
**Refractory products — Determination
of thermal expansion**

Produits réfractaires — Dosage de la dilatation thermique

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO 16835:2014](https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014)

[https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-
d323b4d94221/iso-16835-2014](https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014)



iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO 16835:2014

<https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014>



COPYRIGHT PROTECTED DOCUMENT

© ISO 2014

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

	Page
Foreword	iv
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Contact method with cylindrical test piece	3
4.1 Principle	3
4.2 Apparatus	3
4.3 Test piece	8
4.4 Procedure	10
4.5 Calculation and drawing	10
5 Contact method with rod test piece	14
5.1 Principle	14
5.2 Apparatus, implement and reference sample	14
5.3 Test piece	17
5.4 Procedure	18
5.5 Calculation and drawing	19
6 Non-contact method	22
6.1 Principle	22
6.2 Procedure	23
6.3 Calculation and drawing a figure	23
7 Test report	25
Annex A (informative) Characteristics of the test methods	27
Annex B (informative) Recommended values of linear thermal expansion rate and coefficient of linear thermal expansion of reference sample	28
Annex C (informative) Example of apparatus and test piece for non contact method	30
Bibliography	37

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).

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 33, *Refractories*.

[ISO 16835:2014](https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014)

<https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014>

Refractory products — Determination of thermal expansion

1 Scope

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

This International Standard includes the following three test methods for the thermal expansion of refractory products:

- a) a contact method with a cylindrical test piece;
- b) a contact method with a rod test piece;
- c) a non-contact method.

The characteristics of these methods are shown in [Annex A](#).

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.

ISO 836, *Terminology for refractories*
<https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014>

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

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

3 Terms and definitions

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

3.1

starting point temperature

T_0

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

3.3

lowest limit temperature

T_1

lowest temperature in the measurement range for linear thermal expansion

3.4

highest limit temperature

T_2

highest temperature in the measurement range for linear thermal expansion

3.5
linear thermal expansion

ε_i
ratio of length L_0 at a starting point temperature T_0 versus length change $\Delta L_i (= L_i - L_0)$ between length L_i at a certain temperature T_i and length L_0

Note 1 to entry: $\varepsilon_i = \Delta L_i / L_0$

3.6
linear thermal expansion percentage

E_i
linear thermal expansion expressed as a percentage

Note 1 to entry: $E_i = \varepsilon_i \times 100$; $E_i = \Delta L_i / L_0$ multiplied by 100

3.7
linear thermal expansion curve

curve(s) between the temperature on the abscissa and the linear thermal expansion percentage on the ordinate

Note 1 to entry: There are two types of curves, a rising temperature curve and a declining temperature curve.

3.8
rising temperature curve

curve concerning linear thermal expansion changes caused by rising temperature, which is normally called the linear thermal expansion curve

3.9
declining temperature curve

curve concerning linear thermal expansion changes caused by declining temperature, which is used for the examination of the size change of sample after heating

3.10
average linear thermal expansion coefficient

$\alpha_{T_2-T_1}$
ratio of length change $\Delta L (= L_2 - L_1)$ of a specimen within a temperature interval to that temperature interval $\Delta T (= T_2 - T_1)$, related to the length L_0 at the starting point temperature

Note 1 to entry: That means $\alpha_{T_2-T_1} = \Delta L / (L_0 \Delta T)$. The sample lengths L_1 and L_2 are at the temperatures T_1 and T_2 , respectively. The unit of this value is $^{\circ}\text{C}^{-1}$.

3.11
linear thermal expansion coefficient

α_{T_i}
value of average linear thermal expansion coefficient, $\Delta L / (L_0 \Delta T_i)$ when $\Delta T (= T_2 - T_1)$ approaches zero

Note 1 to entry: 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 $^{\circ}\text{C}^{-1}$.

3.12
reference sample

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

Note 1 to entry: The shape of the reference sample should be the same as that of test piece.

3.13
difference of elongation

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

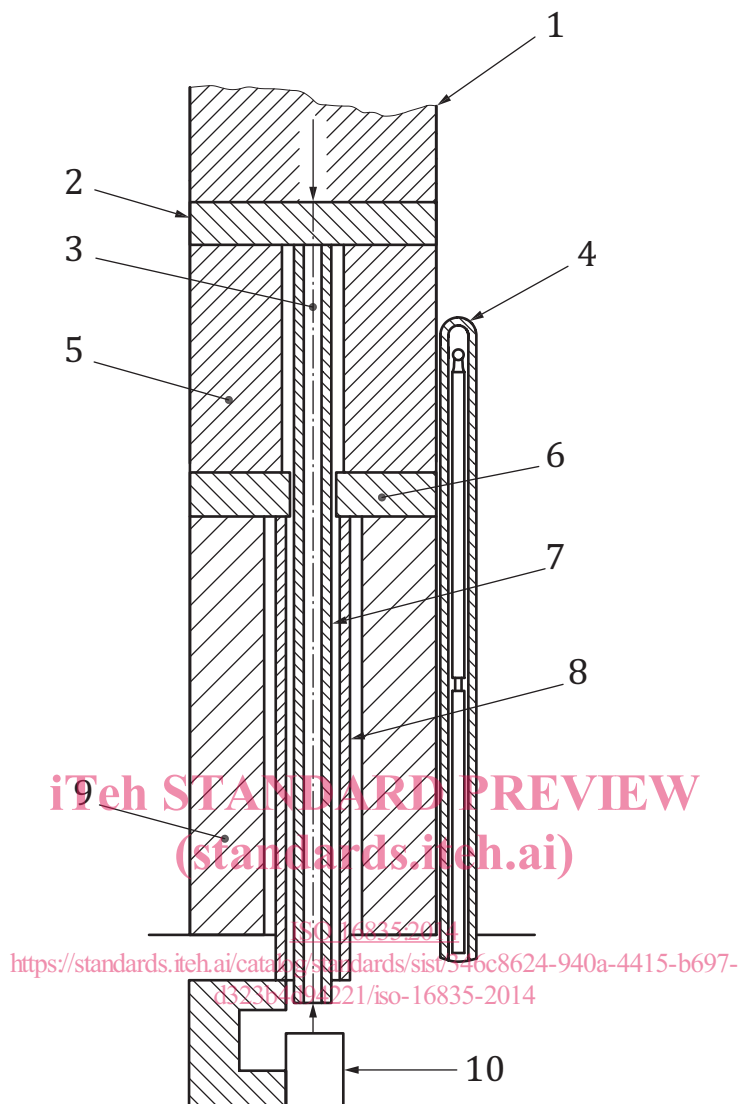
4.2.1.1 General

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 and all central axes aligned vertically. This alignment shall be 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 the 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 ± 1 N.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO 16835:2014](#)

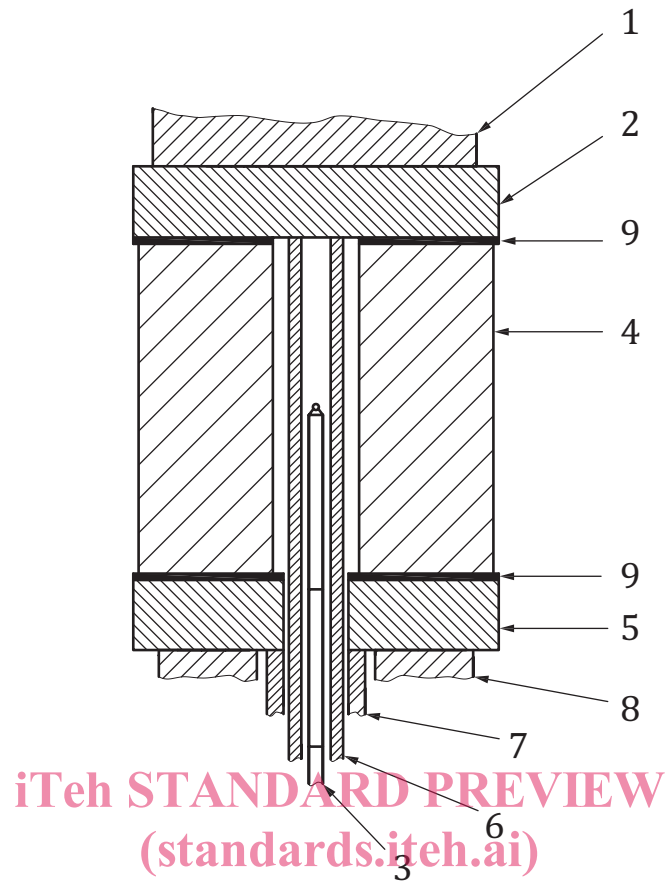
<https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014>



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)



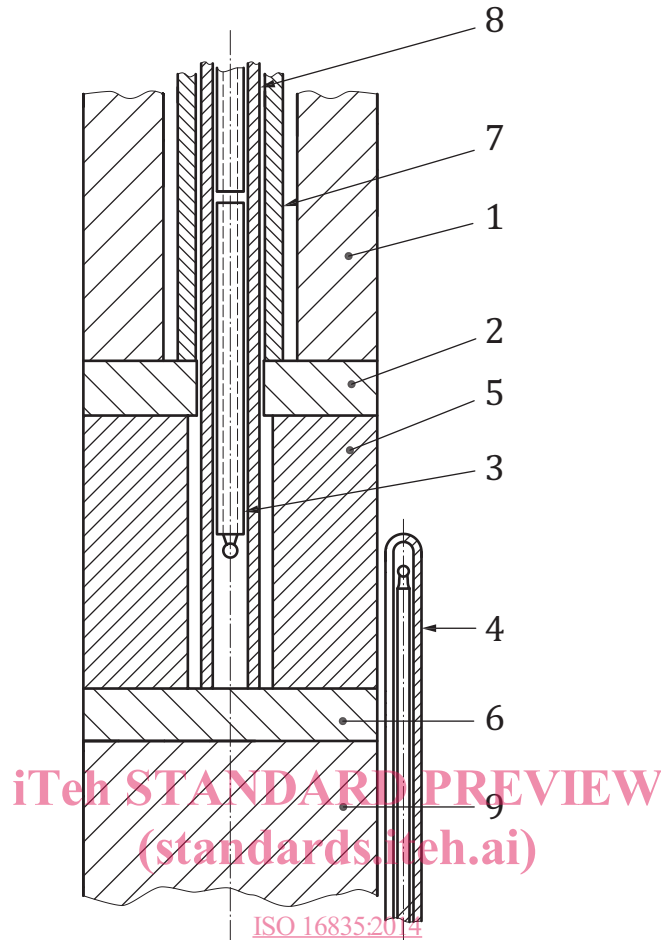
ISO 16835:2014

<https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014>

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
- 4 test piece (outside diameter: 50 mm \pm 2 mm, inside diameter: 12 mm \pm 1 mm, length 50 mm \pm 0,5 mm)
- 5 lower disk-type spacer (outside diameter: 50,5 mm, inside diameter: 10 mm)
- 6 tube for detecting the upper position of test piece (outside diameter: 8 mm, inside diameter: 5 mm)
- 7 tube for detecting the lower position of test piece (outside diameter: 15 mm, inside diameter 10 mm)
- 8 supporting rod (outside diameter: 45 mm, inside diameter: 20 mm)
- 9 platinum or 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)



<https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014>

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 be comprised of the following.

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

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

- b) Supporting rod (9): The supporting rod (9) shall be a cylindrical refractory material of at least 45 mm outside diameter. In the apparatus in [Figure 1](#) and [Figure 2](#), the hole 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 refractory 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 aluminosilicate refractory such as high temperature sintered mullite or alumina, or the basic refractory such as magnesia or spinel. The hole of concentric circle passing through (7) shall be provided at (6) in the apparatus shown in [Figure 1](#) and [Figure 2](#), and at (2) in the apparatus shown in [Figure 3](#). Both ends of (1) and (9) shall be processed so as to be flat and in parallel position, and the spacers (2) and (6) contacted with it shall be processed to make them vertical to the central axis.

When the test piece ready to react with other refractory material, such as silica especially, is measured, the foil of platinum or platinum rhodium alloy (9) of approximately 0,2 mm in thickness may be placed between the test piece and both spacers as shown in [Figure 2](#).

- d) Tube for detecting the 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 apparatus in [Figure 1](#) and [Figure 2](#) or the pressure rod (1) in the apparatus in [Figure 3](#) and is contacted with the lower disk-type spacer adhering closely to the lower surface of the test piece, and shall be capable of moving freely so as not to make contact with the supporting rod.
- e) Tube for detecting the 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 shall 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 deformation and reaction up to the final (highest) test temperature shall be selected.

The material from which the jigs are made should have a T_1 value greater than or equal to the temperature at which the test material has a T_5 value. T_1 and T_5 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. It shall 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 uniform heating zone around the test piece shall be measured beforehand.

The up-and-down moving type or opening-closing type is recommended because they do not hinder 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. These then contact the tip of (7) and the relative deformation amount produced by the deformation of test piece is measured. The measuring instrument shall have the sensitivity which enables the measurement to the nearest of 0,005 mm.

4.2.4 Temperature measurement apparatus

4.2.4.1 Thermocouple for measuring the temperature of test piece

The thermocouple for measuring the temperature of the test piece shall be inserted into the alumina tube (7) which penetrates the test piece so as to be capable of measuring the temperature at the centre of the test piece and shall be arranged so that the hot contact point comes to the centre of the test piece.

4.2.4.2 Thermocouple for controlling the temperature of heating furnace

For thermocouple for controlling the temperature of heating furnace, the thermocouple with protecting tube shall be used and be arranged so that the hot contact comes adjacent to the test piece (see [Figure 1](#)).

It may be arranged adjacent to the heating unit depending on the structure of the furnace.

4.2.4.3 Type and precision of thermocouple

The thermocouple shall be a platinum-platinum rhodium system and the type capable of using up to the final (highest) test temperature shall be selected. The precision of thermocouple shall be verified.

4.2.5 Callipers

The callipers of 0,05 mm minimum scale reading shall be used.

4.2.6 Reference sample

For the reference sample, the high purity sintered alumina object of the same shape as that of the test piece specified in [4.3](#) shall be used. The recommended values of linear thermal expansion rate and coefficient of linear thermal expansion for reference sample are shown in [Annex B](#).

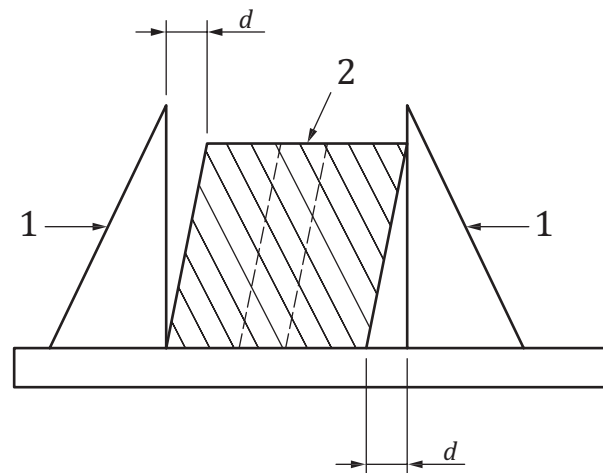
<https://standards.iteh.ai/catalog/standards/sist/346c8624-940a-4415-b697-d323b4d94221/iso-16835-2014>

4.3 Test piece

4.3.1 Shape of test piece

The shape of test piece shall be as follows.

- a) The test piece shall be concentrically cylindrical having a 50 mm \pm 2 mm outside diameter, 12 mm \pm 1 mm inside diameter, and 50 mm \pm 0,5 mm length.
- b) The test piece shall be taken so that the upper and lower surfaces are parallel and right-angled to the central axis, and both surfaces shall be ground and polished so that the difference of length measured at any two points by using callipers does not exceed 0,2 mm. The end surface of test piece shall be placed on a flat surface plate and when a square is applied to the generating line of cylindrical test piece, the deviation, d , between the square and the generating line shall be 0,5 mm or below (see [Figure 4](#)).

**Key**

- 1 square
2 sample

The dimension d is measured by using a feeler gauge.

Figure 4 — Measuring method for verticality

- c) For the purpose of confirming that the upper and lower surfaces of the test piece are smooth throughout the whole surface, the filter paper of 0,15 mm thickness, upon which a carbon paper is placed, shall be placed on a surface plate and each surface shall be pressed to adhere. Both surfaces of the test piece may be coloured by using a stamp ink stand instead of carbon paper. When uncoloured part is found on the surface by this operation, it shall be polished again.

Moreover, the smoothness of the surface may be confirmed by using a square.

4.3.2 Preparation of test piece

4.3.2.1 Shaped refractory

Unless otherwise specified, take the test sample so that the longitudinal direction of the test piece is parallel to the pressurizing direction of the sample for testing at the time of forming.

Moreover, the direction of taking the test piece may be decided according to the agreement between the parties concerned with the delivery by conforming to the purpose of using the thermal expansion result. In the case of unsintered refractory, the test piece taken from the sample after sintering at a definite temperature or the processed test piece sintered under a definite condition may be used.

4.3.2.2 Unshaped refractory

The test piece shall be either formed into the shape specified in 4.3.1 or cut off to form a definite shape. The necessity of sintering and the sintering temperature shall be subjected to the agreement between the parties concerned with the delivery. The preparation, forming, sintering condition of test piece, and the dimension of test piece shall be mentioned in the test report.