

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUAL

REFRACTORY MATERIALS FOR SULPHUR RECOVERY UNITS (CLAUS AND SCOT)

PTS 64.24.32.11

DECEMBER 2010



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This revision of **PTS 64.24.32.11** – REFRACTORY MATERIALS FOR SULPHUR RECOVERY UNITS (CLAUS AND SCOT) (**DECEMBER 2010, 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 **64.24.32.11 (December 1999)** will be removed from PTS binder / e-repository from herein onwards.

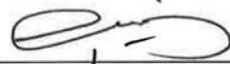
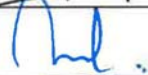
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PREFACE

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The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

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1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the design, installation and inspection of the refractory linings for the equipment of Claus and SCOT sulphur recovery units (SRUs).

Typical refractory (brick) lined equipment is: Claus burner and main reaction chamber, the tube sheet of the waste heat boilers, line burners, reactors, condensers, SCOT burner and reaction chamber, incinerator, flue ducting, stack and sulphur storage pit.

This PTS is applicable to new and existing SRU equipment.

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 the PETRONAS or managed by a Group company, and to Contractors nominated by them.

This PTS is intended for use in Sulphur Recovery Units.

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 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 and abbreviations

Applicator	party that applies the refractory linings specified by the Contractor
bricks	bricks and special shapes
MRC	main reactor chamber
refractory materials, products and linings	dense, insulating, acid-resistant and/or special composite refractory materials
SCOT	Shell Claus Offgas Treating process
WHB	waste heat boiler

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 (7).

1.5 SUMMARY OF MAIN CHANGES

This PTS is a revision of PTS of the same number date December 1999. Other than editorial changes, the following are the major changes to the previous edition.

Section	Changes	Justification
1.6.1	Added new paragraph as follows: "NACE 09358, Corrosion Mitigation and Monitoring in Sulfur Recovery Units, provides details on the process description for Sulphur Recovery Units utilising Claus method."	To inform available reference on process description for Sulphur Recovery Unit.
1.6.2	Added new paragraph on causes of refractory damage as follows: "Besides, Refractory plays a major role in the corrosion control and material selection philosophy of SRUs. Most of refractory failure is normally caused by poor or improper design and/or installation, overheating, thermal shock and chemical attack. Refractory failure can cause severe corrosion attack and equipment damage. Equipment such as reaction furnace, auxiliary burners, converters and condensers are susceptible to this type of damage. Design and selection of a refractory system is based on the following criteria: • Allowable equipment shell metal temperatures. • Equipment outside casing temperature. • Maximum service temperature of the refractory material. • Velocities of flue gases and fluids contained within refractory lining. • Composition of flue gases and fluids. • Abrasive particles in flue gases and fluids. • Casing or shell pressure and pressure fluctuations. • Heat conservation. Refractory protects the tube sheets of the reaction furnace combustion chambers and the shell side of sulfur converters and condensers. A typical shell refractory lining system in the combustion chamber is composed of two layers, alumina firebricks as hot face layer and a back up castable lining. For the other SRU equipment, the typical refractory lining is composed of one layer of castable refractory lining.	Adopt info related to causes of refractory damage and design from NACE 09358, Corrosion Mitigation and Monitoring in Sulfur Recovery Units.

	<i>The combustion chamber tube sheet is protected by two part hexagonal ferrules for the following advantages:</i> <i>• Eliminate the use of stainless steel anchors.</i> <i>• No dry-out of the refractory.</i> <i>• Individual units that can be removed for inspection.</i> <i>• Long-term saving (longer life).</i> <i>• Eliminate tube-to-tube sheet joint failure.</i>	
	<i>Re-word the following phrase:</i> <i>"Circulate steam through the WHB and condensers to above 110 °C; use auxiliary heating equipment for the MRC to raise the temperature to between 110 °C and 180 °C."</i> <i>to;</i> <i>"Steam need to be circulated through the WHB and condensers to achieve temperature above 110°C. Auxiliary heating equipment can be use for the MRC to raise the temperature to between 110 °C and 180 °C."</i>	
7.	<i>Added related standard to this PTS as follow:</i> NACE STANDARD <i>Corrosion mitigation and monitoring in Sulphur Recovery Units</i>	

1.6 PROCESS DESCRIPTION AND BASIC REQUIREMENTS

1.6.1 Process description

SRUs are used to recover sulphur from refinery process gases. Typically, an SRU has a main reaction chamber to burn hydrogen sulphide with air, producing elemental sulphur and sulphur dioxide at a temperature of typically 1250 °C.

The gases are then cooled down to approximately 165 °C using a heat exchanger and condensers recovering most of the sulphur. The higher the initial combustion temperature, the higher the recovery of sulphur.

Thereafter, the gases are fed through catalyst-filled reactors to convert more of the H₂S and SO₂ into sulphur.

At the end of the process the remaining tail gases can either be further treated in a SCOT unit to recover the remaining sulphur or completely burnt in an incinerator before releasing the gases to the atmosphere via a stack.

Generally, the condensing and liquid sulphur flows by gravity from the various condensers into an underground reinforced concrete tank (a sulphur pit), which is lined with acid-resistant refractory, for intermediate storage and for removal of the last traces of H₂S before it is shipped. The collected gas is burnt in an incinerator.

NACE 09358, Corrosion Mitigation and Monitoring in Sulfur Recovery Units, provides details on the process description for Sulphur Recovery Units utilising Claus method.

A typical layout of a Claus unit is shown in Figure 1-1.

1.6.2 Basic requirements for refractory

Refractory linings are required in SRUs to protect the equipment against operational conditions such as high temperature and temperature fluctuations, high sulphur and sulphur dioxide loads, strong oxidising atmospheres and acidic/wet flue gases.

Besides, Refractory plays a major role in the corrosion control and material selection philosophy of SRUs. Most of refractory failure is normally caused by poor or improper design and/or installation, overheating, thermal shock and chemical attack. Refractory failure can cause severe corrosion attack and equipment damage. Equipment such as reaction furnace, auxiliary burners, converters and condensers are susceptible to this type of damage.

Design and selection of a refractory system is based on the following criteria:

- *Allowable equipment shell metal temperatures.*
- *Equipment outside casing temperature.*
- *Maximum service temperature of the refractory material.*
- *Velocities of flue gases and fluids contained within refractory lining.*
- *Composition of flue gases and fluids.*
- *Abrasive particles in flue gases and fluids.*
- *Casing or shell pressure and pressure fluctuations.*
- *Heat conservation.*

Refractory protects the tube sheets of the reaction furnace combustion chambers and the shell side of sulfur converters and condensers. A typical shell refractory lining system in the combustion chamber is composed of two layers, alumina firebricks as hot face layer and a back up castable lining. For the other SRU equipment, the typical refractory lining is composed of one layer of castable refractory lining.

The combustion chamber tube sheet is protected by two part hexagonal ferrules for the following advantages:

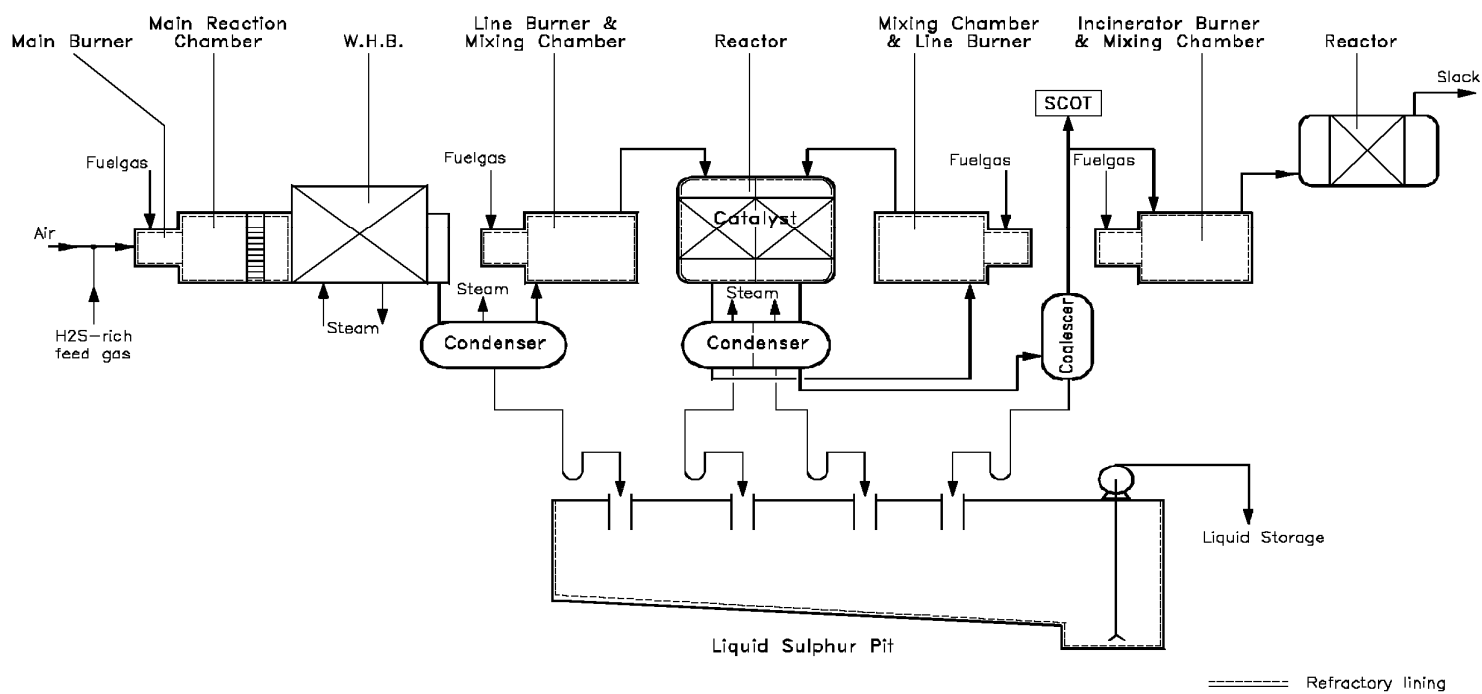
- *Eliminate the use of stainless steel anchors.*
- *No dry-out of the refractory.*
- *Individual units that can be removed for inspection.*
- *Long-term saving (longer life).*
- *Eliminate tube-to-tube sheet joint failure.*

In the various stages of the process, the refractory materials are required to perform different functions.

Refractory brickwork should be selected as the lining material of burners, reaction chambers, mixing chambers and sulphur pits. Monolithic refractory may be applied in reactors and in those areas where brick constructions would be too complicated. For the tube sheet front of the WHB, ceramic ferrules and cast or poured monolithic refractory material should be applied rather than pneumatically or vibrated rammed mixes.

Proprietary systems such as hex-head ferrules, 2-component hexagon ferrules etc. may be used for tube sheet linings.

Figure 1-1 Typical layout of a Claus unit



2. SELECTION OF REFRACTORY LININGS

2.1 GENERAL

With the technical proposals, the Contractor shall submit the thermal design calculations, indicating temperature profiles, refractory thicknesses, anchor systems and the proposed refractory material selection.

Standard shaped refractory bricks should be used, however monolithic refractory materials of equivalent performance may be used. The choice of materials and the method of application shall be in accordance with PTS 44.24.90.31, PTS 64.24.32.30 and the requirements specified below.

2.1.1 Performance conditions

Due to the strong acidic nature of the gases, the backup refractory lining in particular shall be designed to resist attack by any sulphur components penetrating through the linings together with the water vapour which is present due to the process conditions.

This means that the refractory shall:

- be a low-iron grade, due to the strong reducing process conditions and the possible formation of iron sulphide;
- contain low levels of lime in order to avoid calcium sulphate formation; and
- be highly resistant against sulphuric acid and/or ammonium-bisulphate.

At a sufficiently low temperature the sulphur dew-point will be reached resulting in very low pH values. The catalysed conversion of sulphur dioxide into sulphur trioxide may cause dew-point corrosion of the metal vessel. Consequently the lining shall be designed to keep the wall temperature above the dew-point at all times, except during shutdown periods. The design shall prevent the presence of "cold bridges".

Important side reactions during combustion of H_2S are the combustion of ammonia and hydrocarbons:

- Unconverted ammonia may result in the formation of ammonium salts, which will crystallise out at temperatures below 150 °C (e.g. in flue gas ducts or at "cold-bridges"). For complete removal of ammonia the flame temperature must be above 1250 °C.
- Undesired hydrocarbon carry-over may result in runaway temperatures and therefore appropriate control is necessary. Light hydrocarbons burn more rapidly than H_2S and this will influence the stoichiometric combustion process.

2.1.2 Brick linings

Insulating and dense refractory bricks shall be in accordance with PTS 44.24.90.31. Standard arch and key bricks shall be used in circular or curved areas. The use of non-standard bricks shall be avoided as far as possible in order to reduce the quantity of spare parts. An air-setting, high temperature mortar shall be used which shall be non-slagging and chemically compatible with the operational conditions. The mortar grade shall be suitable for at least the rated temperature of the bricks and may be of air or heat setting type depending on the operating temperature. For the insulating back-up brick linings an air setting and chemical bonding mortar should be used.

For refractory brick-lined sulphur pits, an acid resistant mortar (e.g. a halogen-free potassium silicate mortar) shall be used.

2.1.3 Anti-corrosive coating of equipment

The sulphuric acid dew point temperature under normal operating conditions will vary between 150 °C and 200 °C, depending on the ambient conditions. An anti-corrosive coating will not be required if the steel temperature will always be above that temperature but if lower temperatures are anticipated, an internal coating shall be applied that is capable of withstanding the process conditions. If applied, the coating should be permanent, viscous

and non-oxidising (such a coating will normally be bituminous and shall be suitable for a maximum continuous temperature of 205 °C).

2.2 ANCHORS FOR REFRACTORY LININGS

Ceramic anchor bricks shall be used for burner chambers and areas where temperatures exceed maximum metal anchor temperatures. Steel claws may be used for connection to the casing provided the steel grade is suitable for the interface temperatures and is resistant to the chemical load. Allowance shall be made for expansion of the lining.

2.2.1 Metallic anchors

Anchor material dimensions and grades are specified in PTS 44.24.90.31 and PTS 64.24.32.30.

For monolithic linings, V-anchors shall be used for single refractory layers, and shaped V-anchors shall be used for dual-layer refractory linings. The Contractor may propose other suitable anchors for the approval of the Principal.

2.2.2 Metallic anchors for tube sheets

Anchors should only be placed in the centre area of the tube sheet and should not be placed within a one-third radius of the circumference. The placement of anchors shall be governed by the space available between the boiler tube pitch layout and shall be at approximately 100 mm centres, but not exceeding 150 mm.

As far as possible, there shall be at least 10 mm clearance between anchor tips and ferrules. If specified by the Principal, the tips of anchors shall be coated with a thin coat of shellac or equivalent varnish. Thin plastic caps may be used on the tips. Asphalt mastic coatings shall not be used.

No distinction is made between the types of anchors used for cast or rammed applications. The steel grade shall be chosen to suit the governing temperatures.

2.3 LINING DESIGN OF SPECIFIC EQUIPMENT

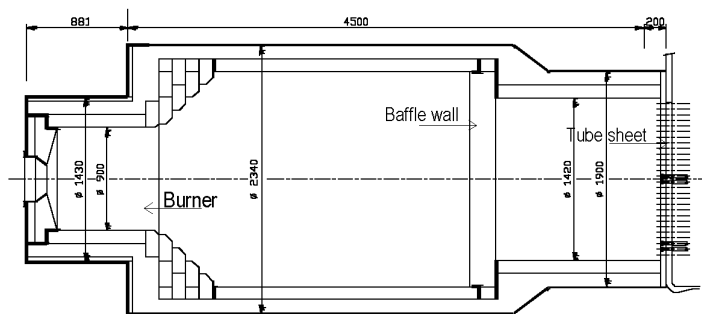
ISO-standardized refractory bricks and sizes should be used. For clarification and typical layout of the refractory linings, reference is made to Appendix 1.

Although PTS 64.24.32.30 and PTS 44.24.90.31 are generally applicable, typical specifications of some refractory materials for the applications mentioned below are listed in Appendix 2 and Appendix 3.

2.3.1 Main reaction chamber and Claus burner

A typical layout of a main reaction chamber is shown in Figure 2-1.

Figure 2-1 Typical layout of a main reaction chamber



2.3.1.1 Claus (LMV) burner

Based on normal operating conditions, the refractory lining of a Claus burner consists of two layers, as shown in Table 2-1.

Table 2-1 Refractory materials for Claus (LMV) burner

Lining	°C	Thickness	Group
Hot face	1600	minimum 115 mm	minimum HA58-HA65, Sillimanite/Andalusite-based
Backup	1400	minimum 115 mm	Group IFB 140 or minimum FC 45
Optional: 2nd back-up	1250	minimum 40 mm, board up to 40 mm	1250 °C Group IFB125 or insulating board (2 ply overlapping)

Note: The above temperatures are typical only.

Brick layers shall be constructed in full stretcher-bond configuration, half-size or three-quarter-size offset.

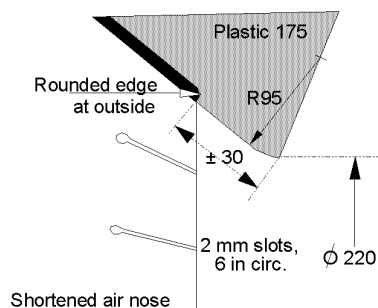
If a ramming or plastic mix will be used as the hot face layer, the upper section shall be adequately supported with ceramic anchor bricks (see Appendix 1).

If insulating board will be used, the width of board sections shall be governed by the radius of the vessel in order to minimise the open spaces behind. Board strips should be placed as 2 layers overlapping each other. Alternatively, the upper two-thirds of the circumference may be fitted with a semi-rigid insulating board.

The burner face should be constructed from specially shaped bricks or prefabricated and prefired blocks.

In order to prevent the burning away or bulging of the heat-resistant steel air-nose, the typical detail shown in Figure 2-2 should be incorporated.

Figure 2-2 Typical air-nose layout



Note: The air nose is normally supplied as an integral part of the burner

2.3.1.2 Main reaction chamber

For normal operational conditions, the refractory lining of the main reaction chamber consists of at least two layers, as shown in Table 2-2.

Table 2-2 Refractory materials for main reaction chamber

Lining	°C	Thickness	Group
Hot face	1600	minimum 115 mm	Minimum HA 55, Sillimanite/Andalusite-based
Backup	1400	minimum 115 mm	Group IFB 140 or minimum FC 45
Optional: 2nd. Backup	850	maximum 25 mm	1050 °C grade insulating board
Baffle wall	1600	230 mm	minimum HA 70, Mullite based (special creep resistant)

NOTE: The above temperatures are typical only.

The connection of the burner to the reaction chamber lining shall be continuous, without a construction joint. The hot face refractory lining shall be designed to prevent burner bricks shifting into the chamber due to thermal cycling.

A radial and longitudinal expansion allowance of at least 80% of the induced expansion movement shall be provided in and between all subsequent refractory layers.

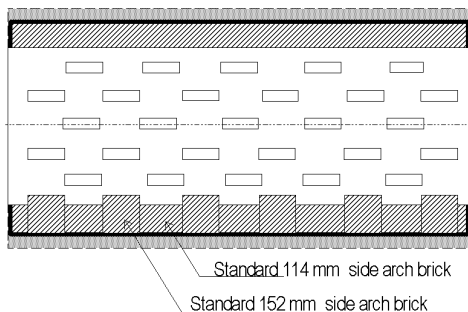
Special care shall be taken at nozzle protrusions to account for refractory expansion and contraction.

Brick layers shall be constructed in full stretcher-bond configuration. Transitions may be constructed in separate rings of either keys or end arches, provided that the diametrical difference is not more than one third of the layer thickness. Larger transitions may be built up with combinations of key and end arch bricks, thus forming the required conical shape.

The optional second backup lining shall have a compressive strength of at least 2 N/mm², or more if needed to withstand the expansion loads induced by the inner refractory lining,.

In case of enhanced ammonia destruction, the typical lining layout shown in Figure 2-3 may be used.

Figure 2-3 Typical layout for enhanced ammonia destruction

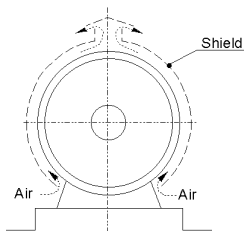


In the hot face layer, individual standard 114 mm side arch bricks shall be replaced with standard 152 mm side arch bricks in both the longitudinal and cross-sectional directions at regular distances, e.g. every second or third brick.

The length of the mixing section, which is commonly the length of the cylindrical section of a main reactor chamber (MRC), shall be as specified by the Principal.

To prevent excessive cooling of non-insulated lined equipment a shield may be fitted around the shell with a suitable gap in between. An exhaust should be placed on the top of the shield to provide adequate ventilation. See Figure 2-4.

Figure 2-4 Protective shield



2.3.1.3 Baffle wall

A baffle wall should be placed in front of the tube sheets to protect them from high temperature excursions, especially when hydrocarbon carry-over and/or direct flame impingement can be expected.

The baffle wall shall have a thickness of 230 mm or 305 mm (i.e. standard brick length) and shall have a free passage area of between 2.5 and 3.5 times the free passage area of the tube sheet. Circular matrix-blocks may be used provided the stability of the wall is assured.

The Contractor shall provide calculations with regard to the intrinsic pressure.

The openings in the baffle wall shall be created by arranging the refractory bricks in chequer configuration and they shall be distributed gradually over the entire baffle wall area. The dimensions depend on the size of standard bricks used, typically a width of one-half brick length and a height of one brick thickness. If the baffle wall is also used as part of a transition from the main chamber into the heat exchanger, the free passage area shall be arranged within the smaller diameter (see shaded area in the cross-section of Figure 2-5).