SLOVENSKI STANDARD
SIST EN 993-4:1998

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Metode za preskušanje gostih oblikovanih ognjevzdržnih izdelkov - 4. del: Ugotavljanje prepustnosti za pline

Methods of test for dense shaped refractory products - Part 4: Determination of permeability to gases

Prüfverfahren für dichte geformte feuerfeste Erzeugnisse - Teil 4: Bestimmung der Gasdurchlässigkeit

Méthodes d'essai pour produits réfractaires façonnés denses - Partie 4: Détermination de la perméabilité aux gaz

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ICS:

81.080	Ognjevzdržni materiali	Refractories

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English version

Methods of test for dense shaped refractory products - Part 4: Determination of permeability to gases

Méthodes d'essai pour produits réfractaires façonnés denses - Partie 4: Détermination de la perméabilité aux gaz

Prüfverfahren für dichte geformte feuerfeste Erzeugnisse - Teil 4: Bestimmung der Gasdurchlässigkeit

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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Contents list

Foreword

This European Standard has been prepared by the Technical Committee CEN/TC 187 "Refractory products and materials", the secretariat of which is held by BSI.

It is closely based on the corresponding International Standard, ISO 8841 : 1991 "Dense, shaped refractory products - Determination of permeability to gases", published by the International Organization for Standardization (ISO).

Reproducibility and repeatability data are not available, but may be given in a subsequent edition.

EN 993 'Methods of test for dense shaped refractory products' consists of 18 Parts:

Part 1 : Determination of bulk density and porosity
Part 2 : Determination of true density
Part 3 : Test methods for carbon-containing refractories
Part 4 : Determination of permeability to gases
Part 5 : Determination of cold crushing strength
Part 6 : Determination of modulus of rupture, ambient temperatures
Part 7 : Determination of modulus of rupture, elevated temperatures
Part 8 : Determination of refractoriness-under-load
Part 9 : Determination of creep in compression
Part 10 : Determination of permanent change in dimensions on heating
Part 11 : Determination of resistance to thermal shock
Part 12 : Determination of pyrometric cone equivalent
Part 13 : Specification for pyrometric cones
Part 14 : Determination of thermal conductivity (hot wire, cross-array)
Part 15 : Determination of thermal conductivity (hot wire, parallel)
Part 16 : Determination of resistance to acids
Part 17 : Determination of bulk density of granular material (mercury method)
Part 18 : Determination of bulk density of granular material (water method)

This European Standard shall be given the status of a National Standard, either by publication of an identical text or by endorsement, at the latest by August 1995, and conflicting national standards shall be withdrawn at the latest by August 1995.

According to the CEN/CENELEC Internal Regulations, the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.

1 Scope

This European Standard specifies a method for the measurement of the permeability to gases of dense, shaped refractory products.

Note : The method specified takes account of the dynamic viscosity of the gas, and therefore the results obtained may not be directly comparable with those obtained by earlier methods which took no account of viscosity. The determination is generally made by the passage of air. Other gases may be used when required and the viscosities of air and nitrogen are given.

2 Normative reference

This European Standard incorporates, by dated or undated reference, provisions from another publication. This normative reference is cited at the appropriate places in the text and the publication is listed hereafter. For a dated reference, subsequent amendments to or revisions of this publication apply to this European standard only when incorporated in it by amendment or revision. For an undated reference the latest edition of the publication referred to applies.

ISO 6906 : 1984 Vernier callipers reading to 0,02 mm

3 Definition

For the purposes of this standard the following definition applies :

3.1 permeability of a material : The property by which the material allows a gas to pass through it when under a difference of pressure.

The permeability (μ) is calculated using the following equation, given for the volume of gas passing through a test piece in a given time.

$$\frac{V}{t} = \mu \cdot \frac{1}{\eta} \cdot \frac{A}{\delta} \cdot (p_1 - p_2) \cdot \frac{(p_1 + p_2)}{2p} \qquad \ldots (1)$$

where :

V is the volume of gas passing through the material, in cubic metres;

t is the time, in seconds, in which that volume of gas passes through the material;

μ is the permeability of the material, in square metres;

η is the dynamic viscosity, in pascal seconds, of the gas at the temperature of the test;

A is the cross-sectional area, in square metres of the material traversed;

δ is the thickness, in metres, of the material traversed;

p is the absolute pressure, in pascals, of the gas;

p_1 is the absolute pressure, in pascals, where the gas enters the material;

p_2 is the absolute pressure, in pascals, where the gas leaves the material.

Notes :

1 Equation (1) corresponds to Darcy's Law, and is deduced from the Hagen Poiseuille Law.

2 Since p is the pressure under which the volume of gas is measured, $p = p_1$ when operating under positive pressure and $p = p_2$ when operating under negative pressure.

3 The factor $(p_1 + p_2)/2p$ is usually very close to unity and may be neglected when operating with small pressure differences, e.g. when $(p_1 - p_2)$ is less than 1 000 Pa.

Equation (1) may be rearranged as

$$\mu = \frac{V}{t} \cdot \eta \cdot \frac{\delta}{A} \cdot \frac{1}{p_1 - p_2} \cdot \frac{2p}{p_1 + p_2} \qquad \ldots (2)$$

Writing equation (2) in the units involved, the unit for permeability is square metres, derived from

$$\frac{m^3}{s} \cdot Pa \cdot s \cdot \frac{m}{m^2} \cdot \frac{1}{Pa} \cdot \frac{Pa}{Pa}$$

If, in equation (1), δ is expressed in centimetres, A in square centimetres and V in cubic centimetres (the units for other quantities being unchanged), an alternative unit for permeability may be derived, namely square centimetres. However, since compound prefixes are not permissible, the conventional prefixes may be used only with the unit square metres, thus $10^{-8}cm^2 = 10^{-12}m^2 = 1\mu m^2$.

4 Principle

A stream of dry gas is passed through the test piece, and the pressure drop across the test piece is recorded for at least three different rates of flow. From these values, and from the size and shape of the test piece, the permeability of the material is determined by calculation.

5 Apparatus

5.1 General

The general layout of the apparatus is shown diagrammatically in figures 1 and 2. Figure 1 shows the arrangement for the passage of gas under pressure and figure 2 for the passage of gas under suction. The connecting piping shall be made of glass in preference to rubber, and shall be as short as possible, so that the pressure loss in the apparatus is very small when compared with the pressure loss produced by the test piece.

5.1.1 Supply of gas (under pressure or suction), consisting of a reservoir of gas at constant pressure.

5.1.2 Test piece holder, with gas-tight seals at the sides of the test piece. Gas tightness shall be ensured by a rubber membrane that is inflated to a pressure of 0,2 N/mm² to 0,4 N/mm². See figure 3.

Note : Modifications will be required if the alternative test piece size (see note to 6.1) is used.

5.1.3 Liquid manometer, of the U-tube type, for measuring the difference in pressure between the two faces of the test piece. The usual experimental precautions for this type of measurement shall be taken, so that the error in the pressure determination does not exceed 1 % (including error reading column height, meniscus error, error in the verticality of the manometer, and measurement of the density of the manometer liquid). The pressure shall be determined close to one face of the test piece in the vessel containing the test piece holder (5.1.2).

Note : A lower pressure reading may result when the pressure away from the test piece is determined in the connecting tubes.

5.1.4 Gas flow measuring equipment, consisting of a sensitive floating flowmeter calibrated for a given temperature and pressure of entry. The flowmeter shall be accurate to within 2 %. The flowmeter shall be calibrated periodically for the gas to be used, and only the middle section of its measuring scale shall be used.

For the measurement of permeability to air only, the rate of air flow is measured by the displacement of air by water, using a graduated cylinder device and a chronometer.

Water sensitive materials, such as doloma, shall not be measured by the method in which air flow is obtained by displacement of water.

5.1.5 Vernier callipers, in accordance with ISO 6906.

5.1.6 Drying oven, capable of being controlled at 110 °C ± 5 °C.

5.1.7 Impermeable dummy test piece, for example an aluminium cylinder.

6 Test pieces

6.1 Dimensions

The test pieces shall be cylindrical, with diameter 50 mm ± 0,5 mm and height 50 mm ± 0,5 mm. The perpendicularity of the axis of the test piece to the faces, and the parallelism between the top and bottom faces of the test piece shall both be within 0,5 mm.

Note : A 50 mm cube test piece may also be used where necessary. In this case the test piece holder (see note to 5.1.2) will need to be modified and the calculation of the results (see 8.3) will be slightly different.

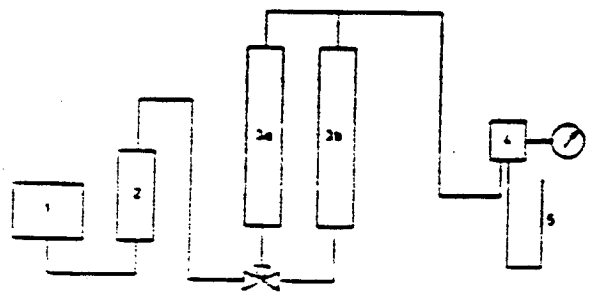
6.2 Preparation

The test pieces shall be cut in such a way that no material is included that was within 4 mm of a face of the brick or item. The direction in which the test pieces are cut, relative to the direction of pressing, shall be stated in the report.

The faces shall be freed from dust formed during the cutting, by brushing under a jet of water following wet cutting, or by a jet of compressed air following dry cutting.

6.3 Drying

The test pieces shall be dried to constant mass in the drying oven (5.1.6) at 110 °C ± 5 °C. Before measurement, the test pieces shall be allowed to cool to room temperature in a desiccator; the time of cooling shall be at least 2 h.



KEY

1 Source of gas (compressed gas cylinder or water reservoir)
2 Desiccator for the gas
3 Floating flowmeters : (a) 0 to 200 cm³/min, (b) 200 cm³/min to 1 500 cm³/min
4 Holder for cylindrical sample
5 U-tube manometer, filled with liquid

Figure 1 - Arrangement of instruments for measuring gas permeability (measured under a pressure head)