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Refractory test-piece preparation — Gunning refractory panels by the pneumatic-nozzle mixing type guns

Préparation d'éprouvettes réfractaires — Panneaux réfractaires pour gunitage au pistolet mélangeur pneumatique

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Foreword

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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 document 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).

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This document was prepared by Technical Committee ISO/TC 33, *Refractories,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 187, *Refractory products and materials,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 20182:2008), which has been technically revised.

The main changes are as follows:

— Scope has been broadened to include preparation of gunned panels under both controlled laboratory (“standard”) conditions and “site” conditions; this broadening of scope aligns with that adopted in ISO18886;

— in 6.5, details of two acceptable support plates have been amended;

— in Clause 4, provision has been made for the use of a gunning liquid other than water and examples of liquids other than water that might typically pertain, are given;

— Clause 8 has been revised;

— in Clause 9 test report item a), details of any stainless-steel wire fibre additions are to be reported;

— A.2 has been amended, specifying that it is the as-cured mass of the panel that is to be used as the basis for rebound calculations.

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.

Refractory test-piece preparation — Gunning refractory panels by the pneumatic-nozzle mixing type guns

WARNING — This document can involve the use of hazardous materials, operations and equipment. It does not attempt to address the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices, and to determine the applicability of regulatory limitations prior to use.

1 Scope

This document describes the procedure for the preparation of test panels from refractory materials by gunning through pneumatic nozzle mixing type guns at ambient temperatures. The test pieces are for the determination of properties on as-gunned products prepared under either "standard conditions" (as required for quality assurance or product development) or "site conditions". In the case of "site conditions", the purpose of the testing is to establish the properties pertaining to a given installation or a given set of installation conditions. In this case, the panel can be obtained during the on-site installation. Parameters such as ambient temperature, gunning elevation, air pressure and curing conditions (temperature, orientation of the panel) applicable during the preparation of the panel are as near as possible to the respective parameters pertaining to the site installation.

It is also possible to simulate certain "site conditions" by gunning panels off-site, for example, in a laboratory setting. This is acceptable under this document, by agreement between interested parties.

This document does not apply to plastic gunning mixes, and to those mixes that contain aggregates that are susceptible to hydration.

This document does not apply to shotcrete type mixes, which are dealt with in ISO 18886.

2 Normative references

The following documents are referred to in the text in such a way that some or all 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 836, *Terminology for refractories*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 836 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
gun
assembly, essentially comprising a chamber into which the refractory is added, together with a mechanism that controls the flow of the material through the unit

Note 1 to entry: Depending on the type used, the gun may be open at the top, or a closed pressurized unit may be used.

3.2
rebound material
material that fails to adhere to the surface when being sprayed and ricochets out of the immediate area

4 Principle

Refractory material is conveyed pneumatically in either a dry or (occasionally), pre-dampened form to the test site, using equipment of the nozzle mixing type. Then liquid (most commonly, water) is introduced to the refractory mix at the nozzle and the mixture is projected onto a support plate (see 6.5).

Examples of liquids other than water that can be used during the "dry gunning" operation described above, include "binders" such as colloidal silica; or setting-time accelerators (which are typically alkaline solutions). Water is the default gunning liquid. Any other gunning liquid, if used, shall be specified.

5 Precision

Differences between various types of equipment and in operator techniques can result in variations in the physical properties of the gunned specimens. For referee testing, the same operator should use the same equipment to produce test specimens.

NOTE At time of publication, interlaboratory testing to determine the precision of this document with respect to different types of material and with respect to the physical tests most performed on specimens cut from gunned panels, has not been scheduled. If such work is completed, a suitable addendum can be included in a future edition. It is stressed that this document deals only with sample preparation. At time of publication, it is considered that interlaboratory testing to evaluate the precision (and accuracy) of specific test methods, is a higher priority.

6 Apparatus

6.1 Gun of the pneumatic nozzle mixing type.

6.2 Air Compressor, capable of supplying a steady airflow at the required pressure and volume.

In some cases, depending on the material to be gunned and the layout, a dedicated air compressor is not necessary to achieve satisfactory results. "Plant air" can be sufficient. In either case, it is recommended that an air filter with "water trap" be fitted on the air inlet side, so that clean, de-humidified air is supplied for use in gunning.

6.3 Mixer. The mixer shall be capable of producing a homogeneous mixture of the material to be tested.

6.4 Hose/nozzle assembly, comprising a reinforced pneumatic hose and a nozzle assembly suitable for the material being gunned.

6.5 Gunned-material support plate, flat, capable of producing a panel having minimum usable dimensions of 380 mm x 380 mm x 115 mm thickness that is suitable for the tests intended to be carried out, after allowance for any material to be cut off as described in Clause 8. The preferred support plate has ledges at both sides and the top edge. An example of the preferred support plate is given in Figure 1a).

An alternative support plate may be used, 300 mm to 500 mm in length, and having top and bottom support edge 100 mm in width and of the same overall length as the support plate. An example of the alternative support plate is given in Figure 1b).

The support plate may be made of wood or steel and shall not flex during use. The support plate may be larger than the minimum panel size, to allow the edges to be removed from the gunned panel, for example, to remove trapped rebound material at the bottom, and other edge effects.

Interested parties shall agree which type of support plate is to be used. The test report shall state the dimensions of the gunned-material support plate and panel produced, and the type of support plate used.

6.6 Air pressure gauge, capable of measuring pressures up to 690 kPa, plus or minus 5 % at all pressures.

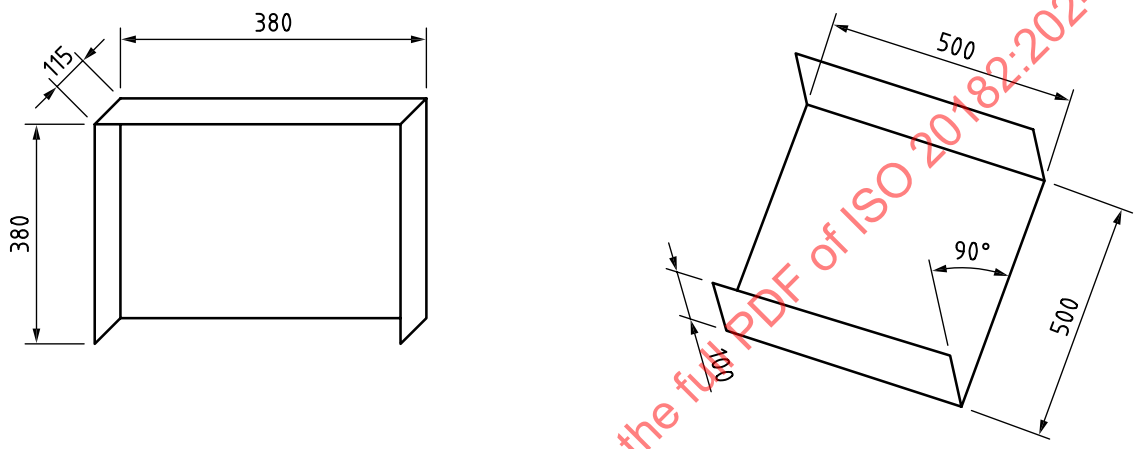
6.7 Water-measuring device, for use if pre-damping is carried out, capable of measuring the water quantity to the nearest 5 %.

6.8 Water-pressure gauge, capable of measuring pressures up to at least 50 kPa greater than the pressure in the supply lines being used and within plus or minus 5 % at all pressures.

6.9 Miscellaneous tools, including a trowel and a shovel.

6.10 Thermometer, capable of being read to the nearest 1 °C.

Dimensions in millimetres



a) Preferred gunned-material support plate **b) Alternative gunned-material support plate**

Figure 1 — Examples of gunned-material support plates

7 Sampling

Take the sample for preparation of a test panel in accordance with established sampling principles, such as those given in ISO 8656-1.

The additional volume of material required for sample preparation will depend on the amount left in the gun hopper after the gunning operation, the amount of rebound material and the amount required to stabilize the gun. The mass of material required will depend on the total volume and the bulk density of the material.

Only full bags of the material to be tested shall be selected and their entire contents shall be loaded into the gun, throughout the gunning operation. In cases where a “feed hopper” is used, the entire contents of the bag(s) shall be loaded into the feed hopper.

8 Procedure

Using Table 1 as a guide, choose the hose diameter appropriate to the refractory mix being gunned.

Table 1 — Feed systems

Maximum aggregate size in mix mm	Internal diameter of hose mm
< 5	38
5 to 8	38
> 8	50

For the preparation of gunned panels under “standard conditions”, the nozzle and the gun are held at the same elevation. If this is not the case, record the difference to the nearest metre. Unless the parties agree otherwise, a minimum hose length of 50 m shall be used. This is normally achieved by linking two standard gunning hoses of 25 m length. This helps to achieve smooth material flow through the hose, without surging.

For the preparation of panels under “site conditions’, where the work face is located above the gun, the elevation shall be recorded to the nearest metre.

If the material to be gunned contains stainless steel wire fibres, this shall be noted in the test report (Clause 9). If the percentage content of fibres and the fibre length are known, these shall also be recorded.

A fibre length of 12 mm is recommended when using 38 mm hose. Larger fibre lengths can cause hose blockages.

Sometimes, wire fibres can be mixed into the dry material on site. In such cases, this operation shall be performed in a suitable mixer before feeding material to the gun.

Occasionally, the use of pre-damping water may be specified. If so, this operation shall be performed in a suitable mixer as per manufacturer’s instructions. Otherwise, if necessary, pre-dampen the material using a water addition in the range 2 % to 5 % by mass for dense castables or 5 % to 12 % by mass for insulating castables.

The gunning liquid pressure should be greater than 150 kPa above the gunning pressure at the nozzle, possibly requiring the use of a pump for the liquid. The “water ring” and nozzle extension will be different for dense and lightweight materials.

Where water is used (either as the only “gunning liquid” or to make up a solution of the “gunning liquid”) the water shall be of potable quality. This is critical for success in the application of this document. Poor water quality can adversely impact the gunning operation and subsequent panel quality.

Record the ambient temperature and the temperature of the refractory material to the nearest 1 °C.

Where necessary, to prevent sticking, apply a plate-release agent, such as light oil or grease, to the support plate.

Place the support plate against a rigid surface, typically at an angle of 60° to 80° to the horizontal. Record the angle of inclination and include it in the test report. This range for angle of inclination is considered “optimal” because steeper angles can cause slumping while more shallow angles can result in undesirable entrapment of rebound material within the gunned panel. Nevertheless, depending on the material and other installation parameters, a good panel can be obtained using an angle of inclination outside the typical range quoted here.

NOTE 1 In off-site simulation of site gunning conditions, it is common for the work face to be located above the gun and for the panel to be supported in a frame, at an angle not within the above range. For example, a negative angle (typically −30° to −50° to the horizontal), can be used to simulate arch gunning.

However, the practice of gunning onto an anchored surface (for example, overhead) is outside the scope of this document because this practice usually has, as its primary purpose, the assessment of adhesion and other gunning characteristics, not the obtaining of a panel for subsequent laboratory testing.

Unless otherwise explicitly agreed between the interested parties, where the gunned panel is being prepared outside, exposure of the material and/or the support plate to direct sunlight during gunning shall be prevented.

Using the minimum amount of liquid that allows the refractory to adhere to the sprayed surface, adjust the air pressure until the material flows freely from the nozzle. This operation should be performed remote from the support plate.

NOTE 2 The air pressure is dependent on whether the material gunned is dense or insulating.

Holding the nozzle at right angles to the work area and typically 0,5 m to 1 m from it, spray in a circular motion over the full width of the test plate, being careful not to entrap rebound material. Continue until the panel's thickness is such that test pieces of the desired size can be cut from the panel, so that all gunned edges are removed in the cutting process.

Where the panel support plate is of the alternative design shown in Figure 1(b), i.e., not open at the bottom, the spraying operation shall be performed by starting at the bottom and working upward.

Interested parties shall agree whether the top surface and edges may be trimmed. The surface shall not be trowelled to obtain a sleek finish.

If a determination of water content is required, take sufficient gunned material, typically 300 g, which is not rebound material. To obtain the most representative result, the sample should be taken from the panel itself, parallel to the direction of spraying. It should include material from the full thickness of the panel. However, other methods of sampling for moisture determination are acceptable where a reasonably accurate, indicative result only, is required. These include the common practice of spraying off to the side of the panel, into a container that can be made “water-tight” until the test for moisture determination is undertaken. In such cases, care shall be taken not to adjust the water just before, or during, the collection of the sample.

For insulating materials, a smaller sample may be taken. The sample size will depend on the density of the material.

To minimize moisture loss, either enclose the panel or cover its surface with an impervious membrane.

Allow the gunned panel to cure in-situ for 24 h before detaching from the support plate. Record the ambient temperature during curing. Where possible (e.g., if the panel is being prepared under controlled laboratory conditions), an ambient temperature during curing in the range of 20 °C to 25 °C shall be used. Where the gunned panel has been prepared under controlled laboratory conditions and the angle of inclination of the support plate has been recorded, this angle of inclination shall, where possible, be maintained during curing of the panel.

Unless otherwise explicitly agreed between the interested parties, exposure of the gunned panel to direct sunlight during curing shall be prevented.

The sample may be stripped after 16 h if sufficient strength has been developed, provided that it remains in a humid atmosphere (minimum 95 % relative humidity) for a total of 24 h.

Cut test pieces from the gunned panel, with the longest side parallel to the ledge, to a size appropriate to the tests to be carried out and mark the direction in which the gunning pressure was applied. The cut surface of a test piece shall be at least 1 cm from the exposed edge of the gunned panel. Cut surfaces shall be smooth enough to allow for strength testing, if required. The as-gunned faces shall not form part of the test pieces.

The forming (i.e., “as-gunned”) direction shall be marked on the gunned panels and on all subsequently cut test pieces.

Dry the samples at 110 °C for 24 h and store for testing. Ensure they do not re-absorb moisture prior to testing.

NOTE 3 For chemically bonded material, a special drying schedule can be required.

While the scope of ISO 1927-6 does not include the testing of specimens cut from gunned panels, it is worth noting that the application of ISO 1927-6 requires that where test pieces are to be tested as- dried, they must be tested immediately after drying and cooling to room temperature. In the case of the determination of permanent linear change (dried to fired), the as-dried measurement should be taken immediately after the test piece has been dried and cooled to room temperature. It is recommended that the same methodology apply to this document where it is practicable to do so.

Where required, determine the proportion of rebound material and, by a method to be agreed between interested parties, the water content. For example, Annex A gives a method for determination of total water content. This can over-estimate the water content if the sample contains ingredients that decompose below 800 °C. Adjustments can be made to accommodate this.

However, if for example, only the free (unbound) moisture content is to be determined, then the method described in Annex A may be modified such that an oven at 110 °C replaces the muffle furnace, and the sub-sample is dried to constant weight.

Other temperatures (with suitable hold times) may be used depending on what moisture loss interested parties wish to establish.

9 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 as-received material, e.g., product name, lot number, production date and details of any stainless-steel fibre addition.

b) a reference to this document, i.e. ISO 20182:2024.

c) details of the process including the following:

- the gun type and operational specifications,
- the length and diameter of the material hose used,
- the type of nozzle mixing and delivery device,
- the temperature of the work area, refractory material, and water,
- the mean air pressure measured in the air hose leading to the gun during the gunning operation, to the nearest 10 kPa,
- the type of gunning liquid (water or other)
- the mean liquid pressure during the gunning operation, to the nearest 10 kPa,
- the distance from the nozzle to the panel during the major part of the gunning operation, to the nearest 0,2 m,
- the angle of inclination of the support plate,
- the difference, if any, in elevation between the nozzle and the gun, to the nearest metre,
- the quantity of water used for pre-damping, if applicable, to the nearest 0,5 % by mass,
- the dimensions of the gunned panel,
- the type of support plate as per Figure 1 a) or b),
- the dimensions of the support plate.

d) if required (by agreement between interested parties) and determined:

- the (total, free or other) water mass fraction of the gunned material, to the nearest 0,1 %,
- the percentage of rebound material, to the nearest 1 %.

e) the identity of the operator.

f) any deviations from the procedure specified.

g) any unusual features (anomalies) observed during the test, in particular:
   — any unusual gunning characteristics, such as surging,
   — any unusual characteristics of the test pieces, such as lamination, segregation, honeycombing.

h) the date of the test.