



Engineering Standard

SAES-N-100

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Refractory Systems

Document Responsibility: Heat Transfer Equipment Standards Committee

Saudi Aramco DeskTop Standards

Table of Contents

1	Scope.....	2
2	Conflicts and Deviations.....	2
3	References.....	2
4	Definitions.....	4
5	Responsibilities.....	6
6	Design.....	6
7	Physical Properties.....	9
8	Metallic Components.....	10
9	Refractory Systems.....	11
10	Refractory Installation.....	12

1 Scope

- 1.1 This standard establishes the minimum mandatory requirements for the design and selection of refractory systems for pressure vessels, boilers, process fired heaters, heat exchangers, flare tips, sulfur recovery unit equipment and piping.
- 1.2 Refractory selections shall be limited to monolithic refractory systems, refractory ceramic fiber (RCF) systems, and Refractory 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

<u>SAES-N-110</u>	<i>Installation Requirements-Castable Refractories</i>
<u>SAES-N-120</u>	<i>Installation Requirements-Extreme Erosion Resistant Refractories</i>
<u>SAES-N-130</u>	<i>Installation Requirements-Fireclay Bricks</i>
<u>SAES-N-140</u>	<i>Installation Requirements-Refractory Ceramic Fiber</i>

Saudi Aramco Standard Drawings

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

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

<i>ASTM C20</i>	<i>Standard Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water</i>
<i>ASTM C24</i>	<i>Standard Test Method for Pyrometric Cone Equivalent (PCE) of Fireclay and High Alumina Refractory Materials</i>
<i>ASTM C113</i>	<i>Standard Test Method for Reheat Change of Refractory Brick</i>
<i>ASTM C133</i>	<i>Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories</i>
<i>ASTM C134</i>	<i>Standard Test Methods for Size, Dimensional Measurement, and Bulk Density of Refractory</i>

<i>Brick and Insulating Firebrick</i>	
<i>ASTM C182</i>	<i>Standard Test Method for Thermal Conductivity of Insulating Firebrick</i>
<i>ASTM C201</i>	<i>Standard Test Method for Thermal Conductivity of Refractories</i>
<i>ASTM C704</i>	<i>Standard Test Methods for Abrasion Resistance of Refractory Materials at Room Temperature</i>
<i>ASTM C892-10</i>	<i>Standard Specification for High-Temperature Fiber Blanket Thermal Insulation</i>
American Petroleum Institute	
<i>API STD 936</i>	<i>Refractory Installation Quality Control Guidelines- Inspection and Testing Monolithic Refractory Linings and Materials</i>

4 Definitions

Anchors: Hardware that supports and holds refractory in place.

Air Setting: Development of 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 multiple -layer lining, the refractory near the shell.

Casing Temperature: The temperature on the outside surfaces of equipment.

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.

Refractory Designer: The company that is responsible for engineering refractory systems.

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.

Gunning and Guniting: 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 process conditions on top of the back-up layers in a multiple layered 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 refractory material temperature

Metal Fibers: Needles added to refractory castables.

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 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.

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

Refractory Systems: A lining system that is designed to resist process conditions.

Saudi Aramco Engineer: The responsible HTE Standards Committee Chairman.

Vapor Barrier: A metal foil imbedded in RCF systems.

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 Refractory Designer is responsible for engineering the refractory systems that are to be used for specific applications, in accordance with this standard.
- 5.2 The Refractory and RCF Manufacturers are responsible to supply materials in accordance with their compliance data sheets.
- 5.3 The Process Licensor shall comply with Saudi Aramco Refractory Systems as specified in this standard.

6 Design

6.1 General

- 6.1.1 The design and selection of a refractory system shall be based but not limited to the following considerations:
 - 1) The allowable shell metal temperatures.
 - 2) Ambient conditions.
 - 3) Outside casing temperatures.
 - 4) Maximum service temperatures.
 - 5) Velocities of flue gases or fluids to which the refractory system is exposed.
 - 6) Composition of flue gases and fluids to which the refractory system is exposed.
 - 7) Abrasive particles in the flue gases and fluids to which the refractory system is exposed.
 - 8) Casing or shell pressure and pressure fluctuations.
 - 9) Optimum heat conservation.
 - 6.1.2 [Section 9](#) of this standard details the minimum design requirements for refractory systems to be specified by the Refractory Designer.
 - 6.1.3 The Refractory Designer shall review and approve detail drawings.
 - 6.1.4 The maximum service temperature limit of refractory material selected for use shall be a minimum of 95°C above the material layer design hot face temperature.
 - 6.1.5 The increase in the value(s) of thermal conductivity of refractory materials in hydrogen rich gases versus the thermal conductivity in air
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must be determined by the Refractory Designer.

6.1.6 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):

$$K_{cr} = (\% \text{ hydrogen} \times 0.01) + 1.0.$$

- 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):

$$K_{cr} = (\% \text{ hydrogen} \times 0.0025) + 1.0.$$

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 mechanical resistance.
- 2) Unless otherwise specified in this standard, the minimum thickness of a single layer of castable refractory supported by anchors shall be 50 mm.
- 3) The minimum thickness of an erosion-resistant castable refractory supported by hexsteel or “S” bars shall be 19 mm.

6.2.2 Multi-Layer Castable Linings

- 1) This type of refractory lining shall consist of one or more layers of back-up refractory lining covered by a layer of another denser refractory on the hot face to provide thermal insulation and/or mechanical resistance.
- 2) The minimum thicknesses of individual castable layers shall be 75 mm for the hot face layer.

6.2.3 Extreme Erosion-Resistant Refractory Linings

- 1) This type of extreme erosion-resistant refractory shall not have an erosion loss that exceeds 4 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
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for heat insulation.

6.2.5 Refractory Ceramic Fiber (RCF) Linings

- 1) This type of refractory system consists of a coating, vapor barrier, attachment studs, locking devices, and one or more layers of RCF lining as specified in [SAES-N-140](#) paragraph 9.4.
- 2) RCF designs can include 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 not be used above temperature of 982°C.
- 5) Selection of RCF system installations shall be subject to the maximum velocity limits of [Table 1](#).

7 Physical Properties

- 7.1 The use of refractory materials containing asbestos is strictly prohibited.
- 7.2 The Refractory Designer shall specify properties that are necessary and sufficient to meet the design requirements of this standard.
- 7.3 The physical properties for castable refractories shall be in accordance with the Saudi Aramco refractory types as specified in [Table 2](#).

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 multi-layer linings for the support of insulating castable refractory shall be “Y” types. Other special types anchors shall be reviewed by the Saudi Aramco Engineer.
 - 8.2.2 All rod type anchor tips shall be specified with rubber, plastic caps or coated.
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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% into the hot face lining thickness but end of the anchor tip a maximum of 25 mm from the hot face. 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. For details of anchors for RCF linings refer to [AB-036395](#) and [AB-036400](#).

8.3 Hexsteel

8.3.1 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.

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

8.3.3 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)

Metallic fiber reinforcement shall be manufactured from melt extracted material, approximately 0.5 mm in thickness and approximately 25 mm long. For gunning application, metallic fiber shall be approximately 19 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:

<u>SAES-N-110</u>	<i>Installation Requirements-Castable Refractories</i>
<u>SAES-N-120</u>	<i>Installation Requirements-Extreme Erosion Resistant Refractories</i>
<u>SAES-N-130</u>	<i>Installation Requirements-Fireclay Bricks</i>
<u>SAES-N-140</u>	<i>Installation Requirements-Refractory Ceramic Fiber</i>

Revision Summary

15 August 2012 Major revision based on conducted Value Engineering.

Table 1 – RCF Installation

RCF System	Velocity Limits
Layered Blanket	Up to 12 m/sec
Rigidized Blanket/Board/Modules	Up to 24 m/sec

Table 2 – Design Data for Castable Refractory

	Type of Castable Refractory [1][4][5]								
	A	B	C	D	E	F	G	H	I
Bulk Density kg/m ³ (lb/ft ³) Cured and Fired at 815°C	880 (55) [2]	1120 (70) [3]	1000 - 1280 (63) [3]	1280 (80) [3]	2080 (130) [2]	2240 (350) [2]	2720 (170) [2]	2720 (170) [2]	2720 (170) [2]
Cold Crushing Strength kg/cm ² (lb/in ²) after firing at 815°C	14 (200)	21 (300)	31 (450)	105 (1500)	525 (7500)	350 (5000)	560 (8000)	560 (8000)	350 (5000)
MOR after firing at 815°C kg/cm ² (lb/in ²)	3 (50)	7 (100)	12 (180)	25 (350)	70 (1000)	98 (1400)	86 (1200)	105 (1500)	70 (1000)
Permanent Linear Change Dried at 110°C to Fired at 815°C	-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/ft ² .F.Hr) at 260°C	0.21 (1.50)	0.18 (1.30)	0.35 (2.47)	0.40 (2.80)	0.24 (1.70)	0.95 (6.30)	1.56 (10.8)	1.61 (11.5)	1.61 (11.5)
at 540°C	0.25 (1.70)	0.20 (1.40)	0.38 (2.63)	0.42 (1.95)	0.23 (1.65)	0.97 (6.90)	1.41 (9.8)	1.75 (12.5)	1.75 (12.5)
at 815°C	0.26 (1.80)	0.23 (1.60)	0.40 (2.79)	0.44 (3.10)	0.26 (1.80)	1.08 (7.70)	1.40 (9.7)	1.96 (14.0)	1.96 (14.0)

- Notes:**
- [1] Type A Lightweight Insulating Castable (SAMS S/N 32163500)
 - Type B Lightweight Insulating Low Iron (less than 1.5%) Castable (SAMS S/N 32163510)
 - Type C Special Lightweight Insulating Low Iron (less than 1.5%) Castable (SAMS S/N 32163520)
 - Type D Special Medium Weight Insulating Castable (SAMS S/N 32163530)
 - Type E Erosion Resistant Fused Silica Castable (SAMS S/N 32163540)
 - Type F Erosion Resistant Insulating Castable (SAMS S/N 32163550)
 - Type G High Temperature 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.
 - [5] Thermal conductivities shall be adjusted for hydrogen environment.

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, 3% weight Type 304 needles. Gunned.
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, 3½% 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 3½% weight Type 304 needles. Gunned.
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 14 gauge, (1.2 mm) Type 304H hexsteel.	Type H or I erosion resistant 25 mm thick. Handpacked.
FCCU-seal pots (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 coating. b) 25 mm thick acid resistant refractory. (Saureisen's type 54LW or equal) c) Type E with 3% weight Type 304 needles. Gunned. Above immersion level: Type E. Gunned.
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. Shroud supports and vapor stops required to minimize gas bypassing. Gunned.
Hydrogen-plants waste heat boilers and transfer lines	840°C hydrogen rich atmosphere.	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). Vibration cast or gunnited. 2) Type B, insulating (back up). Vibration cast or gunnited. Shroud lining: Type B (low iron), insulating cast.

Equipment (Specific Notes)	Operation Condition	Anchors (Material, Sizes and Types)	Refractory Material (Type, Weight % of Needles and Application Method)
Hydrogen-plants furnaces (3) Note: Using RCF instead of castable at the arc section!!!	1090°C low erosion, oxidizing atmosphere.	Walls: sectionally supported wall anchors or manufacturer's design. Ceiling: Manufacturer'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) (7) Sulfur plants-thermal oxidizer(3)	1700°C reducing atmosphere.	Tubesheet: Two Part Hexagonal Ferrule Design or ceramic ferrules, aluminized anchors Shell & Front end: Type 310, 6 mm diameter, V-type.	Tubesheet: Two Part Hexagonal Ferrule Design or Type G, erosion resistant poured Shell & Front end: 90% alumina brick (hot face) with Type C backup. Cast or gunnited.
Fired heater radiant section or boiler furnace (3) (5) Fired heater convection section	980 - 1310°C oxidizing atmosphere, mechanical and thermal spalling. Up to 980°C.	Side walls and roof: manufacturer's design. Floor: Type 304, 6 mm diameter, V-type on a 225 mm square pattern.	Side walls and roof: 3 mm thick coating on casing, RCF, type A or type D insulating. Convection section Type A or D insulating, 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 - formed of minimum 60% alumina refractory.
Fired heaters and boilers- stacks (3)	315 - 815°C mild erosion, some mechanical and thermal spalling.	Type 304, 5 mm diameter, V-type.	3 mm thick coating on shell and breaching. Type A or D insulating thickness.
Flare tips (5)(6)(7)	315 - 1090°C mild erosion, some mechanical and thermal spalling.	5 mm diameter, V-type anchors or coiled wire (6)	Both sides, one shot lining, Type G, 5% weight needles, Type 310. Cast or gunnited (if accessible).

General Note:

All refractory-lined equipment 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 as coating.
- (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) Unless otherwise specified by the Equipment Manufacturer, flare tips less than 600 mm nominal diameter shall not be internally lined.
- (7) Two layer refractory system.