
**Refractory test-piece preparation —
Gunning refractory panels by wet
gunning techniques**

*Préparation d'éprouvettes réfractaires — Panneaux réfractaires pour
gunitage par techniques de gunitage humide*



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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.

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).

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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*.

Refractory test-piece preparation — Gunning refractory panels by wet gunning techniques

1 Scope

This International Standard specifies the procedures for the preparation of test pieces from refractory materials by wet gunning at ambient temperatures. The test pieces are for the determination of properties on wet-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 gunned panel is obtained during the on-site installation. Such parameters as activator addition (type, amount, method of addition), conveying pressure and curing conditions (temperature, orientation of the panel) applying during the preparation of the panel are as near as possible to the same parameters pertaining to the site installation.

This procedure applies to refractory materials that can be transported through a gunning hose after having been mixed with the total water requirement for material placement. The consistency of these materials (see 7.5) is typically such that they would be suitable for placement by casting were they not to be transported through the gunning hose and applied by spraying.

Refractory materials that are pneumatically conveyed in the “dry” state through a gunning hose, even after mixing with a portion of the total water requirement (the bulk of the water being added at the nozzle) are dealt with in ISO 20182.

This International Standard does not apply to the gunning of plastic refractory materials (refer to ISO 1927-1).

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*

ISO 1927-4, *Monolithic (unshaped) refractory products — Part 4: Determination of consistency of castables*

3 Terms and definitions

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

3.1

activator

chemical solution added to the refractory at, or prior to, the gunning nozzle which causes the refractory to set, stiffen or coagulate

Note 1 to entry: This International Standard may 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 International Standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

4 Apparatus

4.1 Gunned-material mould. The preferred mould for preparing samples of wet-gunned material is enclosed on five sides as shown in [Figure 1 a\)](#). An alternative mould is shown in [Figure 1 b\)](#). In either case, the surface being sprayed onto shall be square in shape and the mould shall have minimum dimensions of (300 × 300 × 100) mm. The mould may be made from metal or timber, or a combination of both. It should be of sufficient rigidity that it will not flex when material is sprayed onto it.

Interested parties shall agree on the size and type of mould to be used and these shall be stated in the test report, along with the dimensions of the test panel produced.

A stainless steel expanded metal case, having the same mould dimensions as above, may be used by agreement between interested parties. This type of mould is particularly useful during site installation because it can be fitted to the anchoring, enabling the mould to be filled without undue disruption to the gunning process.

4.2 Air pressure gauge, capable of measuring pressures up to 690 kPa ± 5 % at all pressures.

4.3 Weighing scale, capable of weighing masses of the order of 500 g to 0,1 g.

4.4 Drying oven, having fan-forced ventilation and capable of maintaining a temperature of 110 °C ± 5 °C.

4.5 Miscellaneous tools, e.g. trowel, shovel.

4.6 Thermometer, capable of measuring temperature within a suitable range (typically from -10 °C to 90 °C) with a readability of 1 °C and an accuracy of ±1 °C.

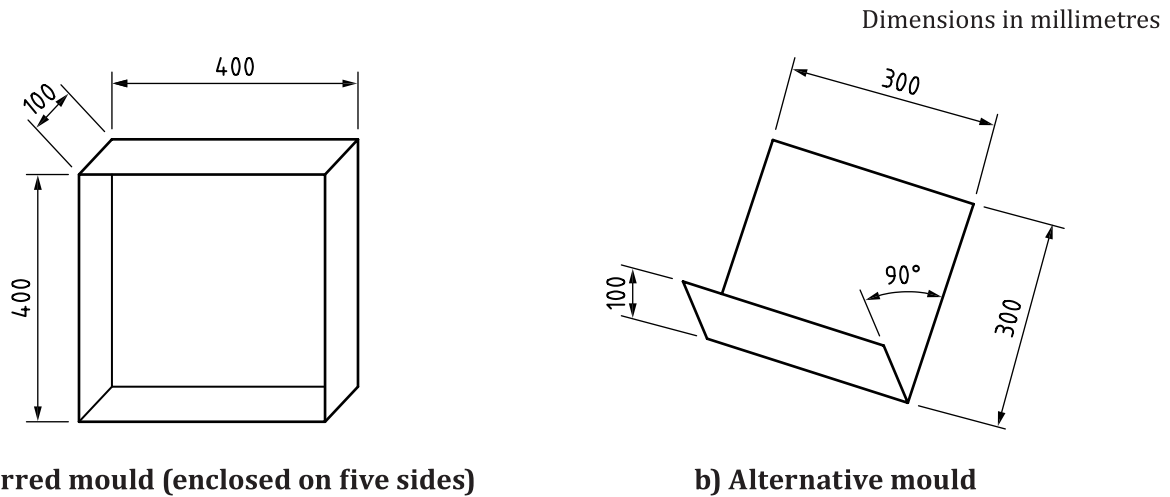


Figure 1 — Examples of moulds used in wet gunning

5 Sampling

The sample for preparation of a test panel should be prepared in accordance with established sampling principles, such as those given in ISO 1927-2.

6 Preparation of test pieces

6.1 Principle

Refractory material is mixed with the total water requirement and transported to a nozzle by suitable means where air may be incorporated to convey the mix to the mould. Activator may also be added at or prior to the nozzle to allow the mix to adhere to the target surface without slumping. [Figure 2](#) shows one example of an equipment set up for wet gunning.

6.2 Equipment

6.2.1 Conveying equipment, for conveying the material through the gunning hose to the gun nozzle. Examples include double piston pumps, gunning machines that use pneumatic conveying, centrifugal pumps and auger screws. The conveying equipment needs to have sufficient power to propel high-density pre-mixed monolithic (unshaped) refractory materials through pipes and/or conveying hoses of suitable diameter, over the required distance from the mixer to the surface being gunned. Extremely high pressures (e.g. 20 MPa piston pressure in a double piston pump) may be developed and the conveying hoses will need to have been designed to withstand these high pressures for long periods of time. If necessary, seek guidance from a reputable equipment supplier.

6.2.2 Activator pump, for conveying activator to the pre-mixed (wet) refractory material at a measured rate.

6.2.3 Air compressor, for supplying compressed air at sufficient constant pressure to ensure that the gunning operation can proceed continuously. The role of the compressed air is to disperse the homogeneous mixture in the conveying hose, irrespective of the location at which activator solution enters the system.

6.2.4 Mixer, capable of producing a homogenous mixture.

6.2.5 Gunning hose/nozzle assembly, reinforced hydraulic hose (and/or pipe) of the shortest practical length and a nozzle assembly suitable for the material to be gunned.

7 Procedure

7.1 Set up the equipment as shown in the example in [Figure 2](#). Ensure that all the equipment is clean and free of blockages. Place the panel mould against a rigid surface, typically at an angle of 60° to 80° to the horizontal. The set-up should be such as to facilitate ease of gunning at right angles to the surface being gunned (see [7.8](#)). Where the gunned panel is being prepared under controlled laboratory conditions, this range for the angle of inclination of the mould shall be mandatory. In such cases, the angle of inclination shall be measured, recorded and included in the test report.

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

7.2 Mix the material with the amount of water as recommended by the manufacturer or as agreed between the interested parties, in the mixer for the recommended time. Where possible (and especially if the panel is being prepared under controlled laboratory conditions), potable water shall be used. Record the mixing time and the water addition (W_a) in litres per tonne of dry material.

7.3 Discharge the mixed material into the hopper above the conveying apparatus.

7.4 Record the ambient temperature and the temperature of the mix in the hopper to the nearest 1 °C.

At high ambient temperatures, especially at temperatures above 32 °C, measures to safeguard against undesirably rapid setting may be adopted by agreement between interested parties. Such measures include, but are not limited to, any one or more of the following: storing materials in an air-conditioned container and only taking them out as required, reducing the temperature of the water supply, e.g. by using ice, and sampling and installing only at night time. For samples prepared in the field, any and all such measures that have been agreed for the actual installation should, by agreement between interested parties, be adopted for the gunned sample preparation. If there is doubt either about the temperature above which suitable measures should be taken for any given material or about the most suitable measures to be taken in any given instance, the product manufacturer may be consulted.

7.5 Take a sample from the hopper and determine the consistency by one of the methods given in ISO 1927-4. Use either the method for determination of consistency recommended by the manufacturer or any other method as agreed between the interested parties.

7.6 Start conveying the material until it exits the nozzle. Check for blockages and material consistency by directing the nozzle into a waste container adjacent to the mould. Once satisfactory consistency is obtained, operate the conveying apparatus continuously.

7.7 Turn on the air supply to the nozzle and, if required, introduce activator solution. Adjust the flow rate of activator according to the manufacturer's guidelines or as agreed between the interested parties. If deviating from manufacturer's guidelines, reasons shall be noted and reported, including the extent of any deviation.

For samples prepared in the field, it may be necessary to deviate from the manufacturer's guidelines in order to obtain properties that are representative of specific on-site installation conditions. For example, when spraying overhead and/or in very cold weather, it may be necessary to exceed the recommended activator addition and in such a case, it would be desirable to obtain properties pertaining to the use of such excess activator. Such variants should be taken into account when comparing properties so obtained with published data obtained under standard conditions.

This does not apply to samples prepared in the laboratory, unless explicitly agreed between the parties.

7.8 Holding the nozzle at right angles to the surface being gunned, and typically 0,4 m to 0,8 m from it, spray in a circular motion over the full area of the mould, starting at the bottom of the mould and working upward. Continue gunning until the panel is at least 100 mm thick. The final thickness will depend on the type of test specimens which are to be cut from the panel (see [7.12](#)). Record the conveying speed (V_d), in tonnes of dry refractory per hour, the conveying pressure, and the activator flow rate (Q_a), in litres per hour, used during the gunning.

By agreement between interested parties, the activator flow rate (Q_a) may be determined either directly (using a flow meter) or indirectly (by using a calibration curve relating flow rate to another parameter, such as activator pump motor frequency of rotation, depending on the type of activator pump used).

7.9 It is recommended that the top surface and edges of the gunned panel should be trimmed.

In some cases, trimming may result in tearing of the gunned panel if it has not developed sufficient strength to prevent this. In such cases, proceed without trimming and ensure that no tears are included in any cut test specimens. Under no circumstances should the surface be trowelled to obtain a sleek finish.

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

7.11 Allow the gunned panel to cure for 24 h before removing from the mould. 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. Also where possible (even for panels prepared in the field), the maximum temperature reached on the surface of the panel during curing should be measured. This temperature may be especially useful for gunned panels prepared and cured in cold weather because it may be indicative of sufficient cement hydration (where applicable) and strength development, in spite of the cold weather. Where the gunned panel has been prepared under controlled laboratory conditions and the angle of inclination of the mould has been recorded at 7.1, 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.

7.12 Cut test pieces from the gunned panel (but see note below), with the longest side parallel to the bottom ledge, to a size appropriate to the tests to be carried out, and mark the direction of gunning. The rough, as-gunned faces shall not form part of the test pieces. However, it is permissible to cut the panels into more manageable sizes before drying.

Where the size of the oven allows it, panels may be dried before cutting. This is the preferred practice in situations where cutting is not practical for an extended period of time after curing. Where panels, whether whole panels or pre-cut panels, are dried before cutting test pieces, the test pieces shall be dried again as per 7.13, prior to testing.

7.13 Dry the test pieces (or whole panels, or cut panels as applicable) in an oven at 110 °C and retain for further testing as required. Ensure that they do not absorb moisture prior to testing.

While the scope of ISO 1927-6 does not include testing specimens cut from gunned panels, it is worth noting that this International Standard requires that where test pieces are to be tested as-dried, they shall 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.

8 Calculation

The quantity of activator added is calculated from Formula (1):

$$A = \frac{Q_a}{V_d} \quad (1)$$

where

A is the activator addition in litres per tonne of dry material;

Q_a is the activator flow rate in litres per hour;

V_d is the conveying speed in tonnes of dry material per hour.

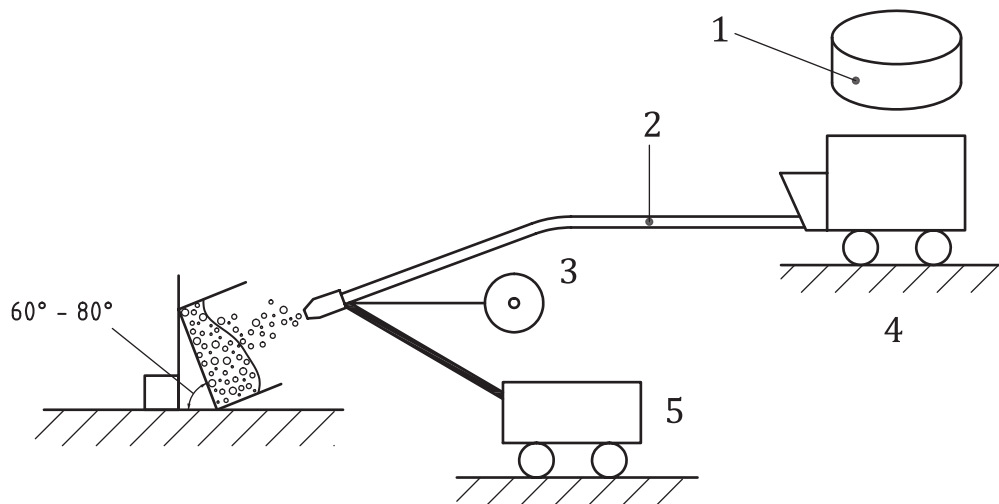
9 Test report

The test report shall include the following information:

- a) a description of the as-received material, including the type of activator, if applicable;
- b) a description of the equipment used, e.g. mixer type and capacity, type of equipment used for material transfer, hose diameter and length;
- c) the ambient temperature and the temperature of the mixed refractory;
- d) the water content of the mixed refractory (in percent on a dry basis);

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- e) the water addition (%) used for mixing;
- f) the mixing time;
- g) the consistency of the mixed refractory and method of consistency determination;
- h) the conveying speed in tonnes per hour, and the conveying pressure in kPa;
- i) the mean air pressure during the gunning operation, to the nearest 10 kPa;
- j) the activator addition in litres per tonne of dry material;
- k) the extent of and reason for any deviation from manufacturer's recommendations;
- l) the type and dimensions on the mould used to produce the panel;
- m) the final dimensions of the panel produced;
- n) the angle of inclination of the mould during gunning, if applicable (refer to 7.1);
- o) the ambient temperature during curing and where measured, the maximum temperature reached on the surface of the panel during curing;
- p) the orientation of the test panel during curing, including, where applicable, the angle of inclination of the mould;
- q) whether test pieces were cut from the panel before or after oven drying;
- r) whether the panel was gunned and subsequently treated under laboratory conditions or under site conditions (i.e. in the field);
- s) any other observations which may assist in interpreting the results;
- t) a reference to this International Standard, i.e. ISO 18886:2016.



Key

- 1 mixer
- 2 gunning hose
- 3 activator pump
- 4 conveying apparatus (e.g. pump or gunning machine)
- 5 air compressor

Figure 2 — Example of equipment set up for wet gunning

Bibliography

- [1] ISO 1927-1, *Monolithic (unshaped) refractory products — Part 1: Introduction and classification*
- [2] ISO 1927-2, *Monolithic (unshaped) refractory products — Part 2: Sampling for testing*
- [3] ISO 1927-6, *Monolithic (unshaped) refractory products — Part 6: Measurement of physical properties*
- [4] ISO 20182, *Refractory test-piece preparation — Gunning refractory panels by the pneumatic-nozzle mixing type guns*

