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DESIGN AND ENGINEERING PRACTICE
(CORE)

MANUAL

**INSULATING AND DENSE REFRACTORY
CONCRETE LININGS**

PTS 64.24.32.30
JANUARY 2011



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PTS Title:	INSULATING AND DENSE REFRACTORY CONCRETE LININGS

This revision of PTS **62.24.32.30 – INSULATING AND DENSE REFRACTORY CONCRETE LININGS (JANUARY 2011, Revision 1)** has been updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS **62.24.32.30 (December 1997)** will be removed from PTS binder / e-repository from herein onwards.

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PREFACE

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TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	SCOPE.....	1
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	1
1.3	DEFINITIONS	1
1.4	CROSS-REFERENCES	2
1.5	SUMMARY OF CHANGES SINCE PREVIOUS EDITION	2
2.0	FUNCTIONS AND TYPES OF REFRACTORY MATERIALS	3
2.1	FUNCTIONS	3
2.2	UNSHAPED REFRACTORY MATERIALS.....	3
2.3	EROSION-RESISTANT REFRACTORY MATERIALS	4
3.0	QUALITY ASSURANCE/QUALITY CONTROL	5
4.0	HEALTH, SAFETY AND ENVIRONMENTAL (HSE) ASPECTS	7
5.0	DESIGN	8
5.1	DESIGN PARAMETERS	8
5.2	TYPES OF LINING	9
5.3	SELECTION OF UNSHAPED REFRACTORY MATERIALS	10
5.4	CERAMIC FIBRE PACKING.....	12
5.5	PROTRUDING NOZZLES AND COLLARS.....	12
6.0	SUPPLY	14
6.1	MANUFACTURE OF REFRACTORY MATERIALS	14
6.2	PREPARATIONS FOR SHIPMENT	14
6.3	REFRACTORY SHIPMENT AND STORAGE	14
7.0	TRANSPORT AND HANDLING OF REFRACTORY LINED EQUIPMENT	15
8.0	INSTALLATION OF UNSHAPED REFRACTORY MATERIALS	16
8.1	GENERAL	17
8.2	INSTALLATION OF MOULDABLE REFRACTORY MATERIALS.....	18
8.3	INSTALLATION OF CASTABLE REFRACTORY MATERIALS	20
8.4	INSTALLATION OF GUNNING REFRACTORY MATERIALS.....	21
8.5	INSTALLATION OF VIBRACAST, PUMPABLE AND SELF-FLOW REFRACTORY MATERIALS.....	23
8.6	INSTALLATION OF EROSION-RESISTANT, CHEMICALLY BONDING REFRACTORY CASTABLES.....	24
8.7	SPECIAL ARRANGEMENTS FOR INSTALLATIONS.....	25
9.0	STARTUP AND OPERATION	26
10.0	INSPECTION AND MAINTENANCE	27
10.1	RESPONSIBILITIES	27
10.2	INSPECTION	27
10.3	REPAIR OF VIBRACAST REFRACTORY LININGS.....	28
10.4	MAINTENANCE	29
11.0	REFERENCES	30

APPENDICES

APPENDIX 1	SPECIFICATION FOR UNSHAPED REFRACTORY MATERIAL	32
APPENDIX 2	SPECIFICATION FOR SAMPLING AND TESTING OF UNSHAPED REFRACTORY MATERIAL	38
APPENDIX 3	APPLICATOR'S PROCEDURE QUALIFICATION (APQ)	45
APPENDIX 4	SPECIFICATION FOR METAL AND NON-METAL MATERIALS FOR ANCHORS	48
APPENDIX 5	REFRACTORY LININGS FOR FCCUs	58
APPENDIX 6	CURING, DRYING AND FIRING OF UNSHAPED REFRACTORY MATERIALS	67
APPENDIX 7	CORE SAMPLES FOR QUALITY CONTROL OF REFRACTORY LININGS	72
APPENDIX 8	CURING COMPOUND	73

1.0 INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the design, supply and installation of insulating and dense refractory concrete linings, and for the design and installation methods for the anchoring which retain the linings on the wall of the equipment.

This PTS is a revision of the PTS of the same number dated November 1991 and also incorporates PTS 30.48.60.34 which is now withdrawn. Hence, this PTS now covers refractory linings for fired equipment as well as monolithic (erosion-resistant), insulating and dense refractory linings in units such as fluidised catalytic cracking units (FCCUs).

Requirements of the refractory Manufacturer shall apply if they are more stringent than those of this PTS.

Refractory bricks and special shapes in insulating, dense or acid-resistant refractory are excluded from the scope of this PTS, for which reference is made to PTS 30.48.60.12, PTS 30.48.60.13 and PTS 44.24.90.31

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C", as described in PTS 00.00.05.05).

This PTS is intended for use in oil refineries, gas plants, chemical plants and, where applicable in exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

The definition of terms relating to unshaped refractory materials shall be in accordance with ISO 1927.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in (11).

1.5 SUMMARY OF CHANGES SINCE PREVIOUS EDITION

The previous edition of this PTS was dated December 1997; a summary of the main changes since the last edition is given below.

Section	Change
3	After the second sentence, add to this clause: and shall be performance in accordance with the relevant ISO standard where available or with the standards shown in Table 3-1 or the equivalent AS, AFNOR, BS or DIN
5.6	Remove clause. Reference document not available (PTS 00.00.06.06-Gen).

2.0 FUNCTIONS AND TYPES OF REFRACTORY MATERIALS

2.1 FUNCTIONS

Dense and/or insulating refractory linings protect equipment from process conditions (e.g. radiant and convection sections of furnaces, waste heat boilers, sulphur recovery units and fluid-bed installations such as FCCUs and Gasification units).

Refractory linings are used:

- to enclose a space in which processes take place at high temperatures, giving protection to the steel enclosure and the environment (e.g. furnaces, kilns, (fluid-bed) incinerators, reaction chambers, (waste heat) boilers, ducts and steel stacks);
- in installations in which solids or gases are separated or contained at high temperatures (e.g. cyclones, reactors, strippers and regenerators).

The application of an erosion-resistant refractory lining is to be considered if the process conditions inside the equipment are of an extreme nature in terms of highly abrasive flows and solids-containing fluids.

Refractory materials should have:

- resistance to high temperatures and temperature fluctuations;
- chemical/mechanical resistance against those substances which come in contact with the refractory material (e.g. gases, slags, catalyst);
- sufficient mechanical strength to form part of the load-bearing structure and withstand loads during maintenance operations.

The specifications governing refractories greatly depend on the location(s) where they are to be used. A substantial investment in refractory products designed to handle high temperatures and destructive operations can be wasted by inadequate design or careless construction/installation.

2.2 UNSHAPED REFRACTORY MATERIALS

Unshaped refractory materials are mixtures of aggregates and binders, prepared ready for use either directly in the supplied condition or with the addition of a suitable liquid, and having a Pyrometric Cone Equivalent (PCE) of at least 1500 °C.

These mixtures are either dense or insulating refractories. The true porosity for insulating refractories is not less than 45%. The materials shall meet the specifications in Appendix 1.

NOTE: Even though some insulating refractories have a PCE lower than 1500 °C, they are still considered as refractory materials.

Refractory materials for monolithic construction and repairs can be further divided into the following subgroups:

2.2.1 Mouldable refractory materials (mouldables and plastic ramming mixes)

These are materials which are either supplied already moist and ready to use or require moistening into a workable consistency. They are prepared for direct installation as bulk or in cakes.

According to the type of product the binder may be ceramic or chemical (mineral, organic-mineral or organic). They are placed by manual or mechanical ramming or by gunning and hardened by the subsequent application of heat.

2.2.2 Castable refractory materials

These "ready mixed" materials are delivered dry and require mixing with water or other liquids. They are placed by pouring or self-flowing, troweling, vibrating, rodding, tamping or pounding, and harden at ambient temperature.

Castable refractories can be supplied with three main types of bonding:

- a) *Hydraulically bonded castables*, containing cement but without deflocculant;
- b) *Chemically bonded castables*, containing one or more chemical bonds (e.g. phosphate, sodium-silicate or no-cement). Calcium silicate binders shall not be used.
- c) *Deflocculated castables*, hydraulically bonded castables containing cement, a minimum of 2% by weight of ultra-fine particles ($< 1 \mu\text{m}$) and at least one deflocculating agent.

2.2.3 Gunning refractory materials

These are "ready-mixed" mixtures which are non-coherent before use and specially prepared for placing by pneumatic or mechanical projection, and which belong, by virtue of their properties, to one of the two preceding groups (2.1.1 or 2.1.2).

2.3 EROSION-RESISTANT REFRACTORY MATERIALS

Erosion-resistant refractory materials are essentially unshaped refractory materials but the mixtures consist of special, hard and dense aggregates, generally with a high alumina content, in order to improve resistance against abrasion. Consequently they have a high density and poor insulating capabilities.

The selection of a material is amongst other things based on and depends upon the erosive effects mainly caused by the velocity and/or angle of impact of a solids-carrying fluid stream, the solids loading and the nature of the solids.

Depending on the process conditions and the abrasive nature of flows or solids-containing fluids, aggregates will be selected to combat erosion for example: tabular alumina, corundum, silicon-carbide or nitrides, tungsten-carbide, zirconia, etc.

Erosion-resistance is generally classified as:

Extremely erosion resistant	if loss of volume of the specimen is less than	4 cm ³ ;
Extra erosion resistant,	if loss of volume of the specimen is less than	12 cm ³ ;
Moderate erosion resistant,	if loss of volume of the specimen is less than	20 cm ³ ;

NOTE: Specimen and testing according to ASTM C 704.

3.0 QUALITY ASSURANCE/QUALITY CONTROL

The required properties of refractory materials and of the applied refractory are specified in (Appendix 1).

Sampling and testing requirements are specified in (Appendix 2) *and shall be performance in accordance with the relevant ISO standard where available or with the standards shown in Table 3-1 or the equivalent AS, AFNOR, BS or DIN*

Requirements regarding the Applicator's Procedure Qualification are specified in (Appendix 3).

Requirements for the anchor materials are specified in (Appendix 4).

The application of refractory lining is a multi-stage process, covering stages such as material manufacture and selection, anchoring system design, refractory application and curing. Omissions or lack of quality control at any stage could lead to complete failure of the lining. It is therefore of vital importance for a quality control procedure to be established for each refractory lining application, covering all aspects from refractory material selection up to and including final inspection of the lining.

The principal quality control aspects which should be covered as a minimum are as follows:

Refractory material selection	Requirements, inspection and testing
Design	Design requirements for achieving a sound refractory lining
Refractory shipment and storage	Requirements, inspection, certification
Welding of anchoring systems:	
- Surface preparation	Requirements, Inspection
- Weld procedure	Procedure, Certification Inspection, Testing
- Welding	Requirements, Inspection, Testing
Installation/Application equipment	Requirements, Inspection
Installation/Application crew	Applicator's Procedure Qualification
Refractory mixing and installation	Requirements, Inspection, Testing
Curing and drying	Requirements, Inspection
Completed lining	Inspection
Lining repairs	Methods, Requirements, Inspection

The Contractor shall assure that all relevant parties have QC procedures in place which address at least all the steps described above and shall verify their application.

The Contractor shall provide refractory suppliers and applicators with sufficient detailed specifications for each of their specific activities.

In particular, the demarcation of responsibilities and the smooth hand-over between parties involved should be duly covered in the quality control programme.

Lining details not covered by this specification shall be included, if necessary, on drawings or in requisitions. They may also be required to be developed by equipment suppliers.

Any conflicting requirements between documents covering refractory systems shall be thoroughly investigated by the Contractor and referred to the Principal for resolution before bidding or proceeding with the refractory work involved.

Table 3-1 Reference table for testing

Properties of refractory materials	Available test methods according to:			
	ISO	EN	ASTM	JIS
Classifications	1109, 1927 2245, 10080	1094-2 1094-3 ENV 1402-1 12475-1 12475-4	C 155, C 401 C 467, C 673	R 2541 R 2561 R 2641
Refractoriness (PCE)	528, 1146	993-12 993-13	C 24	R 2573
Refractoriness under load	1893	993-8	C 16	R 2209
Creep	3187	993-9	C 546, C 832	
Permanent Linear Change (PLC)	2477 2478	993-10 1094-6	C 113, C 179 C 210, C 605	R 2554 R 2576 R 2654
Thermal expansion			C 832, E228	R 2555 R 2577
Thermal shock resistance		ENV 993-11	C 38, C 1100 C 1171, C 1211	
Thermal conductivity	8894	993-14 993-15	C 201, C 417 C 1113	R 2616 R 2618
Density (bulk, true)	5016, 5017 5018, 8840	993-1 993-2 993-17 993-18 1094-4 1094-7	C 135, C 357 C 493, C 604 C 830, C 914	R 2655 R 2205
Cold crushing strength	8895 10059	993-5 1094-5	C 93, C 133	R 2553 R 2575 R 2653
Modulus of rupture	5013 5014	993-6 993-7	C 133, C 583 C 1161	R 2553 R 2575 R 2653
Abrasion resistance			C 704	
Porosity (apparent, true)	5016 5017	933-1 1094-4	C 493, C 830	R 2205
Young's modulus			C 885, C 1198	
Sieve analysis	565		C 92	R 2552 R 2652
Chemical analysis	10058	955-2 955-5 ENV 955-4	C 560 C 571, C 572, C 573, C 574, C 575, C 576	
Workability, moisture content (ball-in-hand)		prENV 1402-4	C 92, C 181 C 860	R 2553 R 2572 R 2574
Gas permeability	8841	993-4	C 577	
Resistance to slag, liquids, gases, vapours	8890, 12676	993-16	C 288, C 621 C 622, C 768 C 874, C 987	R 2214
Sampling and preparation	5022, 8501 8656	ENV 955-4 ENV 1402-2 prENV 1402-3 prENV 1402-5	C 862, C 865	R 2551 R 2571 R 2651
Installation			C 903, C 1054	
Dimensions	5019, 5417 9205, 12678		C 899, 1095	
Vocabulary	R 836	1094-1 ENV 1402-1	C 71	

NOTE: Testing shall be performed in accordance with the relevant ISO standard where available or with the standards shown above or the equivalent AS, AFNOR, BS or DIN.

4.0 HEALTH, SAFETY AND ENVIRONMENTAL (HSE) ASPECTS

Refractory materials are chemical composites and the mixtures can contain or form hazardous chemical components. These can occur in freshly produced mixtures as well as in use, and during removal of aged materials.

With respect to man-made mineral fibres reference is made to MF 88-0825.

Local HSE regulations shall be met. In the absence of such regulations, PRE/R50 and PRE/R51 shall apply.

5.0 DESIGN

5.1 DESIGN PARAMETERS

Besides operating conditions, the design of linings shall also take into consideration construction and maintenance aspects.

Linings can be single or multi-layered, depending on operating temperatures. Maximum allowable surface temperatures of refractories may, for instance, necessitate the use of a hot face layer backed up by an insulating layer (multiple lining). Lining thicknesses are determined by strength, method of application and insulation properties. Attention shall be paid to proper detailing of joints to compensate for thermal expansion and drying shrinkage.

The traditional method of retaining thin-layer erosion-resistant refractory linings to the substrate has been to use continuous armour such as Hex-metal (normal or off-set) or, for highly curved surfaces, Flexmetal. The use of this type of armour is now discouraged as it tends to be very time consuming in terms of application and maintainability. Instead, Speedcells, Tacko anchors, Hexcels and Y studs should be used because they have equivalent fixing capabilities and are easier to install.

NOTE: Speedcell is a registered trademark of Silicon BV, NL. Tacko is a registered trademark of Plibrico Japan. Hexcel is a registered trademark of Causeway Products Ltd.

Table 5-1 summarises the relation between operating/lining design conditions and refractory characteristics and should be used as guidance in lining design.

For materials specifications and anchor materials, reference is made to Appendices 1 and 4 respectively.

Table 5-1 Lining design factors and the related refractory characteristics

Lining Design Conditions	Lining Design Factors	Refractory Characteristics
Operating temperature	Refractoriness of the materials	Maximum service temperature
	Degree of the crack appearance	Linear change
	Necessity of the expansion joint	Thermal expansion
	Strength of the lining	Modulus of rupture or compressive strength
Outer shell temperature and heat loss	Type and thickness of the lining	Modulus of rupture or compressive strength and thermal conductivity
Operating pressure	Tightness to the shell	Linear change and thermal expansion
	Strength and type of the lining	Modulus of rupture or compressive strength
Frequency and degree of temperature variation. Batch Process	Influence of thermal shock	Spalling resistance
Gas composition	Corrosion of refractory	Corrosion resistance (chem. composition, porosity)
	Influence onto thermal conductivity	Thermal conductivity and porosity
Substances contacting the lining (flue gases, slags, catalysts, etc.)	Corrosion of refractory	Corrosion resistance (chem. composition, porosity)
	Influence due to mechanical forces such as erosion	Erosion resistance and modulus of rupture or compressive strength
Mechanical forces against lining (rotation, vibration, abrasion, etc.)	Resistance against mechanical impact	Modulus of rupture or compressive strength
Furnace weight limit	Refractory weight after installation	Bulk density
Initial heating up schedule	Explosion, spalling, cracks, etc. due to steam pressure generated in the lining during heat-up	Porosity, strength and binder characteristics
Installation method	Adaptability for specified. Installation method	Installation feature

5.2 TYPES OF LINING

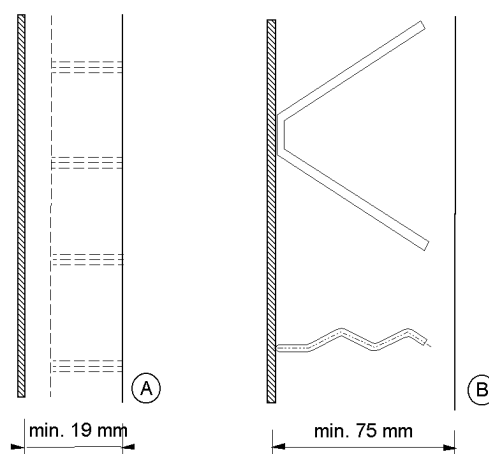
The following types of lining can be identified:

- unshaped refractory ([vibra] cast, self-flow, moulded, rammed, gunned);
- pre-shaped refractory, e.g. bricks, pre-cast monolithic special shapes;
- ceramic fibres.

The types of monolithic refractory lining described below provide a common basis for identification:

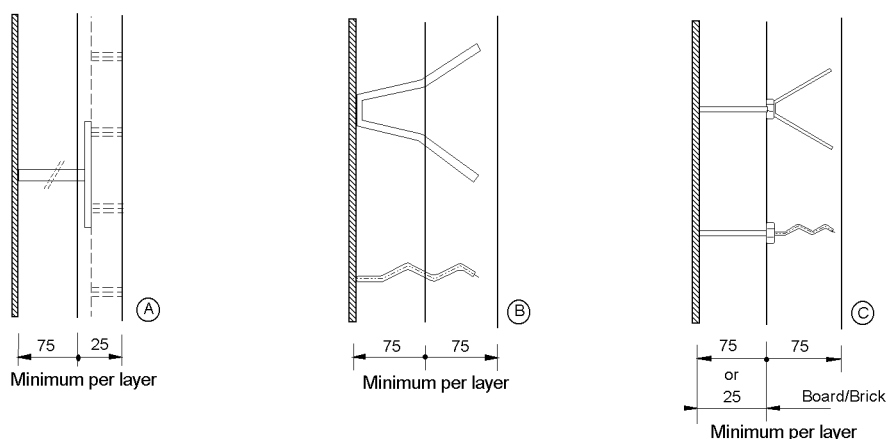
- Single-layer linings, consisting of dense or insulating refractory or ceramic fibres (Figure 5-1);

Figure 5-1 Single Layer Linings



- Multi-layer linings (commonly 2 or 3 layers), consisting of layers of insulating refractory protected by a layer of medium weight or dense refractory (Figure 5-2); Backup layers may consist of either monolithic materials, bricks or fibrous and/or semi-rigid boards.

Figure 5-2 Double Layer Linings



Linings of fired equipment shall be designed so that the outer wall temperature is between 60 °C and 80 °C at the average ambient temperature and wind velocity, which shall be specified by the Principal.

If the fluid in contact with the refractory contains sulphur the first line of defence should be to ensure that the outer wall temperature is well above dew-point (typically 25 °C higher), taking into consideration the level of SO₃ and the internal atmosphere. The process technologist should be consulted for this data. If this margin cannot practically be achieved (e.g. for FCCU regenerators and fired heaters), the wall temperature may be designed at, or even below, dew point if SO₃ vapours migrating through the lining are expected to be largely neutralised by the lime content in the refractory concrete.

5.3 SELECTION OF UNSHAPED REFRACTORY MATERIALS

Selection of the correct refractory material is normally a multi-stage process. Table 5-2 gives guidance for the selection. For material limitations reference is made to (Appendix 1; 4.3).

Proven material properties shall be used in the design and determination of lining thickness and stresses. The chemical and mineralogical composition shall be selected so as to minimise the effect of prolonged exposure in service to reducing atmospheres predominantly composed of hydrocarbons and/or carbon oxides.

For erosion-resistant refractory materials the bond mechanism is a very important factor and their maximum strength shall already be effective at temperatures of approximately 500 °C, yet they shall not react adversely with the aggregate or other raw material should the temperature rise above sintering temperature.

Anchor specifications and methods of installation are described in (Appendix 4).

Table 5-2 Performance review of unshaped refractory materials (not applicable to thin, erosion-resistant refractory linings)

PERFORMANCE PROPERTIES	TYPE OF MATERIAL		
	Mouldable Refractory	Dense Refractory	Insulating Refractory
Bulk Density	High	High	Low
Strength - Impact	Very good	Good	Poor
- Abrasion	Moderate to very good, depends on type of aggregate	Moderate to very good, depends on type of aggregate	Poor
Thermal Shock Resistance	Excellent	Very Good	Good
Thermal insulation	$\frac{1}{2}$ to $\frac{1}{3}$ that of firebrick	$\frac{1}{2}$ to $\frac{1}{3}$ that of firebrick	$\frac{1}{2}$ to $\frac{1}{5}$ that of firebrick
Slag resistance	Increases with Al ₂ O ₃ content	Increases with Al ₂ O ₃ content	Poor
Minimum section thickness	90 -100 mm	75 mm	75 mm
Storage life	6 - 12 months	6 - 12 months	6 - 12 months
Site mixing required	No	Yes	Yes
Installation method	Ramming	Casting, Gunning or Troweling	Casting, Gunning or Troweling
Curing	None required	24 hours	24 hours
Air drying	None required	24 - 72 hours	24 hours
Heat drying 100 -130°C	6 - 8 hours	6 - 8 hours	6 - 8 hours
Initial heating rate	50 °C/h	25 °C/h	25 °C/h
Wall Shuttering	None required	Casting -Yes	Casting -Yes
Roof Shuttering	Yes	Gunning -No	Gunning -No
Installation rate -Walls	Moderate	Casting -Yes	Casting -Yes
-Roofs	Slow	Gunning -No	Gunning No
		Fast	Fast
		Fast	Fast

5.3.1 Mouldable refractory materials

Ramming is a particularly useful method of application for burner walls, burner throats and special roof constructions.

Rammed lining thickness should be between 100 mm and 250 mm. If abrasion, melting or spalling of the surface is expected, additional thickness may be required.

Standard anchors for rammed constructions consist of special shaped ceramic anchor bricks fixed to the casing with cast or welded stainless steel claws. Below 800 °C stainless steel "Bell" type or cast-hooks may be used instead.

5.3.2 Castable and gunned applied refractory materials

The thickness of a single layer in the lining shall be between 75 mm and 150 mm. If abrasion, melting or spalling of the surface is expected, additional thickness may be required.

Erosion-resistant and armoured linings may be thinner, generally 19 mm or more.

The standard for anchorage in dense or insulating refractory concrete linings are V-anchors, double shaped V-anchors or Y-anchors which are corrugated and have equal length prongs suitable either for hand welding or stud welding (Appendix 4).

5.3.3 Stainless steel fibres in applications

Metal fibres manufactured as plain chopped wire shall not be used. If stainless steel fibres are to be included in the refractory lining, this shall be specified in the lining design documentation, but only steel fibres of hooked ended drawn wire fibres or melt-extract types, approx. 25 mm long, shall be used (Appendix 4).

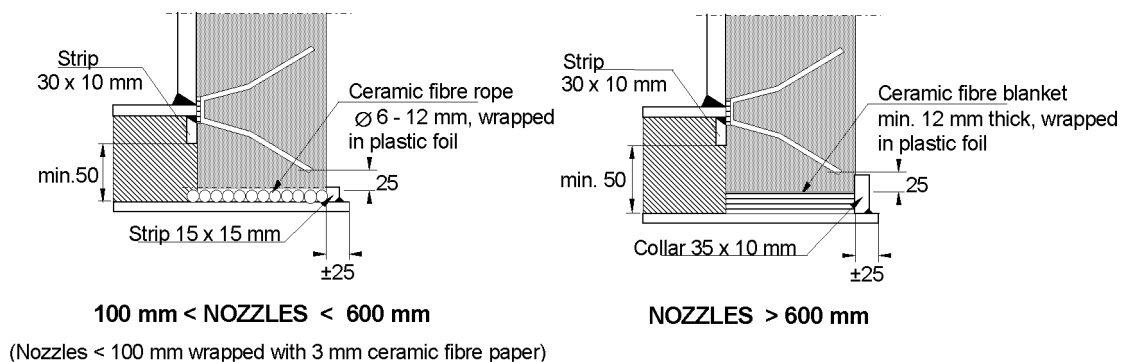
The Contractor shall provide for the Principal's approval, the Supplier's technical details covering bond enhancement, improved lining properties, additional costs and test results to demonstrate the performance of the fibres to be used in the design.

5.4 CERAMIC FIBRE PACKING

The choice between ceramic or anorganic fibres depends on the service temperature and the atmosphere in which the fibres have to function. Anorganic fibres have a temperature of use below 800 °C and a limited chemical resistance.

Ceramic fibre packing is required in expansion joints in order to keep them free of extraneous matter; ceramic fibre packing is required in nozzle neck regions in monolithic linings as typically shown in Figure 5-3 below. See also (8.7.2).

Figure 5-3 Ceramic fibre around nozzles



Fibres shall be packed to a density of 150 kg/m³ (i.e. hand tight). The typical thickness shall be checked against or based on calculation of the resulting differential thermal expansion of the materials and the operating temperature.

Wraps of ceramic fibre shall be securely attached to avoid movements during refractory application. The ceramic fibre composites should not absorb moisture from the applied refractory concrete or packed wool shall not be wetted. Water repellent ceramic fibre materials should be used or the packing should be wrapped in thin plastic foil, e.g. polyethylene foil. The leachable chloride content shall not exceed 10 mg/kg. Chloride-containing foils such as PVC shall not be used.

5.5 PROTRUDING NOZZLES AND COLLARS

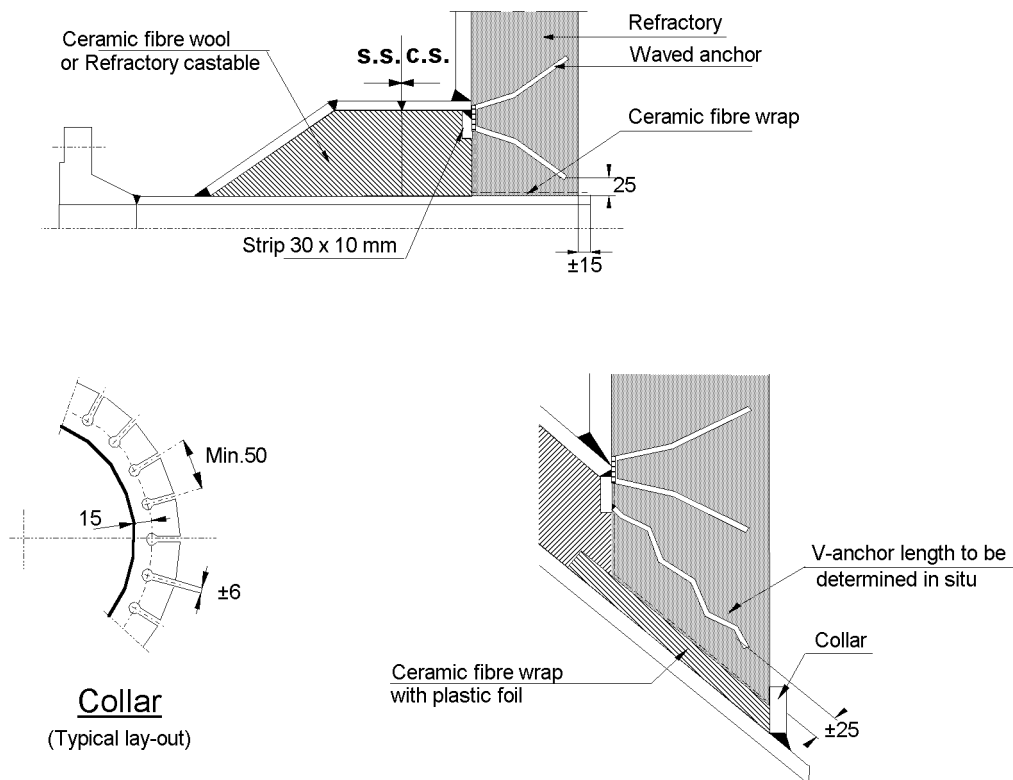
Stainless steel nozzles protruding through (insulating) gunned refractory linings shall be designed according to figures 5-3 and 5-4, e.g. with an internal and externally placed nozzle. The refractory lining is not allowed deeper into the external nozzle than 15 mm, and the remaining space shall then be filled with ceramic fibre wool as shown in (5.4).

Depending on the nozzle's diameter, small strips or collars shall be welded onto the nozzle in front of the lining to prevent the ceramic fibre wraps from shifting forward out of the joint. Collars shall be provided with cuts at regular distances depending on the operating temperature, according to figures 5-3 and 5-4.

If nozzles protrude at an angle through the refractory lining, it shall be ensured that surrounding anchors will adequately support the refractory linings including those nearest to the nozzle. If required, extra anchors shall be fitted or strips shall be welded laterally into the external nozzle, without obstructing expansion allowances, to allow extra anchors to be fitted.

For nozzles which protrude through 'cold wall' linings (e.g. those mainly lined with dense refractory and/or vibrated castables) the ceramic fibre wool stuffing in the external nozzle is not required.

Figure 5-4: Typical nozzle layout



6.0 SUPPLY

6.1 MANUFACTURE OF REFRACTORY MATERIALS

Refractory Materials shall comply with the materials specification in (Appendix 1). Sampling and testing shall be in accordance with (Appendix 2).

6.2 PREPARATIONS FOR SHIPMENT

Each shipment shall be clearly identified according to the requirements of (Appendix 1).

Each pallet or container shall be clearly identified with the batch number and shall be waterproofed.

6.3 REFRACTORY SHIPMENT AND STORAGE

The Manufacturer's instructions for storage, handling and shipment of materials shall be followed. Shipment of refractory should be scheduled so that it will be **installed** within its specified shelf life. Material which has been in store longest shall be used first.

Some Manufacturers, aware of the limited storage problems, have anticipated this by formulating special (unshaped) refractory materials which are supplied with the agents limiting shelf life kept separate from the main aggregates/mixtures. For example, insulating or dense refractory materials are supplied with suitable quantities of the cement separate, so that the proper mixtures can be made when required by adding the necessary amount of potable water.

For ramming mixes this gives a practically unlimited shelf-life with no wastage because only the required quantities are mixed. Potable water is required to make it ready for use and installation.

Refractory materials shall be protected during storage from extreme weather conditions and exposure to sun. In winter, plastic mouldable refractory materials may freeze and must be thawed before use. This is done by removing only the outside packaging, not the foil, and storing them in a warm place. Thawing may take several days; the material is ready when it can easily be shaped by hand.

All hydraulic setting refractory materials shall be protected from moisture absorption during shipment and storage. Air-tight and moisture-tight polythene bags shall then be used.

Refractory that shows signs of having set (hard or unbreakable lumps in the dry mixture) prior to installation shall be rejected and removed from the job site. Left-overs from previous jobs as well as damaged bags shall also be immediately removed from the job site.

7.0 TRANSPORT AND HANDLING OF REFRACTORY LINED EQUIPMENT

Refractory installation in furnaces, process equipment, ducting etc. normally takes place on site. It is advantageous to install refractory linings as one major exercise, which allows sound preparation and proper execution; no extra precautions (e.g. for transport or critical jointing) are then required. However, it is recognised that prefabrication of equipment linings can save both time and money, and can provide acceptable results. In such cases the Contractor shall submit procedures covering the design, manufacture and transportation for approval by the Principal.

The procedures shall address at least the following:

- *Maximum weights and overall dimensions* in view of transport facilities, access to the site/plant, and final erection.
- *The shape* of the equipment and/or pieces of equipment. These should be as "compact" as possible since protuberances, small radii or awkward dimensions may give rise to damage in handling and transport.
- *Binding and securing methods*. Portable sections should be sufficiently bound or secured so that loading and unloading from barges, railroad cars or trucks will not crack the refractory lining. Rigid box forms are preferred. Lighter bindings consisting of sheets and T-sections should only be used together with an adequate (diagonal) bracing. Rigging should therefore be such that flexure and distortion do not have an impact on the integrity of the lining. Stiffening rings or structures should be applied where necessary.
- *Time of moving*. To prevent possible cracking, deformation or distortion of the lining, the equipment should be left idle until the lining has been completely cured and air-dried (and 'water-free'-dried, if this is done at the prefabrication stage rather than at final installation on site). Refractory materials which remain hygroscopic shall be fired.
- *Inspection*. The installed refractory linings shall be inspected prior to shipment and upon arrival at site, see (10).

8.0 INSTALLATION OF UNSHAPED REFRACTORY MATERIALS

Reference is made to BS 7335-1 and BS 7335-2 for working procedures in the installation of refractory linings by casting and/or gunning techniques.

8.1 GENERAL

The Applicator shall have successfully passed the Applicator's Procedure Qualification (APQ) as specified in (Appendix 3), for the installation of the actual lining. An APQ is required for each crew and type of installation .

The Applicator shall verify that the anchorage and cleanliness of the surface to be lined are adequate before starting the lining activity. Requirements for anchor installation are specified in (Appendix 4).

Depending on the abrasive nature of the refractory material, it is recommended to perform the test procedure in (Appendix 3; 5), in order to ensure the proper working/mixing of the refractory material components.

It is recommended that during refractory installation all nozzles or small openings protruding through the refractory lining be closed by means of plugs (of polystyrene, wood, etc.), slightly tapered for easy removal afterwards.

Provisions shall be made to maintain the refractory materials and equipment to be lined at a moderate temperature (10 °C to 25 °C) until curing is complete. The refractory and steel temperatures shall be continuously monitored and recorded until curing is complete. Thereafter, the lining shall be protected from exposure to water, frost, condensation or extreme heat until commissioning of the lining.

Because refractory materials may contain aggressive chemical substances, safety regulations shall be strictly adhered to. When working with the materials, personnel shall wear masks, rubber industrial gloves and eye protection.

8.2 INSTALLATION OF MOULDBLE REFRACTORY MATERIALS

8.2.1 Preparation

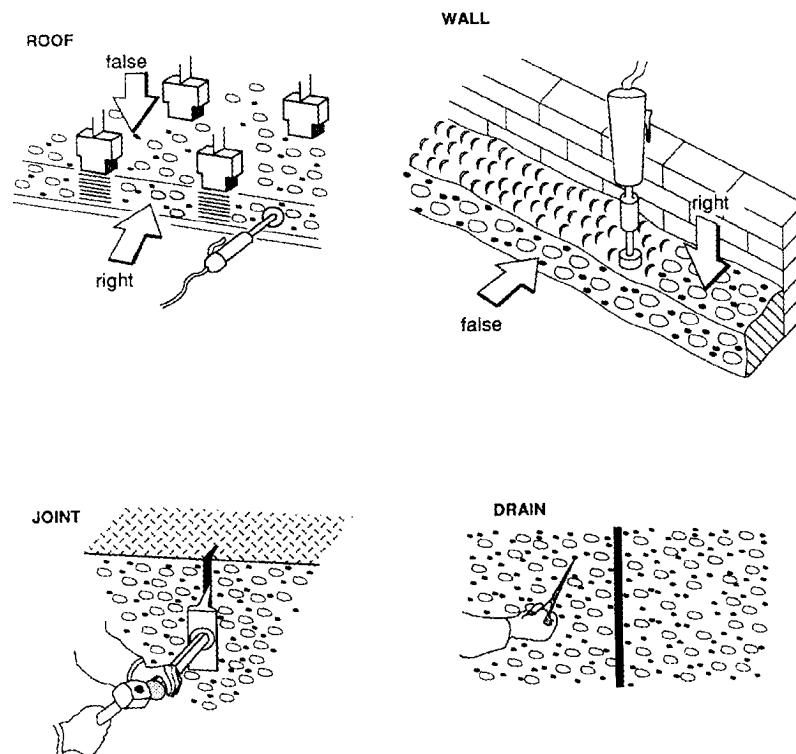
Mouldable, plastic refractory materials are generally supplied ready-to-use, so no special preparations are necessary before the start of the work.

8.2.2 Installation

Mouldable, plastic refractory materials are normally supplied in cartons and packed in foil as cakes, already sliced into approx. 60 - 65 mm thick slices. Otherwise, such slices shall be cut and then broken into small, hand-size pieces. The first layer may be applied as slices; subsequent small pieces shall be placed one after the other and rammed home. A layer thicker than the slice thickness shall not be rammed at one time.

Compacting shall be executed with pneumatic hammers having a frequency of 900 - 1200 blows/min., using as few strokes as possible to avoid the formation of layers.

Figure 8-1 Ramming methods



Ramming shall be in the direction shown in Figure 8-1, gradually shifting the hammer sideways, providing uniform and thorough compacting and knitting all parts monolithically together, leaving no voids. The rammed refractory surface should not be smooth; it should show hammer impressions (which indicates a good knit with the next material). When ramming refractory in overhead positions, before continuing the next layer, a roughened surface is required to achieve an intimate bond.

To save time and material, rammed refractories should be placed behind form work (e.g. shutter boards, forms, etc.) to prevent loss of compacting force, ensure firmness, minimise cracks and ensure the specified lining thickness.

In rammed applications, tile anchors shall be placed after pre-moulding with dummy tiles; alternatively, a tile anchor may be used as a dummy. When fixing the anchor tiles, proper engagement with the anchor jaws and adequate expansion allowance with intersected layers shall be assured.

Only in large applications may the use of plastic, mouldable refractory materials suitable for gunning be considered. These products are supplied in a moist state and gunned by

special rotor gunning machines. Unlike normal gunning, such an application requires dedicated skills and much higher capacity equipment, e.g. rotor gun, air pressure and capacity, etc.

The main advantage is the uniform application that is possible and the re-use of non-polluted, rebound material.

8.2.3 Trimming

After the refractory has been compacted, the surface shall be trimmed with a scraper before the material hardens. In thick applications (over 100 mm), venting holes shall be provided having a diameter of approximately 3 mm, a spacing of 100 mm to 150 mm, about two-thirds depth and pointing slightly upwards, as required.

Uniformly compacted and installed plastic and mouldable refractory materials will often show cracks after drying and firing. Especially in burner walls/throats, score lines 30 mm to 50 mm deep and 2 mm to 3 mm wide (Figure 8-1) shall be used to direct crack formation in a desired direction.

When halting application for short periods, the finished area shall be cut at right angles to the shell and the surface roughened and covered with plastic sheets to ensure that the refractory material remains moist. Longer halts are only permitted if marked-off sections have been finished, adequately secured against collapse or damage, and covered with plastic sheets.