Engineering Standard

SAES-N-100 30 November 2004

Refractory Systems

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Saudi Aramco DeskTop Standards

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1 Scope

1.1 This standard establishes the minimum mandatory requirements for the design and selection of refractory systems for pressure vessels, boilers, process heaters, heat exchangers, flare tips, sulfur recovery unit equipment and piping.

1.2 Refractory selections shall be limited to castable refractory systems, refractory ceramic fiber (RCF) systems, and fireclay brick systems.

1.3 The requirements detailed in this standard are aimed at standardizing refractory systems used in Saudi Aramco facilities.

1.4 For equipment and refractory systems not covered by this standard, the Saudi Aramco Engineer is to be contacted for guidance in determining the extent to which this standard is applicable.

1.5 This entire standard may be attached to and made a part of purchase orders.

1.6 This standard covers the design requirements and material selection of new and existing refractory systems.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-112	*Meteorological and Seismic Data for Plant Design*
SAES-N-110	*Installation Requirements-Castable Refractories*
SAES-N-120	*Installation Requirements-Extreme Erosion Resistant Refractories*
SAES-N-130	*Installation Requirements-Fireclay Bricks*
SAES-N-140	*Installation Requirements-Refractory Ceramic Fiber*

Saudi Aramco Materials System Specification

32-SAMSS-022	*Manufacture of Components for Flare Systems*

Saudi Aramco Standard Drawings

AB-036395	*Refractory Ceramic Fiber Modulus Installation Details*
AB-036396	*Hexsteel Details*
AC-036397	*Anchoring Details for Castable Refractories*
AB-036400	*Refractory Ceramic Fiber Layered Blanket and Blanket/Boards Installation Details*
AB-036914	*Support Details at Nozzles and Manways for Castable Refractories*

Commentary Note:

The Saudi Aramco Drawings listed above and referenced in this standard shall be used for the generation of detailed refractory system drawings, specific for each application.

3.2 Industry Codes and Standards

American Society for Testing and Materials

ASTM C20	*Standard Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water*

ASTM C24	*Standard Test Method for Pyrometric Cone Equivalent (PCE) of Fireclay and High Alumina Refractory Materials*
ASTM C113	*Standard Test Method for Reheat Change of Refractory Brick*
ASTM C133	*Standard Test Methods for Cold Crushing Strength and Moudulus of Rupture of Refractories*
ASTM C134	*Standard Test Methods for Size, Dimensional Measurement, and Bulk Density of Refractory Brick and Insulating Firebrick*
ASTM C182	*Standard Test Method for Thermal Conductivity of Insulating Firebrick*
ASTM C201	*Standard Test Method for Thermal Conductivity of Refrctories*
ASTM C704	*Standard Test Methods for Abrasion Resistance of Refractory Materials at Room Temperature*

American Petroleum Institute

API STD 560	*Fired Heaters for General Refinery Service*
API RP 936	*Refractory Installation Quality Control Guidelines-Inspection and Testing Monolithic Refractory Linings and Materials*

4 Definitions

Anchors: "V" or "Y" shaped hardware that supports and holds castable refractory in place.

Air Setting: A curing procedure for refractories that develop a strong bond at air ambient temperatures by virtue of chemical reactions within the binder phase that is usually activated by water additions.

Back-up Layer: In a dual-layer lining, the refractory near the shell.

Casing Temperature: The temperature on the outside surfaces of a fired process heater, including radiant/convection sections, hot flue gas and hot air ducts.

Cold Crushing Strength: A measure of a refractory's ability to resist failure under a compressive load as determined at room temperature after drying or firing.

Design Engineer: The contracting company that is responsible for specifying refractory system requirements on data sheets or equipment specifications.

Equipment Manufacturer: The company that is responsible for the fabrication of boilers, process heaters, pressure vessels, heat exchangers, and flare tips to which refractory is installed.

Gas bypassing: The ingress of gases between the refractory lining and the shell of equipment.

Gunniting and Gunning: A method of applying castable refractories using pneumatic force.

Hexsteel and "S" bars: Metal supports for extreme erosion-resistant castable refractory.

Hot face: The layer that is exposed to high temperatures and erosion on top of the back-up layer in a dual layer system.

"K" Factor: Thermal conductivity expressed in W/m °C (Btu-in/ft² °F Hr).

"Kcr" Factor: A factor used for correcting the "K" value of a refractory material in air to the "K" value of the material in a hydrogen atmosphere.

Maximum Continuous Use Temperature: The maximum temperature at which a refractory material can be used continuously.

Maximum Service Temperature: The maximum value of the gas temperature or design temperature of a process stream.

Metal Fibers: Stainless steel needles added to refractory castables to increase strength.

Modulus of Rupture (MOR): A measure of transverse or "cross-breaking" strength of a solid body.

MSDS: Material Safety Data Sheets for refractory material, supplied by the Refractory Manufacturer.

Plastic Refractory: A pre-mixed, phosphate-bonded refractory material.

Refractory Ceramic Fibers (RCF): Fibers made from melting alumina/silicate in an electric furnace.

RCF Manufacturer: The company that manufactures RCF products from raw materials and that designs RCF systems.

Refractory Manufacturer: The company that manufactures refractory products other than RCF from raw materials.

Refractory Systems: A lining system that is designed to resist high temperatures, hot gases, and the action of erosive materials. Components include anchors, reinforcement, vapor barriers, and refractory materials needed for complete installation.

Saudi Aramco Engineer: The Supervisor of the Piping and Valves Unit, Consulting Services Department, Dhahran.

Vapor Barrier: A high-temperature coating that is applied to the shell of equipment to protect the steel from condensing corrosive gases. For RCF, the vapor barrier consists of a metal foil imbedded in RCF and high temperature coating on the shell.

Vibration Casting: Castable installation technique where by refractory is mixed with water and placed in a formed enclosure with the aid of which causes the refractory to become "fluid like" and thereby flow and consolidate to the desired shape of the formed enclosure.

5 Responsibilities

5.1 The Design Engineer is responsible for specifying the minimum lining thickness(s) and the refractory systems that are to be used for specific applications, in accordance with this standard.

5.2 The Equipment Manufacturer is responsible for preparing fully detailed engineering drawings of the refractory system. As a minimum, the drawings shall include anchorage design including spacing and orientation, refractory thicknesses, all materials, surface preparation, and welding details.

5.3 The RCF Manufacturer is responsible for the complete design of an RCF system, in accordance with the specifications supplied by the Design Engineer.

6 Design

6.1 General

6.1.1 The design and selection of a refractory system shall be based on the following considerations:

1) The allowable shell metal temperatures.

2) Outside casing temperatures.

3) Maximum service temperatures.

4) Velocities of flue gases or fluids to which the refractory system is exposed.

5) Composition of flue gases and fluids to which the refractory system is exposed.

6) Abrasive particles in the flue gases and fluids to which the refractory system is exposed.

7) Casing or shell pressure and pressure fluctuations.

8) Optimum heat conservation.

6.1.2 Section 9 of this standard details the minimum design requirements for refractory systems to be specified by the Design Engineer.

6.1.3 The Design Engineer shall review and approve the Equipment Manufacturer's and RCF Manufacturer's drawings, as applicable, for compliance with this standard.

6.1.4 Prior to fabrication and production welding, all welding procedures are to be submitted to the Consulting Service Departments Welding Specialist, or a representative designated by the Consulting Services Department.

6.1.5 The continuous-use temperature of hydraulic-setting castable refractory materials shall be a minimum of 95°C above the maximum service temperature of the equipment for hot face layer. For back-up layer, the continuous-use temperature shall be a minimum of 165°C above the calculated temperature of the back-up layer.

6.1.6 The continuous-use temperature of RCF materials shall be a minimum of 150°C above the maximum service temperature of the equipment.

6.1.7 The increase in the value(s) of thermal conductivity of refractory materials in hydrogen rich gases versus the thermal conductivity in air must be determined by the Design Engineer. The design "K" values specified in paragraph 7 of this standard are values in air and shall be corrected as required based on the percentage of hydrogen in the process gas.

6.1.8 The minimum thermal coefficient correction factors for increased thermal conductivity due to hydrogen pressures shall be determined as follows:

1) For refractory materials with dry bulk densities up to and including 1280 kg/m³ (80 lb/ft³):

Kcr = (% hydrogen X 0.01) + 1.0.

2) For refractory materials with dry bulk densities above 1280 kg/m³ (80 lb/ft³) up to and including dry bulk densities of 1920 kg/m³ (120 lb/ft³):

Kcr = (% hydrogen X 0.0025) + 1.0.

6.2 Minimum Lining Requirements

6.2.1 Single-Layer Castable Linings

1) This type of lining shall consist of a single layer of a castable refractory to provide thermal insulation and/or erosion resistance.

2) Unless otherwise specified in this standard the minimum thickness of a single layer of castable refractory supported by anchors shall be 75 mm.

3) The minimum thickness of an erosion-resistant castable refractory supported by hexsteel or "S" bars shall be 25 mm.

6.2.2 Dual Layer Castable Linings

1) This type of refractory lining shall consist of a layer of an insulating back-up of refractory covered by a layer of a dense refractory on the hot face.

2) The minimum thicknesses of individual castable layers shall be the thicknesses that are specified in 6.2.1.

6.2.3 Extreme Erosion-Resistant Castable Linings

1) This type of extreme erosion-resistant refractory shall not have an erosion loss that exceeds 6 cm³ after firing at 815°C, in accordance with the procedures specified in ASTM C704.

2) This type of extreme erosion-resistant refractory shall not be used for heat insulation.

3) This type of extreme erosion-resistant refractory shall be supported by means of hexsteel or "S" bars.

6.2.4 Extreme Erosion-Resistant Plastic Castable Linings

This type of extreme erosion-resistant refractory shall satisfy the same erosion resistance as required for extreme erosion-resistant castable linings.

6.2.5 Refractory Ceramic Fiber (RCF) Linings

1) This type of refractory system consists of a vapor barrier coating, metal foil, attachment studs, locking devices, and one or more layers of RCF lining.

2) RCF designs shall be limited to, the layered blanket ("wallpaper") type, blanket/board type or the moduled type.

3) The spray-on and wet blanket types of RCF designs shall only be used with the prior approval of the Saudi Aramco Engineer.

4) Layered blanket and blanket/board designs shall be used up to a hot-face temperature of 1090°C.

5) Module designs shall be used when the hot-face temperature is above 1090°C.

6) For layered blanket systems, the top two layers shall have a density of 129 kg/m³ (8 lb/ft³). The bottom layers shall have a density of 97 kg/m³ (6 lb/ft³).

7) For blanket/board systems, the top two layers shall have a density of 129 kg/m³ (8 lb/ft³). The bottom layers shall have a density of 97 kg/m³ (6 lb/ft³).

8) Module construction shall be of the pre-compressed, folded blanket ("soldier") type and shall be manufactured from RCF blanket material of 129 kg/m³ (8 lb/ft³) density prior to compression.

9) Selection of RCF system installations shall be subject to the maximum velocity limits of Table 1.

6.3 Fired Process Heaters

6.3.1 The design temperature of the outside casing surfaces of process fired heaters shall be specified in accordance with API STD 560 and the requirements of this standard.

6.3.2 The outside casing surface design temperatures shall be determined in accordance with the criteria below:

The values of ambient air temperatures shall be in accordance with SAES-A-112, corresponding to the average annual temperature, in still air, for the specific site location.

7 Physical Properties

7.1 General

7.1.1 The use of refractory materials containing asbestos is strictly prohibited.

7.1.2 The Design Engineer shall specify properties that are necessary and sufficient to meet the design requirements of this standard.

7.1.3 The physical properties for castable refractories shall be in accordance with the Saudi Aramco refractory types as specified in this standard.

7.2 Design Data for Castable Refractories

7.2.1 The physical properties to be specified on data sheets and used in design calculations shall be in accordance with values specified in Table 2 of the Data for Castable Refractory.

7.2.2 The Saudi Aramco Materials System (SAMS) catalog provides a complete physical, chemical and service descriptions. These descriptions include maximum continuous use temperature, bulk density, cold crushing strength, modulus of rupture (MOR), linear change, average thermal conductivity, and maximum erosion loss.

7.2.3 The generic descriptions that are detailed in SAMS are to be used for the purchase of all castable refractories, including DC (Direct Charge) orders and all projects. Table 2 lists the SAMS stock numbers (S/N) per Saudi Aramco Refractory Type.

8 Metallic Components

8.1 General

The material selection for anchorage, supports, and metallic fiber reinforcement shall be based on the design hot-face temperature and corrosion resistance.

8.2 Anchors

8.2.1 Anchors for single-layer, castable linings shall be "V" shaped types. Anchors for dual-layer linings for the support of insulating castable refractory shall be "Y" types.

8.2.2 All "V" and "Y" type anchors shall be specified with rubber or plastic caps.

8.2.3 For details of anchors for castable refractory linings, refer to AC-036397.

8.2.4 Individual anchors shall extend a minimum of 75% of the lining thickness. For anchors with unequal leg lengths, the longest leg shall extend a minimum of 75% of the lining thickness.

8.2.5 Anchors for all types of RCF linings shall be welded to equipment.

8.2.6 For details of anchors for RCF linings refer to AB-036395 and AB-036400.

8.3 Hexsteel

8.3.1 Hexsteel shall be the offset-lance, tight-clinched type.

8.3.2 Riveted type hexsteel construction shall only be used on external surfaces of piping that is 12 inch NPS and less.

8.3.3 Hexsteel that is to be supported by "T" studs for two component linings shall be specified as 19 mm, 14 gauge bars.

8.3.4 Hexsteel that is to be welded directly to equipment or piping for the support of 25 mm thick extreme-erosion resistant refractory is to be 25 mm, 14 gauge bars.

8.3.5 All ends of hexsteel are to be welded to edging bars or to adjacent hexsteel. Loose ends are prohibited.

8.3.6 For installation details of hexsteel, refer to AB-036396.

8.4 Nozzles and Manways

Details of nozzle and manway openings in refractory lined pressure vessels and piping shall be in accordance with AB-036914.

8.5 Metallic Fiber Reinforcement (Needles)

8.5.1 Unless otherwise specified in this standard, the density of metallic fiber reinforcement shall be 80 kg/m³ (5 lb./ft³).

8.5.2 Metallic fiber reinforcement shall be manufactured from melt extracted material, approximately 0.5 mm in thickness and approximately 25 mm long.

8.6 "S" Bars

"S" bars shall be used only for the support of extreme erosion-resistant refractory.

9 Refractory Systems

9.1 The refractory systems for specific equipment shall be in accordance with the requirements in Table 3, "Mandatory Refractory Systems".

9.2 The types of castable refractory material that are specified in Table 3 are the Saudi Aramco Refractory Standard Type.

9.3 Complete generic descriptions corresponding to the Saudi Aramco refractory type are detailed in SAMS.

10 Refractory Installation

Refractory systems shall be shop and/or field installed in accordance with the procedures as detailed in the following standards:

SAES-N-110	*Installation Requirements-Castable Refractories*
SAES-N-120	*Installation Requirements-Extreme Erosion Resistant Refractories*
SAES-N-130	*Installation Requirements-Fireclay Bricks*
SAES-N-140	*Installation Requirements-Refractory Ceramic Fiber*

Revision Summary

30 November 2004	Revised the "Next Planned Update". Reaffirmed the contents of the document and reissued with no other changes.

Table 1 – RCF Installation

RCF System	Velocity Limits
Blanket	Less than 9 m/sec
Modules	Up to 18 m/sec
Blanket/Board	Up to 24 m/sec

Table 2 – Design Data for Castable Refractory

	Type of Castable Refractory [1][4]								
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Bulk Density kg/m³ (lb/ft³) Cured and Dried at 815°C	880 (55) [2]	1120 (70) [3]	880 (55) [3]	1280 (80) [3]	2080 (130) [2]	2240 (350) [2]	2720 (170) [2]	2720 (170) [2]	2720 (170) [2]
Cold Crushing Strength kg/cm² (lb/in²) after firing at 815°C	20 (300)	21 (300)	31 (300)	105 (1500)	525 (7500)	350 (5000)	560 (8000)	560 (8000)	350 (5000)
MOR after firing at 815°C kg/cm² (lb/in²)	20 (300)	7 (100)	12 (180)	25 (350)	70 (1000)	98 (1400)	86 (1200)	105 (1500)	70 (1000)
Permanent Linear Change	-1.5%	-0.5%	-1.2%	-0.2%	-0.1%	-0.2%	-0.1%	-0.4%	-0.2%
Thermal Conductivity K value in W/m.°C (Btu-in/ft².F.Hr) at 260°C at 540°C at 815°C	0.21 (1.50) 0.25 (1.70) 0.26 (1.80)	0.18 (1.30) 0.20 (1.40) 0.23 (1.60)	0.35 (2.47) 0.38 (2.63) 0.40 (2.79)	0.40 (2.80) 0.42 (1.95) 0.44 (3.10)	0.24 (1.70) 0.23 (1.65) 0.26 (1.80)	0.95 (6.30) 0.97 (6.90) 1.08 (7.70)	1.56 (10.8) 1.41 (9.8) 1.40 (9.7)	1.61 (11.5) 1.75 (12.5) 1.96 (14.0)	1.61 (11.5) 1.75 (12.5) 1.96 (14.0)
Max. Continuous Use Temperature	1095°C	980°C	1540°C	1200°C	1215°C	1315°C	1700°C	1650°C	1705°C

Notes: [1] Type A Lightweight Insulating Castable (SAMS S/N 32163500)
Type B Lightweight Insulating Low Iron Castable (SAMS S/N 32163510)
Type C Special Lightweight Insulating Low Iron Castable (SAMS S/N 32163520)
Type D Special Medium Weight Insulating Castable (SAMS S/N 32163530)
Type E Medium Weight Erosion Resistant Fused Silica Castable (SAMS S/N 32163540)
Type F Erosion Resistant Insulating Castable (SAMS S/N 32163550)
Type G Hydraulic Setting Erosion Resistant Castable (SAMS S/N 32163560)
Type H Chemical Setting Extreme Erosion Resistant Castable (SAMS S/N 32163570)
Type I Chemical Setting Extreme Erosion Resistant Plastic (SAMS S/N 32163580)

[2] Density with Cast Insulation.

[3] Density with Gunnited Installation.

[4] Variation of ±10% to the values shown in the table are acceptable except for max. continuous use temperature the values shown are the minimum.

Table 3 – Mandatory Refractory Systems

Equipment (Specific Notes)	Operation Condition	Anchors (Material, Sizes and Types)	Refractory Material (Type, Weight % of Needles and Application Method)
FCCU-regenerator shell, heads and plenum chamber	760°C mild erosion oxidizing atmosphere	Type 304H, 6 mm diameter, V-type.	Type-D, medium weight heat insulating, 5% weight Type 304 needles. Gunnited.
FCCU-U-bends, Y-sections, standpipes, other external catalyst transfer lines	510-750°C extreme erosion, oxidizing or reducing atmosphere.	Type 304H, 6 mm diameter V-type.	Type F, erosion resistant, heat insulating, 3-½% weight Type 304 needles. Vibration cast or gunnited (if diameter permits).
FCCU-Regenerator cyclones (1)	760°C extreme erosion, oxidizing atmosphere.	25 mm, 14 gage Type 304H hexsteel, or S bars.	Type H or I, extreme erosion resistant hexsteel or use 3% weight Type-304 needles with S bars. Handpacked.
FCCU-reactor cyclones (1)	550°C extreme erosion, oxidizing atmosphere.	25 mm, 14-gage Type - 304H or 410S hexsteel, or S bars.	Type H or I, extreme erosion resistant 25 mm thick in hexsteel or use 3% weight Type 304 needles in S bars. Handpacked.
FCCU-flue gas lines	760°C oxidizing atmosphere, heavy erosion on elbow and medium erosion on straights.	Type 304, 6 mm diameter, V-type.	Elbows: Type-F, erosion resistant insulating with 3-½% weight Type 304 needles. Gunnited.
FCCU-steam generator	760°C medium erosion, oxidizing atmosphere.	High alumina ceramic ferrules, 125 mm long on inlet tubesheet.	Type E (fused silica) 125 mm thick with 3% weight Type 304 needles. Cast.
FCCU-slide valves (2)	510-760°C severe erosion.	25 mm 13 gage, Type 304H hexsteel.	Type H or I erosion resistant 25 mm thick. Handpacked.
FCCU-seal ports (3) (4)	260-760°C acidic water.	Immersion Lining: a) No anchors required b) V-type anchors. c) Type 304, 6 mm diameter, V-type 75 mm long. Above immersion level: Type 304, 6 mm diameter, V-type, 75 mm long.	Immersion level: a) 3 mm thick vapor barrier. b) 25 mm thick acid resistant refractory. (Saureisen's type 54LW or equal) c) Type E with 3% weight Type 304 needles. Gunnited. Above immersion level: Type E. Gunnited.
Naphtha reformers-reactors wall lining	550°C hydrogen rich atmosphere.	Type 304, 6 mm diameter on a 225 mm square pattern.	Type B (low iron), insulating 100 mm thick, 5% weight Type 304 needles. Shroud supports and vapor stops required to minimize gas bypassing. Gunnited.

Table 3 – Mandatory Refractory Systems (Cont'd)

Equipment (Specific Notes)	Operation Condition	Anchors (Material, Sizes and Types)	Refractory Material (Type, Weight % of Needles and Application Method)
Hydrogen-plants waste heat boilers and transfer lines	840°C hydrogen rich astmosphere.	Two component lining: Type 310, 500 mm long, V-type. Shroud lining: Incoloy 800, shrouds.	Two component lining: 1) Type G, erosion resistant (hot face), 3% weight type 310 needles. Vibration cast or gunnited. 2) Type B, insulating (back up), 5% weight type 304 needles. Vibration cast or gunnited. Shroud lining: Type B (low iron), insulating cast.
Hydrogen-plants furnaces (3)	1090°C low erosion, oxidizing atmosphere.	Walls: sectionally supported wall anchors or manufacturer's design. Ceiling: Manufacturter's design.	Walls RCF. Ceiling: Type A insulating, 5% weight Type 304 needles, gunnited Floor: High duty firebrick (unmortared) (hot face), Type C (back up). Cast.
Sulfur plants-reaction furnace (3) (8) Sulfur plants-thermal oxidizer (3) (9)	1540°C oxidizing atmosphere.	Tubesheet: ceramic ferrules, aluminized anchors or Two Part Hexagonal Ferrule Design Shell & Front end: Type 310, 6 mm diameter, V-type on a 225 mm square pattern.	Tubesheet: Type G, erosion resistant poured or Two Part Hexagonal Ferrule Design Shell & Front end: 90% alumina brick (hot face) with Type C backup. Cast or gunnited.

Table 3 – Mandatory Refractory Systems (Cont'd)

Fired heater radiant section or boiler furnace (3) (5) (6) Fired heater convection section	980 - 1310°C oxidizing atmosphere, mechanical and thermal spalling. Up to 980°C.	Side walls and roof: manufacturer's design Type 310 minimum. Floor: Type 304, 6 mm diameter, V-type on a 225 mm square pattern.	Side walls and roof: 3 mm thick vapor barrier on casing, RCF, type A or type D insulating. Convection section Type A or D insulating, with optional 5% weight Type 304 needles, gunnited or RCF (up to 80 ft/sec gas velocity). Floor: High duty fireclay brick laid dry (hot face). Type A insulating (back up). Cast. Divider walls super duty and high duty fireclay brick laid with air set mortar and expansion joints. Burner blocks - super duty fireclays or formed air set plastics.
Fired heaters and boilers-stacks (3)	315 - 815°C mild erosion, some mechanical and thermal spalling.	Type 304, 3 mm diameter, V-type.	3 mm thick vapor barrier on shell and breaching. Type A or D insulating thickness with optional 5% weight type 304 needles.
Flare tips (6)(7)(8)	315 - 1090°C mild erosion, some mechanical and thermal spalling.	3 mm diameter, V-type anchors or coiled wire (7)	Both sides, one shot lining, Type G, 5% weight needles, Type 310. Cast or gunnited (if accessible).

General Note:

Existing boilers, flare tips, and fired heaters (furnaces) which are refractory-lined with castable type refractories, shall be maintained and repaired using the same refractory systems as specified by the original Equipment Manufacturer. Modifications to original design require Saudi Aramco Engineer's Approval.

Specific Notes:

(1) Hexsteel with Type H refractory shall be used for new installations, and "S" bars with Type I refractory shall be used for maintenance repairs. Materials of hexsteel and "S" bars are to be the same material and Type as the equipment.

(2) Slide valve bodies are to be lined in accordance with the requirements for FCC standpipes.

(3) An asphaltic mastic coating rated to 175°C shall be used for a vapor barrier.

(4) Use a refractory material, which is resistant to acidic water.

(5) The anchor material specified is for clean fuel (less than 5% sulfur). For fuels with a higher sulfur content, refer to AB-036395 and AB-036400.

(6) The anchor materials for flare tips shall be specified in accordance with 32-SAMSS-022.

(7) Unless otherwise specified by the Equipment Manufacturer, flare tips less than 600 mm nominal diameter shall not be internally lined.

(8) The minimum lining thickness shall be 50 mm

(9) Two layer refractory system