INTERNATIONAL STANDARD

ISO 1927-6

First edition
2012-12-01

Monolithic (unshaped) refractory products —

Part 6: Measurement of physical properties

Produits réfractaires monolithiques (non façonnés) —
Partie 6: Détermination des propriétés physiques

Reference number
ISO 1927-6:2012(E)

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Published in Switzerland

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

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.

ISO 1927-6 was prepared by Technical Committee ISO/TC 33, *Refractories*.

ISO 1927 consists of the following parts, under the general title *Monolithic (unshaped) refractory products*:

— *Part 1: Introduction and classification*

— *Part 2: Sampling for testing*

— *Part 3: Characterization as received*

— *Part 4: Determination of consistency of castables*

— *Part 5: Preparation and treatment of test pieces*

— *Part 6: Measurement of physical properties*

— *Part 7: Tests on pre-formed shapes*

— *Part 8: Determination of complementary properties*

Monolithic (unshaped) refractory products —

Part 6:
Measurement of physical properties

1 Scope

This part of ISO 1927 specifies methods for the determination of properties of unshaped materials from test pieces prepared and stored according to ISO 1927-5.

The methods are applicable to dense and insulating castables and to ramming materials (including plastics) as defined in ISO 1927-1 before and after firing.

2 Normative references

The following referenced documents are indispensable for the application 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 1893, *Refractory products — Determination of refractoriness under load — Differential method with rising temperature*

ISO 1927-5, *Monolithic·(unshaped)·refractory·products — Part 5: Preparation and treatment of test pieces*

ISO 3187 *Refractory products — Determination of creep in compression*

ISO 5013 *Refractory products — Determination of modulus of rupture at elevated temperatures*

ISO 5014: *Dense and insulating shaped refractory products — Determination of modulus of rupture at ambient temperature*

ISO 5017, *Dense shaped refractory products — Determination of bulk density, apparent porosity and true porosity*

ISO 5018, *Refractory materials — Determination of true density*

ISO 8895, *Shaped insulating refractory products — Determination of cold crushing strength*

ISO 10059-1, *Dense, shaped refractory products — Determination of cold compressive strength — Part 1: Referee test without packing*

ISO 10059-2, *Dense, shaped refractory products — Determination of cold compressive strength — Part 2: Test with packing*

3 Determination of geometric bulk density

3.1 Principle

This determination is carried out according to a geometric method. It can be applied to green, dried or fired test pieces. The condition of the test pieces shall be stated in the test report.

3.2 Test pieces

The test piece shape shall be one of the following:

— shape A: Length: 230 mm; width: 114 mm; thickness: 64 mm,

— shape B: Length: 230 mm; width: 64 mm; thickness: 54 mm, or

— shape C: Length: 230 mm; width: 64 mm; thickness: 64 mm, or

— shape D: Length: 160 mm; width: 40 mm; thickness: 40 mm.

The test pieces shall be prepared and stored according to the relevant sections of ISO 1927-5.

NOTE For ramming materials taphole and dry mixes, as an alternative to these shapes, cylindrical test pieces, of diameter 50 mm $\pm$ 1 mm and height 50 mm $\pm$ 1 mm can be used.

Three test pieces produced at the same time shall be tested.

3.3 Apparatus

3.3.1 Balance, capable of measuring mass to the accuracy specified in 3.4.1.

3.3.2 Callipers, capable of measuring to the accuracy specified in 3.4.2.

3.4 Procedure

3.4.1 Determination of the mass m of the test piece

For the test pieces of shape A, B and C, determine the mass to the nearest 1 g.

For 50 mm cylinders, measure the mass to an accuracy of $\pm$ 0,1 g.

3.4.2 Determination of the volume, V, of the test piece

Determine the volume of the test piece by carrying out four measurements of each dimension along the centre-line of each face:

— for rectangular test pieces, on length, width and thickness;

— for cylindrical test pieces, on height and diameter.

All measurements shall be made to an accuracy of $\pm$ 0,1 mm.

3.4.3 Calculation of geometric bulk density

The geometric bulk density, ρ_g, is given by:

$$\rho_g = \frac{m}{V} \tag{1}$$

where

m is the mass of the test piece, in grams;

V is the volume of the test piece obtained by calculation using the mean dimensions given in cubic centimetres.

3.5 Calculation and expression of test results

Calculate the geometric bulk density either in g/cm^3 to the nearest 0,01 g/cm^3, or in kg/m^3 to three significant figures.

Report the test result as the mean of all determinations, including the mean value and all individual results in the test report.

4 Determination of density and porosity

4.1 Principle

This determination is applied to fired test pieces.

4.2 Test pieces

The test pieces shall be shapes A, B, C or D prepared, stored and fired according to the relevant sections of ISO 1927-5 (see 3.2).

NOTE For ramming materials, taphole and dry mixes, cylindrical test pieces can be used as an alternative to shapes A, B, C or D (see 3.2).

4.3 Procedure

4.3.1 Determination of bulk density

4.3.1.1 Dense materials

Determine the bulk density and the apparent porosity, and calculate the total porosity in accordance with ISO 5017.

NOTE In the presence of glazing, the firing skin should be removed.

4.3.1.2 Insulating materials

Determine the bulk density in accordance with Clause 3 since it is not possible to use the water absorption method with these materials.

4.3.2 Determination of true density

Determine the true density in accordance with ISO 5018 using a liquid which will not react with the material.

4.4 Calculation

The individual values and the mean value of the properties shall be given as test results.

Calculate the bulk density and the true density in g/cm^3 to the nearest 0,01 g/cm^3, or in kg/m^3 to three significant figures.

Calculate and report the open and total porosity in %, rounded to the nearest 0,1 %.

5 Determination of cold modulus of rupture

5.1 Principle

This determination is applied to dried or fired test pieces (shapes A, B, C or D).

5.2 Test pieces

Use test pieces as specified in 3.2 and with the following tolerances:

— width and height ± 0,5 mm;

— parallelism of cross-section sides ± 0,2 mm;

— parallelism of top and bottom sides ± 0,3 mm;

— distance between supports 180 mm ±1 mm; or 100 mm ± 0.5 mm for shape D.

— radius of curvature at the load bearing edges;

— bearing edges 15 mm ± 0,5 mm.

Dry the test pieces at 110 °C ± 5 °C to constant mass and cool to room temperature, taking care to avoid moisture pick-up. For unfired test pieces, the test shall be carried out immediately after drying and cooling, and for fired pieces, within three days.

5.3 Apparatus and procedure

Use the apparatus and procedure as specified in ISO 5014 with the following rates of increase of stress:

— dense products 0,15 MPa/s ± 0,015 MPa/s;

— insulating products 0,05 MPa/s ± 0,005 MPa/s.

Apply the stress perpendicular to the direction of fabrication.

5.4 Test results

Calculate the cold modulus of rupture in MPa rounded to the nearest 0,1 MPa.

6 Determination of cold crushing strength

6.1 Principle

This determination is applied to dried or fired test pieces.

6.2 Test pieces

6.2.1 General

The preparation, size and dimensions of the test pieces shall be agreed between the parties concerned and noted in the test report.

NOTE The determination of cold crushing strength can be carried out on test pieces of different sizes. The results obtained from these test pieces can differ.

Dry the test pieces at 110 °C ± 5 °C to constant mass and cool to room temperature, taking care to avoid moisture pick-up. For unfired test pieces, the test shall be carried out immediately after drying and cooling, and for fired pieces, within three days.

Apply the stress perpendicular to the direction of fabrication except for the cylindrical test pieces.

6.2.2 Prismatic test pieces

Use broken halves produced from the cold modulus of rupture test (see Clause 5), without sawing or grinding the test pieces.

NOTE The use of this size is more suitable for quality control applications.

6.2.3 Cubic test pieces

Prepare three test pieces from shape C by sawing cubes of 64 mm ± 0,5 mm in edge length.

For testing after drying, the test pieces shall be sawn and trued after curing and before drying at 110 °C.

NOTE 1 If sawing could damage the test piece, then sawing should be performed after drying at 110 °C. The test piece should then be dried again immediately after sawing.

For testing after firing, the test pieces shall be sawn and trued after firing.

NOTE 2 Cubes should not be sawn from broken halves obtained from the cold modulus of rupture test.

6.2.4 Cylindrical test pieces for ramming materials, taphole and dry mixes

Prepare three test pieces of height 50 mm ± 0,5 mm and 50 mm ± 0,5 mm in diameter, from shapes A, B or C, by sawing, coring and truing or directly produced by ramming.

6.3 Apparatus

Use the apparatus specified in ISO 10059-1 or ISO 10059-2 for dense unshaped materials and as specified in ISO 8895 for insulating unshaped materials.

6.4 Procedure

6.4.1 Dense materials

For tests utilizing broken halves (see 6.2.2), place the test pieces in the ancillary adapter (see Figure 1) so that the 64 mm edge (shapes A and C) the 54 mm edge (shape B) or the 40 mm edge (shape D) is vertical.

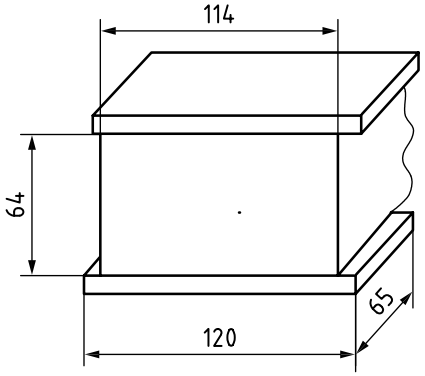
Place the 114 mm edge (shape A), or the 64 mm edges (shapes B and C) central to, and flush with the 120 mm edge of the lower plate. The free edges of the press plate shall be symmetrical (shape D) (see Figure 1).

For tests with cubic or cylindrical test pieces, take care that the loading surface is prepared according to the procedure described in 6.2.3 or 6.2.4.

For both cases, apply the stress smoothly and continuously at a rate of 1,0 MPa/s ± 0,1 MPa/s until the test piece fails.

Record the maximum load indicated.

Dimensions in millimetres



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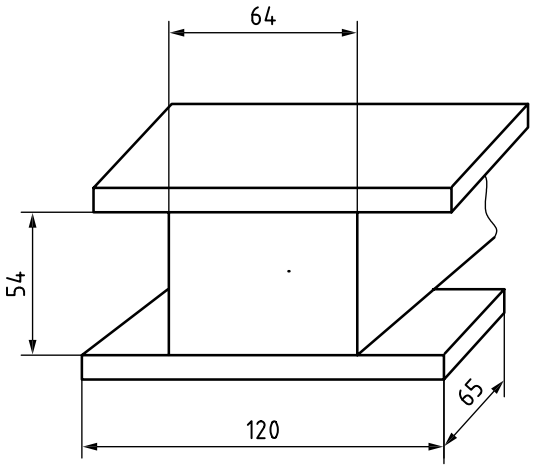

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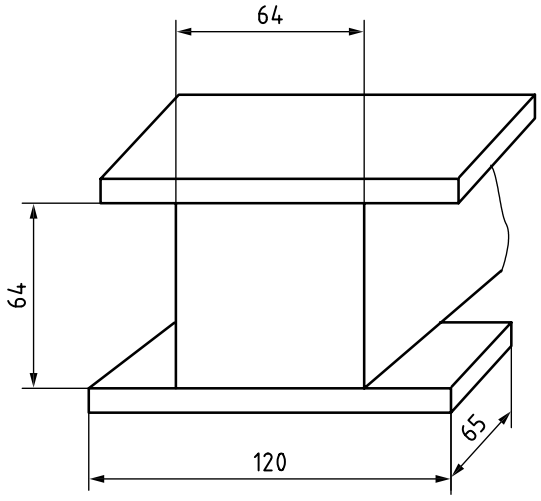

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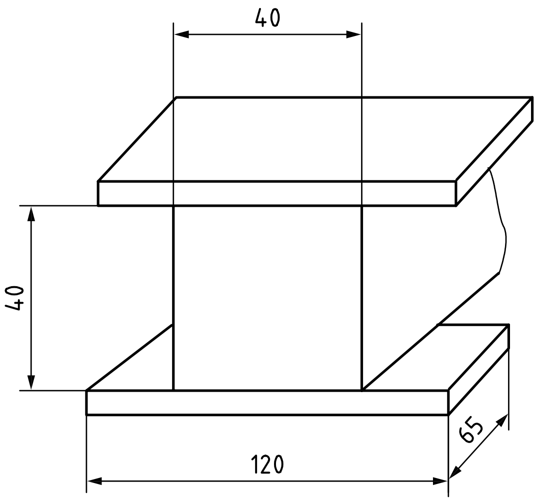

d)

Figure 1 — Position of the broken halves of the test pieces on the lower platen

6.4.2 Insulating materials

Prepare test pieces from shape A of dimensions 114 mm × 114 mm × 64 mm and test in accordance with ISO 8895.

NOTE The cold crushing strength is calculated from the maximum force recorded when the test piece collapses or when its height is reduced to 90 % of its original value, the stress being increased at the prescribed rate.

6.5 Calculation and expression of results

Calculate the cold crushing strength, σ, in accordance with ISO 5014 using the equation:

$$\sigma = \frac{F_{\text{max}}}{A_0}$$

where

F_{max} is the maximum load recorded, in newtons;

and

— for tests with the broken halves of test pieces (see 6.2.2), A_0 is given by the 65 mm edge of the platen and the width of the test piece concerned (114 mm or 64 mm)

or

— for tests with other types of test pieces, A_0 is the mean initial cross-sectional area of the test piece over which the load is applied.

Express the cold crushing strength in MPa to the nearest 0,5 MPa.

Include the procedure used in the test report.

7 Determination of permanent linear change

7.1 Principle

Use test pieces as given in the relevant clauses of ISO 1927-5 (see Clause 3), carrying out the measurement on the length.

7.2 Apparatus

Use apparatus capable of measuring the test piece length to the nearest 0,1 mm.

7.3 Procedure

7.3.1 Linear change on drying

Determine the length of the test pieces, L_0, after dismantling the mould and then immediately after drying at 110°C and cooling to room temperature, L_1.

The measurement is made from impression of shrinkage marks (shapes A, B and C) or by the use of a dial calliper gauge. The shrinkage marks for use as reference points may be made immediately after forming as a substitute to length measurement provided they have a minimum distance of 200 mm from each other and are clearly visible after firing at the test temperature.

The means of making the measurement shall be included in the test report.

7.3.2 Linear change on firing

Determine the length of the test pieces after drying, L_1, and after firing, L_t, observing the firing conditions given in the relevant sections of ISO 1927-5.

7.3.3 Total linear change

Determine the length of the test pieces after dismantling the mould, L_0, and after firing, L_t, observing the conditions given in the relevant sections of ISO 1927-5.

7.4 Calculation

7.4.1 Linear change on drying

Calculate the linear change on drying, L_d in %, using the equation:

$$L_d = \frac{L_1 - L_0}{L_0} \times 100$$

where

L_1 is the length of the test piece after cooling to room temperature (see 7.3.1);

L_0 is the length of the test piece after dismantling the mould (see 7.3.1).

Report the result to the nearest 0,1 %.

7.4.2 Linear change on firing

Calculate the linear change on firing, L_f in %, using the equation:

$$L_f = \frac{L_t - L_1}{L_1} \times 100$$

where

L_t is the length of the test piece after firing (see 7.3.2).

Report the result to the nearest 0,1 %.

7.4.3 Total linear change

Calculate the total linear change, L_c in %, using the equation:

$$L_c = \frac{L_t - L_o}{L_o} \times 100$$

Report the result to the nearest 0,1 %.

8 Determination of modulus of rupture at elevated temperatures

8.1 Principle

Use test pieces with shape and size in accordance with ISO 5013 taken from shape A, B, C or D by sawing and truing up and prepared, stored and fired in accordance with the relevant clauses of ISO 1927-5.

Cut each test piece from the shape so that the upper longitudinal face of the test piece in the testing position (i.e. the face subject to a compressive stress) coincides with, or is parallel to, one of the original faces of the shape (face perpendicular to the direction of moulding or pressing).

No other longitudinal face of the test piece shall be the original face of the shape.

NOTE When it is not possible to take test pieces from shape A, B, C or D, they can be directly prepared and this fact should be noted in the test report. In this case, they lead to different results.

Dry the test pieces at 110 °C ± 5 °C for a minimum of 24 h.

8.2 Apparatus and procedure

Use the apparatus and procedure for the determination of the modulus of rupture as specified in ISO 5013.

8.3 Calculation and expression of results

Calculate and express the modulus of rupture, σ_f, in MPa as given in ISO 5013.

9 Determination of refractoriness under load and creep in compression

9.1 Principle

These determinations may be carried out on test pieces after drying or after firing at a temperature to be agreed between the parties concerned. This shall be noted in the test report.

9.2 Test pieces

Use cylindrical test pieces, in accordance with ISO 1893 or ISO 3187, taken from shapes A or B or C by sawing, coring and truing up, and prepared, stored, dried or fired according to the relevant sections of ISO 1927-5.

Dry the test pieces at 110 °C ± 5 °C for a minimum of 24 h.

NOTE If the test pieces, due to the nature of the material, cannot be taken by sawing, coring and truing up, they can be prepared directly and this fact should be noted in the test report (see 6.2.3).

9.3 Procedure

Determine the refractoriness under load in accordance with ISO 1893 and the creep in compression in accordance with ISO 3187.

In the case of creep in compression, the temperature and duration of the test shall be the subject of agreement between the parties concerned.

9.4 Calculation and expression of test results

Calculate and express the results given in ISO 1893 for refractoriness under load and in ISO 3187 for creep in compression.

10 Test report

The test report shall include at least the following information:

a) all information necessary for identification of the sample tested, including a description of the material tested, type, group, etc;

b) a reference to this International Standard, i.e. ISO 1927-6:2012;

c) a description of the preparation, size and dimensions of the test piece, including any deviations from the test piece preparation given in ISO 1927-5;

d) the methods used, including details of the firing conditions, i.e:

   1) firing temperature;

   2) soak period;

   3) firing atmosphere;

e) the results of the test, including the results of the individual determinations and their mean, calculated as specified in clauses 3 to 9;

f) the name of the test laboratory including the place and date of preparation and treatment, report identification and signatory;

g) any deviations from the procedure specified;

h) any unusual features (anomalies) observed during the test;

i) the date of the test.

Bibliography

[1] ISO 5016:1997, *Shaped insulating refractory products — Determination of bulk density and true porosity*

[2] ISO 2477:2005, *Shaped insulating refractory products — Determination of permanent change in dimensions on heating*

[3] ISO 1927-1, *Monolithic (unshaped) refractory products — Part 1: Terminology and classification*

ICS 81.080

Price based on 11 pages