

# Engineering Standard

SAES-N-120

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## Installation Requirements – Extreme Erosion Resistant Refractories

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## Saudi Aramco DeskTop Standards

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## 1 Scope

- 1.1 This standard covers the requirements for the installation, testing, and inspection of extreme erosion-resistant refractory systems for pressure vessels, cyclones, and piping.
- 1.2 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.
- 1.3 This entire standard may be attached to and made a part of purchase orders.
- 1.4 This standard covers the installation of new extreme erosion-resistant refractory and the repair of existing erosion-resistant refractory.

## 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-N-100](#)

*Refractory Systems*

[SAES-W-010](#)

*Welding Requirements for Pressure Vessels*

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### Saudi Aramco Standard Drawings

[AB-036396](#)

*Hexsteel Details*

[AC-036397](#)

*Anchoring Details for Castable Refractories*

[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.*

### Saudi Aramco Inspection Requirements

*Form 175-328110*

*Inspection Requirements for Refractories*

## 3.2 Industry Codes and Standards

### American Society of Mechanical Engineers

*ASME SEC IX*

*Qualification Standard for Welding & Brazing  
Procedures, Welders, Brazers, and Welding  
and Brazing Operations*

### American Society for Testing and Materials

*ASTM C133*

*Test Methods for Cold Crushing Strength and  
Modulus of Rupture of Refractory Brick and  
Shapes*

*ASTM C134*

*Test Methods for Size and Bulk Density of  
Refractory Brick and Insulating Firebrick*

### Steel Structures Painting Council

*SSPC SP 3*

*Power Tool Cleaned*

*SSPC SP 5*

*White Metal Blasting*

## 4 Definitions

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

**Curing:** The initial ambient temperature holding period following refractory placement. Curing is required to displace all free water prior to dryout.

**Dryout:** The initial controlled heating of refractory linings after curing to temperatures near their service temperature. Dryout is to achieve the required physical properties of the lining at its service temperature.

**Equipment Manufacturer:** The company that is responsible for the fabrication of, pressure vessels, piping and cyclones to which refractory is installed.

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

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

**Refractory Inspector:** The person or company authorized by the Saudi Aramco Inspection Department to inspect refractory installations to the requirements of this standard.

**Refractory Installer:** The company that is responsible for the installation of refractory systems.

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

**Refractory Systems:** A lining system that is designed to 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.

## 5 Responsibilities

- 5.1 The Refractory Installer is responsible for installing refractory systems in accordance with the requirements of this standard and of the specific requirements of the Refractory Manufacturer and the Equipment Manufacturer.
  - 5.2 The Refractory Installer is also responsible for preparing a complete installation procedure in accordance with the requirements of the Refractory Manufacturer, the Equipment Manufacturer, and this standard.
  - 5.3 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.
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## 6 Welding

### 6.1 General

- 6.1.1 All refractory anchor welding shall be in accordance with the requirements of ASME SEC IX, QW-190 for fillet welds or QW-192 for stud welding, as appropriate, and with the requirements of [SAES-W-010](#).
- 6.1.2 All refractory anchors, stud supports, vapor stops, and edging bars for the support of castable refractory materials on pressure vessels and pressure piping are to be made only with the shielded metal arc (SMAW) or gas tungsten arc welding (GTAW) welding processes and shall be welded all around. For anchors, stud welding is an acceptable alternative.
- 6.1.3 The Refractory Installer shall submit Welding Procedure Specifications and Performance Qualification Records to the Refractory Inspector for review and approval prior to welding.
- 6.1.4 The Refractory Installer shall prepare and have available the detailed anchor welding procedure(s) that is to be used. This procedure(s) shall include results of the procedure qualification tests.
- 6.1.5 For anchors welded by SMAW or GTAW, the procedure qualification test shall include tension tests to failure on three anchors that have been welded according to the procedure and on materials that will be used for production welds. One welded anchor shall be bent through 90° and shall show no evidence of failure in the weld.

### 6.2 Welding Details

- 6.2.1 Refractory anchorage, including: anchors studs, supports and similar items shall not be welded within 12.5 mm of circumferential and longitudinal seams of pressure vessels and piping. Anchors of edging bars type shall not be welded less than 50 mm parallel to circumferential or longitudinal seams of pressure vessels and piping.
- 6.2.2 If equipment is to be post weld heat treated, all anchors are to be welded prior to heat treatment.

## 7 Storage and Handling

- 7.1 Refractory materials must be stored in dry weather tight structures at minimum and maximum temperatures of 5-25°C.
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- 7.2 The sealed packages must not be opened until required.
- 7.3 The Refractory Manufacturer's precautions, as specified on the MSDS sheets, must be strictly followed.

## 8 Surface Preparation

- 8.1 All surfaces shall be clean, dry, and, free from oil, grease, weld slag, and mill scale prior to installation of refractory.
- 8.2 Surfaces to be lined shall be white metal blasted in accordance with SSPC SP 5.

## 9 Installation of Hexsteel

- 9.1 Prior to installation, hexsteel shall be rolled or formed concentric with the inside wall of the equipment being lined and in a direction such that the long bars are perpendicular to the flow ("hard way"). Any loosened hexsteel connections shall be welded. Loose hexsteel is not permitted.
- 9.2 Hexsteel shall be installed in accordance with [AB-036396](#).
- 9.3 Hexsteel shall be installed in sections that are as large as possible.
- 9.4 If a small or irregular piece of hexsteel is used, each 0.05 m<sup>2</sup> of this piece shall be welded to a stud, a spacer, or an equipment wall in addition to the adjacent hexsteel.
- 9.5 Longitudinal hexsteel joints shall be offset to avoid continuous seams.
- 9.6 Details of nozzle and manway openings in refractory-lined pressure vessels and piping shall be in accordance with [AB-036914](#).
- 9.7 Anchors and T studs shall be welded in accordance with [AC-036397](#).

## 10 Installation of Refractory

- 10.1 General
    - 10.1.1 All expired material shall not be used.
    - 10.1.2 Packages must not be opened until required.
    - 10.1.3 The water that is used to mix refractory shall comply with the following:
      - (1) The pH shall be within a range of 5.8-8.6.
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(2) The quality of the water shall be within the following limits:

Total Impurity Level	<1000 ppm
Calcium	< 300 ppm
Magnesium	< 300 ppm
Chlorine	< 200 ppm
Iron	< 500 ppm
Sulfur	< 200 ppm

10.1.4 Add-mixtures are not permitted unless approved by Saudi Aramco Engineer.

10.1.5 Except for in-situ patching and repairs, linings shall be installed indoors.

10.1.6 Linings shall not be applied when the temperature of the backing surface exceeds 32°C.

10.1.7 Linings shall be protected against heat induced accelerated setting by maintaining the temperature of the area being lined at 32°C or less during application and for a minimum of 24 hours after application.

10.1.8 In order to achieve the temperature limitations specified in paragraphs 10.1.6 and 10.1.7, the backing surface may be shaded from direct sunlight, applying indoors, or applying refractory at night with proper illumination. Cooling by use of water spraying is prohibited.

10.1.9 The lining material temperature, the backing surface temperature and the atmospheric temperature around the lining during and 48 hours after refractory application must not be below 10°C.

10.1.10 Surfaces are to be kept dry before, during and after installation.

## 10.2 Mixing

10.2.1 The Refractory Manufacturer's mixing instructions, installation instructions, and precautions must be strictly followed.

10.2.2 For mixing, a Hobart, Model #D-33 commercial mixer (or approved equal) with two, 30-quart mixing bowls, a beater and a wire whip (all stainless steel) shall be used.

10.2.3 The quantity to be mixed shall only as much as can be applied within 15 minutes after addition of water. Any mixed refractory that is not

used within 15 minutes shall be discarded. Mixing shall not continue after plastic stage occurs.

- 10.2.4 All equipment, mixing bowls, and tools must be kept clean and free of foreign material and must be cleaned thoroughly after each mix.

### 10.3 Sample Testing Prior to Installation

10.3.1 The following sample testing procedure shall be followed:

- (1) Select three packages at random from each batch or lot, then take 5 lbs of dry and damp material from each batch or lot.
- (2) Reseal the packages that the samples were taken from and mark them "Package Opened for Sampling".
- (3) Mix the three samples of the dry material together to give a uniform mixture. Repeat this procedure with the damp material.
- (4) Take enough of the sample mix to prepare five 50 mm cubes for the cold crushing strength tests.
- (5) Seal the remainder for possible re-test.
- (6) Mix the two materials together, and add the required amount of water (refer to mixing instructions in paragraph above) and cast five cubes.
- (7) Air cure and dryout the samples in accordance with Chapter 11.
- (8) Perform cold-crushing strength and bulk density tests in accordance with ASTM C133 and ASTM C134. The cold-crushing strength and bulk density values are the average result obtained for the five test cubes.
- (9) Any sample that does not meet the minimum published strength or density will be cause for rejection of the complete batch.

### 10.4 Application

10.4.1 The mixed refractory shall be hand packed thoroughly into the hexsteel. Working as needed to fill anchorage holes in hexsteel and to eliminate air bubbles and pockets. After material has been uniformly distributed, a plastic or wooden mallet shall be used to hammer the refractory into the hexsteel in order to eliminate any voids or air pockets and in order to increase the installed density of the material.

10.4.2 Extreme care must be taken to prevent any overlaying of lining material over the hexsteel. The refractory shall be screeded smooth



and flush with the face of the hexsteel. The hexsteel pattern shall be visibly distinguishable after screeding of the lining.

## 10.5 Sample Testing During Application

- 10.5.1 Samples shall be taken during each shift that refractory is being applied. Approximately 8 to 10 samples shall be at the following times during each shift: first batch each shift; last batch each prelunch break; first batch after each prelunch break; last batch before lunch; first batch after lunch; last batch before post lunch break; first batch after post lunch break, and last batch of the shift.
- 10.5.2 All samples shall be in the form of a 50 mm cube.
- 10.5.3 Samples shall be hand packed into molds. A number scratched carefully onto the top of each sample using a small diameter rod. A chart shall be kept showing the following information: sample number, date and time sample was taken, and location where sample was taken.
- 10.5.4 The Refractory Installer shall keep a sketch and log showing clearly where each batch of refractory has been applied and locations where samples were taken.
- 10.5.5 After the 24 hour air set, muffle furnace drying-out temperatures and cycles for samples shall be as follows:
- (1) Heat to 82°C - 93°C and hold for one hour.
  - (2) Heat to 150°C and hold for three hours.
  - (3) Heat to 370°C and hold for four hours.
  - (4) Cool to ambient temperature.
- 10.5.6 After air curing and drying out, two density checks shall be made from each shift's samples in accordance with ASTM C134. Densities shall not be less than 2,400 kg/m<sup>3</sup>.
- 10.5.7 After air curing and drying out, all samples shall be subjected to cold-crushing strength tests in accordance with ASTM C133.
- 10.5.8 All testing is to be carried out by an experienced laboratory.
- 10.5.9 Physical properties shall not be less than 90% of the published values. Refractory that does not meet the required values for properties after dryout shall be replaced at no cost to Saudi Aramco.
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## **11 Curing and Dryout**

### 11.1 General

Refractory shall be air cured and furnace dried out when practical. All conflicts between the procedural requirements of this standard and the Refractory Manufacturer's procedures shall be submitted to the Saudi Aramco Engineer for resolution. The more stringent procedure will govern in such cases. In no case shall this standard be interpreted to relax the requirements of the Refractory Manufacturer's curing and dryout procedures.

### 11.2 Curing

11.2.1 After the lining has been applied, it shall be allowed to air set for a minimum of 48 hours. Lining shall be protected from injury at all times, particularly during the early stages of hardening.

11.2.2 During the 48-hour air set, no water shall be permitted to come into contact with the lining. It shall not be sealed from contact with the atmosphere. Moist curing is not permitted.

### 11.3 Dryout

11.3.1 Adequately calibrated temperature measuring devices shall be installed to monitor the temperature. When dryout is by auxiliary burners, temperature monitoring must be provided on the gas outlet and burner areas.

11.3.2 The maximum dryout temperature must be controlled so as not to reduce the mechanical properties or chemical composition of the materials of the lined equipment.

11.3.3 When dryout is done in a furnace, the temperature measuring devices shall be installed on the refractory side and on the external surfaces of equipment to indicate differentials between metal and refractory temperatures.

11.3.4 Unless otherwise specified by the Refractory Manufacturer, the minimum holding times during dryout shall be 1 hour per 25 mm of refractory thickness.

## **12 Inspection, Testing and Repairs**

### 12.1 General

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- 12.1.1 All inspection shall be carried out in accordance with Saudi Aramco Inspections Requirement Form 175-328110 and the requirements of this standard.
  - 12.1.2 All testing shall be done in accordance with the ASTM standards as referenced in this standard.
  - 12.1.3 All testing shall be conducted by a fully qualified independent laboratory.
- 12.2 Prequalification Testing
- 12.2.1 Procedure and crew prequalification testing shall be carried out by the Refractory Installer prior to any lining.
  - 12.2.2 Documented evidence of the application crew's prequalification shall be made available to the Refractory Inspector prior to production.
  - 12.2.3 Two 600 mm x 600 mm test panels of hexsteel welded to 6 mm thick plate shall be lined with refractory. No production lining shall be installed until these panels have cured for 48 hours and until they have been hammer tested by the Refractory Inspector. The production lining may begin after the Refractory Inspector has approved panels as acceptable. The installer shall suitably identify the qualification test panels and shall store them properly until completion of the refractory application.
  - 12.2.4 In the event that a crew fails to pass this test, the crew and procedure may be changed to improve mixing and application. The above specified prequalifications tests shall then be repeated.
  - 12.2.5 It is the responsibility of the Refractory Installer to verify that the test results conform to the published data.
  - 12.2.6 At the completion of curing and drying, the lining shall be randomly checked for voids or damaged areas. The tests shall be conducted by lightly tapping with a 1-pound hammer.
  - 12.2.7 Any refractory that is found to be defective due to presence of voids, honeycombing, insufficient curing, or construction damage shall be totally removed to the full thickness of the layer and shall be relined to comply with this standard and to meet the satisfaction of the Refractory Inspector.
  - 12.2.8 After at least 48 hours of air curing, the lining shall be visually examined in its entirety for cracks, holidays, and damaged portions. It
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shall be sounded at random by lightly striking the surface with a one-pound ball-peen hammer and by audibly noting the presence of voids and insufficient hardness. If the refractory is questionable or defective, it will produce a dead dull sound. The size of dull sounding areas shall be investigated, and samples test results shall be compared before a decision is made on removal of the refractory. Visual examination and hammer testing shall be repeated after furnace dryout. Hammer testing shall not replace refractory sample testing.

12.2.9 The Refractory Installer's test reports for each batch or lot of refractory supplied and samples test reports shall be furnished to the Refractory Inspector.

### 12.3 Inspection of Hexsteel

All hexsteel welds shall be visually inspected for complete fusion and dimensional conformance with referenced drawings.

### 12.4 Repairs

12.4.1 Any part of the work that is defective due to the presence of voids, honeycombing, insufficient curing, or construction damage shall be removed to the full thickness of the layer or to the base metal.

12.4.2 Removal of defective lining shall be accomplished only through the use of hand tools. Power tools are strictly prohibited because they can cause disintegration of the lining material and anchorage by vibration.

12.4.3 All hexagons adjacent to a repair area must be checked for sound refractory prior to repair. The repair, testing, and inspection procedure will be the same as the procedure used for the original installation.

12.4.4 Refractory lining cracks with a width of 1/8" and larger and a depth of more than 20% of refractory thickness shall be repaired.

### 12.5 Checklist for Extreme Erosion-resistant Refractory Installation

The following is a checklist of activities that shall be used by the Refractory Installer for the installation of extreme erosion-resistant refractory.

#### **Revision Summary**

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

## Checklist for Extreme Erosion-Resistant Refractory Installation

### A. PRIOR TO INSTALLATION

#### Materials

- Verify the types of materials supplied, data sheets and mixing instructions
- Verify availability of MSDS sheets

#### Documents

- Verify approved detail assembly drawings

#### Surface Preparation and Hexsteel

- Surface preparation meets spec.
- Welding procedures

#### Weather Protection

- Verify that materials are properly stored
- Verify that equipment to be lined is prepared for inclement weather conditions

#### Equipment

##### Mixers

- Verify number and type are adequate
- Back up mixer is available
- Location relative to work
- Cleanliness

##### Sample Molds

- Cubes
- Plate for erosion testing

##### Pneumatic Rammers

- Number
- Operating condition

### B. INSTALLATION

#### Condition

- Ambient
- Weather protection

#### Mixing

- Water source
- Storage container
- Cleanliness
- Method of adding water
- Water quality
- Water temperature
- Mixing time
- Mix temperature
- Water percentage

#### Ramming

- Rammer size
- Material fills area
- Technique of stopping ramming relative to anchors

#### Production Sampling

- Proper molds and size
- Frequency of samples
- Sampling procedure matches installation procedure
- Curing
- Handling

#### Dry Out

- Firing equipment
- Burner locations relative to refractory
- Dryout schedule
- Thermocouple locations
- Recording equipment

#### Inspection after Dryout

- Cracking
- Hammer testing