed in the apparatus, the  $U$ -value and the thermal resistance of each specimen shall be determined with the method defined in Annex A of ISO 19916-1:2018.

#### 4.4.3 Setting of thermocouples

Thermocouples of which accuracy is guaranteed shall be placed to measure temperature at the following points. The thermocouples shall be applied on the glass and the heat transfer control board surface in such a way that the thermocouples do not change the temperature at the measuring point.

- Hot and cold side glass surface close to the centre of the specimen.
- Air temperature of hot and cold side at the point facing the centre of the specimen and at 100 mm to 200 mm from the glass surface. When the heat transfer control board is used, thermocouple shall be placed on the board at the point facing the centre of the specimen.

The diameter of thermocouple wire should be no more than 0,25 mm. The thermocouples should thermally contact the glass and the board surface for no less than 20 mm in length, using thin adhesive plastic tape having emissivity close to that of the surface. Metallic tape should not be used. The tip of the thermocouple on the glass should be positioned at the mid-point between two pillars and the contacting thermocouple wires should be located along a line mid-way between two adjacent rows of pillars. An example is shown in [Figure 3](#).



**Key**

- 1 pillar
- 2 tip of thermocouple
- 3 plastic adhesive tape
- 4 thermocouple wire
- 5 no less than 20 mm

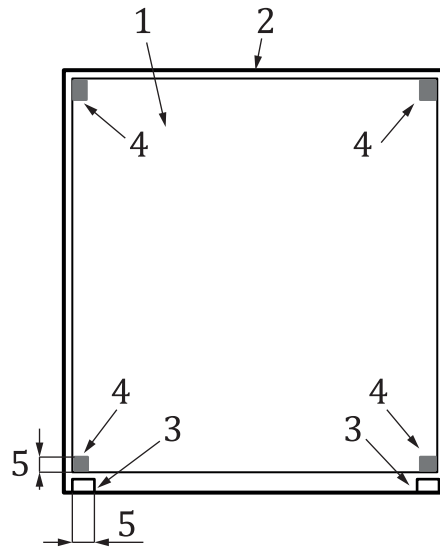
**Figure 3 — Example for setting a thermocouple on a glass surface**

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**4.4.4 Installation of specimens (standards.iteh.ai)**

Place a specimen vertically at the opening of the test apparatus, taking care that significant stress is not induced in the specimen by the method of fastening. In particular, all four edges shall be free to bend during the test.

**EXAMPLE** The specimen is placed on two setting blocks at the bottom corners and fixed at four corners. The setting blocks and fixing materials contact the specimen for a distance of no more than 30 mm from the corner of the specimen. A diagram of the fixing structure is shown in [Figure 4](#).

**Key**

- 1 vacuum insulating glass specimen
- 2 frame of the apparatus
- 3 setting block
- 4 fixing material
- 5 maximum 30 mm

**Figure 4 — Example for fixing structure of the specimen**

The gap between the specimen edge and the frame is sealed with a soft material, such as adhesive tape, in order to stop air flow through the gap.

NOTE The edge constraints affect stress in the specimen. This document specifies the test method with no edge constraint condition in order that test results obtained in different laboratories are comparable.

#### 4.4.5 Temperature profile

Air temperature at both sides of the specimen shall be controlled at constant temperature. Temperature difference of the hot side and cold side glass surfaces  $\Delta T_{VIG}$  shall be at no less than the value calculated with [Formula \(1\)](#), which is derived from condition of circumstance that air-to-air temperature difference is 40 °C and heat transfer coefficients are 8 W/(m<sup>2</sup>·K) and 23 W/(m<sup>2</sup>·K) on both side of surfaces.

NOTE 8 W/(m<sup>2</sup>·K) and 23 W/(m<sup>2</sup>·K) are the respective values of the reference internal and external heat transfer coefficients in ISO 10292.

$$\Delta T_{VIG} \geq 40 \times R / (0,168 + R) \quad (1)$$

where

$\Delta T_{VIG}$  is the temperature difference of the hot side and cold side of the glass surfaces, in °C;

$R$  is the thermal resistance of the specimen, in m<sup>2</sup>·K/W.

The temperature difference of the hot side and cold side glass surfaces  $\Delta T_{VIG}$  shall be controlled within ±5 % range around average value during the steady-state temperature condition for at least 1 h.

#### 4.4.6 Determination of heat transfer coefficient

The heat transfer coefficient at the centre of the specimen on the hot and cold sides shall be calculated with [Formulae \(2\)](#) and [\(3\)](#):

$$h_{\text{hot}} = (\Delta T_2 / \Delta T_1) / R \quad (2)$$

$$h_{\text{cold}} = (\Delta T_2 / \Delta T_3) / R \quad (3)$$

where

$h_{\text{hot}}$  is the heat transfer coefficient on the hot surface of the specimen, in W/(m<sup>2</sup>·K);

$h_{\text{cold}}$  is the heat transfer coefficient on the cold surface of the specimen, in W/(m<sup>2</sup>·K);

$\Delta T_1$  is the average value, under steady-state temperature condition, of the temperature difference between hot side air and hot side glass surface in °C, or the average value of temperature difference between the board and the hot side glass surface in °C when the heat transfer control board is used on the hot side;

$\Delta T_2$  is the average value, under steady-state temperature condition, of the temperature difference between hot side glass surface and cold side glass surface, in °C;

$\Delta T_3$  is the average value, under steady-state temperature condition, of the temperature difference between cold side air and cold side glass surface in °C, or the average value of temperature difference between the board and the cold side glass surface in °C when the heat transfer control board is used on the cold side.

NOTE The heat flow through the specimen  $Q$ , in W/m<sup>2</sup>, can be calculated as shown below:

$$Q = \Delta T_1 / (1 / h_{\text{hot}}) \quad (4)$$

$$Q = \Delta T_2 / R \quad (5)$$

$$Q = \Delta T_3 / (1 / h_{\text{cold}}) \quad (6)$$

[Formulae \(2\)](#) and [\(3\)](#) can be derived from [Formulae \(4\)](#), [\(5\)](#) and [\(6\)](#).

#### 4.4.7 Requirements

##### 4.4.7.1 Heat transfer coefficient

The calculated heat transfer coefficient on the hot surface of the specimen  $h_{\text{hot}}$  and heat transfer coefficient on the cold surface of the specimen  $h_{\text{cold}}$  shall be 8,0 W/(m<sup>2</sup>·K) ± 2,0 W/(m<sup>2</sup>·K).

NOTE The value 8,0 W/(m<sup>2</sup>·K) is selected as a free convection condition as used in Formula (13) of ISO 10292:1994. The range ± 2,0 W/(m<sup>2</sup>·K) is to account for variations in the measurement.

##### 4.4.7.2 Proportional change in the temperature difference

The proportional change in the temperature difference at the hot and cold sides of the specimen from the beginning to the end of the steady-state temperature condition  $\Delta T_c$ , in %, shall be calculated using [Formula \(7\)](#).

$$\Delta T_c = 100 \times |\Delta T_e - \Delta T_b| / \Delta T_b \quad (7)$$