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Refractory products — Determination of thermal expansion

Produits réfractaires — Dosage de la dilatation thermique

ICS 81.080

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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.

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ISO 16835 was prepared by Technical Committee ISO/TC 33, *Refractories*..

Refractory products — Determination of thermal expansion

1 Scope

This International Standard specifies test methods for the thermal expansion of refractory products. This standard describes a method for determining the linear thermal expansion percentage, the linear thermal expansion curve and the linear thermal expansion coefficient.

NOTE This international standard includes the following three test methods for the thermal expansion of refractory products. The characteristics of these methods are shown in Annex A.

a) Contact method with cylindrical test piece.

b) Contact method with rod test piece.

c) Non-contact method.

2 Normative references

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

IEC 60584-1, *Thermocouples - Part 1: Reference tables*

IEC 60584-2, *Thermocouples - Part 2: Tolerances*

ISO 6906, *Vernier callipers reading to 0,02 mm*

ISO 3611, *Micrometer callipers for external measurement*

ISO 836, *Terminology for refractories*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 836 apply together with the following.

3.1
starting point temperature, T_0
the starting point temperature for collecting thermal expansion results, (record ambient temperature)

3.2
reference material
materials with a known linear thermal expansion (percentage) and coefficient. Using in shapes similar to test pieces

3.3
lowest limit temperature, T_1
the lowest temperature in the measurement range for linear thermal expansion

3.4
highest limit temperature, T_2
The highest temperature in the measurement range for linear thermal expansion

3.5
linear thermal expansion, $\varepsilon_i = \Delta L_i / L_0$
the ratio of length L_0 at a starting point temperature T_0 versus length change ΔL_i $(=L_i - L_0)$ between length L_i at a certain temperature T_i and length L_0.

3.6
linear thermal expansion percentage, $E_i = (\Delta L_i / L_0) \times 100$
$\varepsilon_i = \Delta L_i / L_0$ multiplied by 100

3.7
linear thermal expansion curve
the curve(s) between temperature on abscissa and linear thermal expansion percentage on ordinate with the length changes of a specimen with temperatures. There are two types of curves, a rising temperature curve and declining temperature one

3.8
rising temperature curve
a curve concerning linear thermal expansion changes caused by rising temperature. Normally, called the linear thermal expansion curve

3.9
declining temperature curve
a curve concerning linear thermal expansion changes caused by declining temperature. Used for the examination of the size change of sample after heating

3.10
average linear thermal expansion coefficient, $\alpha_{T_2 - T_1}$
the ratio of length change $\Delta L (= L_2 - L_1)$ of a specimen within a temperature interval to that temperature interval $T_2 - T_1$, related to the length L_0 at the starting point temperature. The sample lengths L_1 and L_2 are at the temperatures T_1 and T_2, respectively. The unit of this value is °C^{-1}.

3.11
linear thermal expansion coefficient, α_{T_i}
In 3.10, a value of $\Delta L / (L_0 \Delta T_i)$ when ΔT approaches zero infinitely. This means the slope of the tangent line on the relational line between linear thermal expansion $\varepsilon_i = \Delta L_i / L_0$ at a certain temperature T_i and the temperature T_i. The unit of this value is °C^{-1}.

3.12
reference sample
the substance of which the linear thermal expansion rate and coefficient of linear thermal expansion are known

NOTE This should be made into the same shape as that of test piece.

3.13
difference of elongation
the difference in length between the test piece and the reference sample of the same length as that of test piece when heated from the lower limit temperature to the upper limit temperature

4 Contact method with cylindrical test piece

4.1 Principle

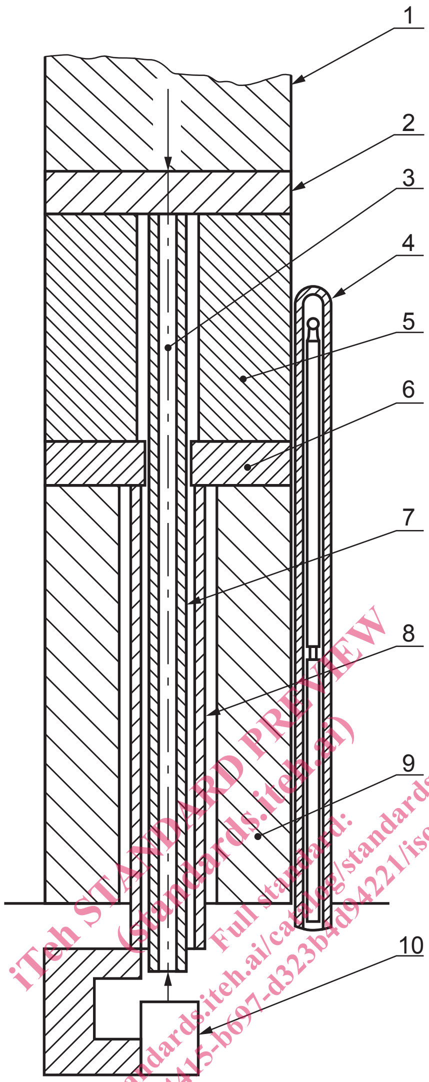
The amount of dimensional change of the cylinder test piece is continuously measured by using a contact type measurement instrument while heating at the specified rate in a heating furnace, and the linear thermal expansion rate, curve of linear thermal expansion rate, average coefficient of linear thermal expansion and coefficient of linear thermal expansion are obtained.

4.2 Apparatus

4.2.1 Thermal expansion test apparatus

4.2.1.1 General

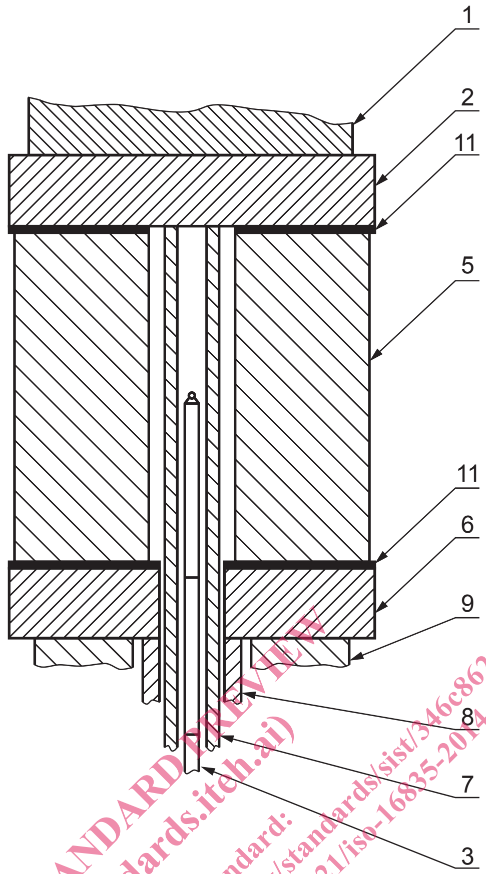
The circular pressure rod (1), test piece (5) and supporting rod (9) of the thermal expansion test apparatus shall be set in a heating furnace aligning each of their central axes along which they shall be vertically maintained throughout the test as shown in Figure 1 and Figure 2. The structure of the apparatus shall be such that the thermal expansion of test piece produced when a pressure of 0.01 MPa is applied to the direction of this central axis and the temperature is raised can be calculated from the relative change amount of the length of detecting tubes (7) and (8) contacted with the spacers (2) and (6) of the upper surface and the lower surface of the test piece. The contact force shall not change more than ± 1N.



Key

1 Pressure rod
2 Upper disk-type spacer
3 Thermocouple for measuring temperature of test piece
4 Thermocouple for controlling temperature of heating furnace
5 Test piece
6 Lower disk-type spacer
7 Tube for detecting the upper position of test piece
8 Tube for detecting the lower position of test piece
9 Supporting rod
10 Measurement instrument

Figure 1 — Schematic drawing of the thermal expansion test apparatus (in case of measuring the change rate of test piece at the lower part of apparatus)



Key

1 Pressure rod (outside diameter: 45 mm or over)

2 Upper disk-type spacer (outside diameter: 50,5 mm)

3 Thermocouple for measuring temperature of test piece

5 Test piece (outside diameter: 50 mm ± 2 mm, inside diameter: 12 mm ± 1 mm)

6 Lower disk-type spacer (outside diameter: 50,5 mm, inside diameter: 10 mm)

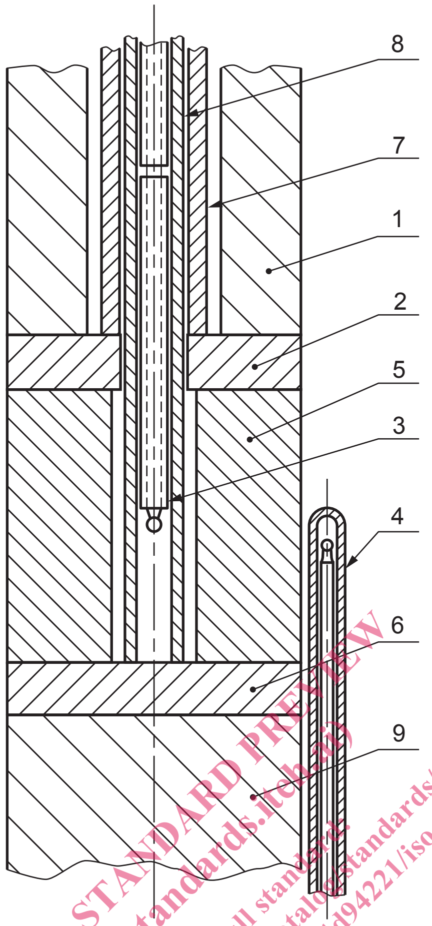
7 Tube for detecting the upper position of test piece (outside diameter: 8 mm, inside diameter: 5 mm)

8 Tube for detecting the lower position of test piece (outside diameter: 15 mm, inside diameter 10 mm)

9 Supporting rod (outside diameter: 45 mm, inside diameter: 20 mm)

11 Platinum rhodium foil (outside diameter: 50,5 mm, inside diameter: 10 mm)

Figure 2 — Detail drawing of thermal expansion test (in case of measuring the change rate of test piece at the lower part of apparatus)



Key

1 Pressure rod
2 Upper disk-type spacer
3 Thermocouple for measuring temperature of test piece
4 Thermocouple for controlling temperature of heating furnace
5 Test piece
6 Lower disk-type spacer
7 Tube for detecting the upper position of test piece
8 Tube for detecting the lower position of test piece
9 Supporting rod

Figure 3 — Schematic drawing of thermal expansion test apparatus (in case of measuring the change rate of test piece at the upper part of apparatus)

4.2.1.2 Constitution of thermal expansion test apparatus

The apparatus shall comprise the following.

a) Fixed pressure rod (1): The fixed pressure rod (1) shall be a cylindrical fire resistant material of at least 45 mm outside diameter. In the apparatus in Figure 3, the pore of concentric circle for passing through the tubes for detecting the upper and lower positions shall be provided.

NOTE Care shall be taken so as not to contact with the hole of upper lid of the heating furnace.

b) Supporting rod (9): The supporting rod (9) shall be a cylindrical fire resistant material of at least 45 mm outside diameter. In the apparatus in Figure 1 and Figure 2, the pore of concentric circle for passing through the tubes for detecting the upper and lower positions shall be provided.

c) Disk-type spacers (2) and (6): The disk-type spacers (2) and (6) shall be the fire resistant material inserted for preventing the test piece from adhering to (1) and (9) by fusion due to chemical reaction, for example a disk of at least 50 mm outside diameter and 5 mm to 10 mm thickness of the alumino-silicate refractory such as high temperature sintered mullite or alumina, or the basic refractory such as magnesia or spinel. The pore of concentric circle passing through (7) shall be provided at (6) in the apparatus of Figure 1 and Figure 2, and at (2) in the apparatus of Figure 3. The both ends of (1) and (9) shall be processed so as to be flat and in parallel, and the spacers of (2) and (6) contacted with it shall be processed to be vertical to the central axis.

NOTE When the test piece readily to react with other fire resistant material such as silica especially is measured, the foil of platinum or platinum rhodium alloy (11) of approximately 0.2 mm in thickness may be placed between the test piece and the both spacers as shown in Figure 2.

d) Tube for detecting lower position of test piece (8): The tube for detecting the lower position of test piece (8) shall be the alumina tube of which the tip penetrates the supporting rod (9) in the apparatus in Figure 1 and Figure 2 or the pressure rod (1) in the apparatus in Figure 3 and is contacted with the lower spacer adhering closely to the lower surface of the test piece, and shall be capable of moving freely so as not to contact with the supporting rod.

e) Tube for detecting upper position of test piece (7): The tube detecting the upper position of test piece (7) shall be the alumina tube of which the tip penetrates the supporting rod (9), the lower disk type spacer (6) and test piece (5) in the apparatus in Figure 1 and Figure 2 and is contacted with the upper disk-type spacer adhering closely to the upper surface of test piece, and be capable of moving freely so as not to be contacted with those. In the apparatus in Figure 3, the structures of these d) and e) are reversed.

f) Material and preparation of jigs: For the jigs, the material capable of enduring the load without the deformation and reaction up to the final (highest) test temperature, shall be selected. That is, the temperature corresponding to $t_{.05}$ (5 % softening point) of the sample should be $t_{.01}$ (1 % softening point) or over of the material.

NOTE *t*.01 and *t*.05 are obtained according to ISO 1893:2007.

4.2.2 Heating furnace

The heating furnace shall be the tubular furnace of which the central axis conforms to the measurement system, be capable of heating the test piece up to the final (highest) test temperature at the specified rate of rising temperature [see c) in 4.4.1] in the atmosphere and of heating uniformly 12.5 mm of the upper and lower sides of test piece at 500 °C or higher within ± 20 °C of the specified temperature. The uniformly heating zone around the test piece shall be measured beforehand.

NOTE The up-and-down moving type or opening-closing type is recommended because of not hindering the setting of measurement system.

4.2.3 Detector for amount of deformation of test piece

The dial gauge or differential transformer transducer connected to an automatic recorder shall be used. These are fixed to the tip of (8), the gauge head at the tip of spindle, in the case of dial gauge, or the core, in case of differential transformer transducer, contacts to the tip of (7), and the relative deformation amount produced by the deformation of test piece is measured. The measurement instrument shall have the sensitivity which enables the measurement to the nearest of 0,005 mm.

