

# Installation of monolithic refractories —

## Part 2: Code of practice for installation by gunning

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# Committees responsible for this British Standard

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- British Cement Association
- British Ceramic Research Ltd.
- British Metallurgical Plant Constructors' Association
- British Steel Industry
- Coke Oven Managers' Association
- Combustion Engineering Association
- Department of Trade and Industry
- Energy Industries Council
- Engineering Equipment and Materials Users' Association
- Institute of Refractories Engineers
- METCON
- National Federation of Master Steeplejacks and Lightning Conductor Engineers
- Refractories Association of Great Britain
- Refractory Contractors' Association

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## Foreword

This Part of BS 7335 was prepared under the direction of the Refractory Products Standards Policy Committee.

The purpose of this code of practice is to advise on good or recommended practices before, during and after installation. Nothing in the code should be taken as a specification for either the materials or their installation.

*Assessed capability.* Users of this British Standard are advised to consider the desirability of assessment and registration of a supplier's quality systems against the appropriate Part of BS 5750 by a third party certification body.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 22, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

## 1 Scope

This Part of BS 7335 describes good practice for working procedures in the installation of refractory linings by gunning techniques. The code is specifically concerned with the “dry” gunning of initial or replacement linings, using refractory materials bonded by calcium aluminate cement. Major repairs, involving the removal of old panels of the lining back to the shell, are also covered. Recommendations for ensuring that compliance with the agreed design has been achieved are included, where appropriate.

Wet gunning and gunning repairs to hot linings are excluded. The gunning of linings for steel chimneys is specifically described in BS 4207.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

## 2 Definitions

For the purposes of this Part of BS 7335, the definitions given in BS 3446-1 apply, together with the following.

### 2.1

#### **gunning**

the hot or cold application of a refractory material by means of a pneumatic gun<sup>1)</sup>

### 2.2

#### **predamping**

the process of mixing an amount of water, less than the total water content, with dry material prior to dry gunning

### 2.3

#### **dry gunning**

a gunning process in which dry or predamped material is pneumatically conveyed to a nozzle where water is added

### 2.4

#### **wet gunning**

a gunning process in which concrete premixed with the total water content is conveyed under pressure to a nozzle where air is used to propel the concrete into position

### 2.5

#### **hot gunning**

the repair of a hot furnace lining by gunning

### 2.6

#### **material delivery hose**

hose used for conveying the gunning material from the gun to the nozzle

### 2.7

#### **panel**

the minimum area of lining that is gunned in any continuous operation

## 3 Planning

NOTE The installation should be planned in detail, in advance, so that work on site can proceed quickly and efficiently. The check list in 3.1 to 3.19 is given as an aid to drawing up such a plan.

**3.1** The safety requirements of the site should be considered, taking guidance where necessary from appropriate publications by the Health and Safety Executive. (See 7.11.)

**3.2** A drawing detailing the materials of construction, the thickness of the lining layer(s), specification and arrangement of anchors, and other features, such as expansion allowance and joint arrangements, should be available.

**3.3** The extent of the job and the time available should be determined so that the required rate of installation may be calculated and an appropriate schedule for gunning prepared. Allowance should be included for any preparation of the shell which may be necessary, including the fixing of anchors.

**3.4** The number of men required to enable each panel of the lining to be placed continuously and correctly in the allocated time should be established.

**3.5** The material storage conditions and storage duration should be evaluated so that suitable packaging, for example hermetically sealed drums or paper sacks, may be agreed. If possible gunning material should be ordered well in advance and delivered to site shortly before installation commences.

**3.6** A water supply of appropriate quality, capacity and temperature should be provided.

**3.7** Materials handling and waste disposal facilities should be provided as appropriate for the materials and equipment involved.

**3.8** The number and type of formers, profile boards, scaffolding and staging required to achieve the planned installation should be determined, and prepared and installed prior to commencement of refractories installation.

**3.9** Guns, nozzles, predamping equipment, and hoses for air, water and gunning material, appropriate for the planned installation, should be provided. Wear of components within the gunning equipment, and the possible effect of the inclusion of trace materials from this source in the gunned lining, should be assessed and appropriate counter-measures taken where necessary.

<sup>1)</sup> Repeated from BS 3446-1.

**3.10** Suitable electrical power supplies should be arranged, with due regard to voltage, frequency, current and phase requirements. Artificial lighting should be provided, if necessary.

**3.11** A compressed air supply for gunning equipment should be arranged. An existing on-site air supply may be adequate in some cases but provision of an air compressor is usually necessary.

**3.12** If necessary, auxiliary heating or cooling should be arranged, for example space heating or water cooling of the shell of the unit to be lined.

**3.13** The optimum siting of the various items of gunning equipment for efficient operation should be decided.

**3.14** A suitable welding procedure for anchors should be agreed.

**3.15** The size of panels to be gunned and the sequence of panel installation should be decided, if not specified in the vessel design. If the size and shape of the vessel are suitable, square panels of 1 m to 2 m side are usually employed.

**3.16** If not already designated (in a working drawing), the refractories manufacturer/supplier or the furnace designer should be consulted regarding the type and spacing of joints between panels.

**3.17** The curing and drying out procedure to be adopted should be agreed (see clauses 11 and 12).

**3.18** If required, a quality control procedure should be agreed for gunning materials (see clause 5) and/or for the gunned lining, samples taken from it or samples fabricated simultaneously with it (see clause 13).

**3.19** If required, the quality of workmanship and the efficiency of the equipment may be assessed at the commencement of the operation.

## 4 Personnel

Operations directly involved in installation by gunning are as follows:

- a) nozzle operation;
- b) gun operation;
- c) feeding the gun;
- d) trowelling off and removal of rebound;
- e) curing.

With certain types of gun, more than one operation may be performed by a single operator. However, with most types of gun a minimum crew of two men is required, a nozzleman and a gun operator. The gun operator may also feed material to the gun, and both men may perform the other operations on completion of gunning each panel of the lining. The number of men employed may be increased for faster installation.

If predamping is undertaken using a batch type mixer (see 7.7), additional personnel may be required to feed, operate and empty the mixer and to transport the predamped material to the gun. If a continuous type mixer is used and arranged to feed directly into the gun, it is usually possible to proceed without extra personnel.

## 5 Gunning materials

### 5.1 Quality control

These recommendations are concerned with the quality of the gunning material as tested prior to installation. The quality of the gunned lining, which depends on both the quality of the gunning material and on the method of installation, is described in clause 13.

Any problem associated with the gunning material will be compounded in terms of time and expense if it remains undetected until after installation, particularly if it causes failure on commissioning or in service. It is recommended, therefore, that acceptable limits for appropriate properties of the gunning material should be agreed between the parties concerned, and that supplies of the gunning material should be sampled and tested to ensure that the agreed requirements are met. The following options may be considered for quality control of supplies of gunning material.

- a) It may be agreed between the parties concerned that the quality control procedures of the refractories manufacturer/supplier are adequate, particularly where an accredited quality assurance scheme is operated. (See BS 5750).
- b) A scheme of sampling and testing specific to the job in hand may be agreed between the parties concerned. (See, for example, the sampling scheme and testing procedures in BS 1902-7.)

If option b) is implemented, the sampling of the material is most easily carried out at some stage before final palleting or storage of the consignment, such as at the end of the manufacturer's production line. Only whole bags or containers should be taken as samples. Selected samples should be stored in accordance with the guidance given in 5.2 until required for the preparation of test pieces, in order to avoid deterioration.

**NOTE** Properties obtained from test pieces prepared by casting will not necessarily agree with those for gunned test panels or samples taken from the installed lining.

## 5.2 Storage

All gunning materials should be used as soon as possible after manufacture, since they deteriorate during storage. Storage time may be reduced by arranging for the manufacturer/supplier to deliver fresh stock shortly before the work commences.

No precise storage life can be quoted, but, as a guide, the manufacturers of most gunning materials aim for a storage life of at least 6 months under good conditions. Gunning material in torn, punctured or open containers should be discarded. If undated material is to be stored, it should be stamped with the delivery date or batch number.

For prolonged storage times, the gunning material should be kept in a clean, dry, well-ventilated building. It should be stored off the ground on a ventilated platform (e.g. a pallet) and placed under a cover (e.g. a tarpaulin), arranged so as to prevent any ground moisture from causing condensation or high humidity under the cover.

Gunning materials should not be stored at temperatures above 35 °C immediately before use, as rapid setting may result. In cold conditions, the precautions recommended in 8.5.2 may be taken.

After being stored for some time, gunning material from the bottom of stacks may have lumps in it. These should break down when lightly rubbed between the fingers. If they do not, the material may have hydrated and the whole bag should be discarded.

Storage life depends on many factors, including the type of aggregate, cement, additives, packaging and storage conditions. Some additives, such as accelerators or inhibitors, may themselves deteriorate in storage. Gunning materials may be supplied in various types of container, from hermetically sealed drums to multi-walled paper sacks. Whilst better quality containers provide better protection in adverse storage conditions, they do not necessarily extend storage life. Some gunning materials may deteriorate even when stored in hermetically sealed containers.

Where the condition of the gunning material after storage is uncertain or any doubts exist, the refractories manufacturer/supplier should be consulted.

## 6 Water supply

### 6.1 Quality

The water for mixing to make the concrete should be clean, free from harmful matter and preferably of drinking quality to avoid the presence of dissolved chemicals which might have adverse effects on the setting or refractory properties of the gunned material. If there is any uncertainty, samples of water should be taken for analysis. (See BS 3148.)

### 6.2 Capacity

#### 6.2.1 General

The water supply should conform to the conditions of feed rate and pressure detailed in 6.2.2 and 6.2.3. If the mains water supply is inadequate, a water pump should be used (see clause 7).

#### 6.2.2 Feed rate

The supply rate required depends on the number and capacity of the guns and predamping machines to be used, the water addition required for the materials to be installed, and the proposed installation rate. As a guide, a supply of 30 L/min would be sufficient to supply one predamping machine and one gun operating at a high feed rate and with a high water addition.

#### 6.2.3 Pressure

The minimum water supply pressure should be 2.8 bar <sup>2)</sup>, plus 0.1 bar per metre of lift from the supply location to the nozzle.

### 6.3 Temperature

The water temperature should normally be in the range 5 °C to 25 °C. In cold conditions a heated water supply may be used (see 8.5.2). A heated water supply may be obtained by placing immersion heater(s) in the water tank (if used), or by using a water pump with an integral heater.

## 7 Equipment

### 7.1 General

The number, type and capacity of guns and hoses required will be dependent on the personnel and the time available to complete the installation project. Such considerations will also be reflected in the capacity of the compressed air supply and water pump required, though this will depend primarily on the distance of the gunning nozzle from the gun, its height above the gun, and the density and maximum size of the aggregate in the gunning material.

<sup>2)</sup> 1 bar = 10<sup>5</sup> N/m<sup>2</sup> = 100 kPa.

Additional standby units might also be considered necessary. Therefore, no definitive directives can be given, but the general principles are given in 7.2 to 7.15.

## 7.2 Guns

### 7.2.1 General

There are two basic types of gun for application of dry or predamped material, as follows:

- a) double chamber gun;
- b) rotating barrel or rotating bowl gun.

The two types are differentiated by the means used to contain the dry or predamped gunning material during operation of the gun. Guns of type a) hold the gun mix in a pressurized chamber as it is metered into the material delivery hose, whilst guns of type b) meter the gunning material directly from a hopper at atmospheric pressure.

Guns may be further differentiated by the means used to feed the material into the material delivery hose, four possible methods being as follows:

- 1) rotating feed-wheel;
- 2) screw feed;
- 3) rotating barrel;
- 4) rotating bowl.

The metering system used may be driven by an electric, diesel or air-powered motor, depending on the particular model of gun used. Some manufacturers provide a choice of power unit. Since compressed air is required in all cases for transport of material to the nozzle, it is often convenient to choose an air-powered machine. However, an alternative type may be considered if the source of compressed air is limited, since the air-powered motor alone may require up to 3 m<sup>3</sup>/min of air when running at full speed, depending on the size of the gun. Most types of gun incorporate a speed control, so that the output may be reduced to well below the maximum. In this way the consumption of compressed air may be reduced at the expense of feed rate.

### 7.2.2 Rotating feed-wheel gun

The rotating feed-wheel gun is a double chamber machine, comprising an upper and a lower chamber, the latter being maintained at the same pressure as the material delivery hose. The upper chamber is kept at atmospheric pressure whilst being filled with the dry gunning material, then raised to the pressure of the lower chamber. The lower bell valve drops open and the dry mix is transferred to the lower chamber. The lower bell valve is then held closed while the upper chamber is depressurized to allow refilling. The rotating feed-wheel, at the base of the lower chamber, continuously dispenses predetermined quantities of the dry mix into the material delivery hose. (See Figure 1 and Figure 2.)

The feed-wheel gun clearly requires some skill in operation to reload repeatedly the upper chamber without allowing the lower chamber to become empty. The double chamber design prevents the escape of dust associated with the feed wheel system, but some dust will necessarily be associated with the loading operation.

### 7.2.3 Screw feed gun

In a screw feed gun a rotating auger is used to dispense the dry mix in a controlled manner into the material delivery hose, giving a smooth output of material, but at a relatively low feed rate. An air-driven internal vibrator may be incorporated to maintain the flow of dry mix from the lower chamber into the auger. If the vibrator is not activated or malfunctions, slow or erratic material feed may occur.

### 7.2.4 Rotating barrel gun

In the vertical rotating barrel gun, the dry mix is continuously fed into a hopper at atmospheric pressure. Beneath this hopper a horizontally mounted wheel brings a series of barrels or segments, open top and bottom, in turn beneath the hopper. The segments are mounted vertically and fill with dry gunning material under gravity. As the wheel rotates, the full segment is sealed top and bottom between rubber gaskets and is then pressurized from the top. The bottom of the segment is simultaneously connected to the material delivery hose so that the dry mix is blown into the hose. The hose is also pressurized and assists in emptying the segment by the venturi effect. As rotation continues, each segment in turn is filled and its contents blown out. This system therefore provides a pulsed supply of material. (See Figure 3.)

The horizontal rotating barrel gun employs a similar principle of operation, but with the barrel axis horizontal.

Since the seal to the pressurized feed system is effected by rubber gaskets, excessive dust emission will occur in operation if the gaskets become worn or are incorrectly seated on the rotating barrel. An exhaust outlet is provided to depressurize automatically the segments before they are refilled from the hopper, and severe dust emission will occur if this outlet becomes blocked. This gun can easily be dismantled for cleaning and replacement of gaskets or the rotating barrel. Barrels of different volume capacity may be fitted to provide a variation in feed rate additional to any control of rotational speed which may be provided.

### 7.2.5 Rotating bowl gun

Like the rotating barrel gun, this type of gun employs a hopper at atmospheric pressure from which material drops under gravity into the segments of a rotating wheel. In this case the wheel is in the form of a bowl with U-shaped radial segments. Each segment in turn is pressurized from the inner opening, the air flow being turned through 180° as it blows the dry mix into the material delivery hose. This feature allows a more compact design than the equivalent capacity of rotating barrel gun. Sealing of the pressurized section of the bowl is achieved by a single, sector-shaped, rubber pad, rather than a full circular gasket, but the comments in 7.2.4 on seating and wear of gaskets apply equally to this pad. The circumference of the remainder of the bowl is sealed by an oiled felt ring, which should be correctly fitted and maintained to prevent leakage of material from the sides of the machine. (See Figure 4.)

Unlike the other types of gun described, no air is introduced into the material delivery hose other than that which passes through the pockets of the feed bowl.

This gun is also easily dismantled for cleaning and replacement of parts. A smaller feed bowl may be fitted to reduce the capacity of the machine, if required.

## 7.3 Hoses

### 7.3.1 General

Fabric-reinforced hose of at least 12 bar rating should be used for air, material and water transport in all normal gunning applications. A suitable hose is type 2 complying with BS 5118. For very high pressure applications, an appropriately increased rating of hose should be used.

### 7.3.2 Air hose

It is essential that the hose from the compressor, or other air supply, to the gun has an internal diameter at least equal to that of the material delivery hose in use, down to a minimum of 32 mm. Smaller diameter hoses may be used to supply other air-powered equipment, subject to the equipment manufacturer's recommendations.

### 7.3.3 Material delivery hose

Suitable hose is available in nominal internal diameters between 19 mm and 62 mm (see BS 6597). The 38 mm size is used for most applications; 50 mm hose is used for large tonnage operations where maximum delivery rate is required, and smaller sizes are occasionally used for very small operations.

The material delivery hose should have a minimum length of 30 m and there should always be sufficient length to allow freedom of movement at the nozzle. The use of a longer hose may reduce any surging which occurs in the material feed.

### 7.3.4 "Blow down" hose

This hose is for removing rebound material from the set lining. It should be of 12 mm to 19 mm internal diameter and fitted with a manual control valve and a metal extension tube.

## 7.4 Connectors

Connectors of at least 12 bar rating should be used for non-restrictive hose, and should interlock securely to ensure safe operation. An appropriate type of connector should be used for any higher pressure applications.

## 7.5 Nozzle assemblies

The nozzle assembly comprises the water body and the nozzle itself. (See Figure 5.)

Three basic types of water body are available:

- a) water ring type;
- b) water plate type;
- c) multiple hole tube for high pressure applications.

For the purposes of this code of practice, nozzles are divided into three groups:

- 1) short nozzles (under 300 mm length);
- 2) long nozzles (over 300 mm length);
- 3) right angle nozzles (short metal nozzles for use in confined spaces).

Short rubber nozzles may be used with metal shrouds to prevent distortion at high air pressures.