Engineering Standard

SAES-N-120 11 April 2012

Installation Requirements - Extreme Erosion Resistant Refractories

Document Responsibility: Heat Transfer Equipment Standards Committee

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 process equipment 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 new installation of 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-N-110	*(Installation Requirements - Castable Refractories)*

SAES-W-010	*Welding Requirements for Pressure Vessels*

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*
AD-036916	*Refractory Repairs and Terminations*

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 & Modulus of Rupture of Refractory Brick & Shapes*
ASTM C134	*Test Methods for Size and Bulk Density of Refractory Brick and Insulating Firebrick*
ASTM C862	*Practice for Preparing Refractory Concrete*

American Petroleum Institute

API RP 936	*Refractory Installation Quality Control Guidelines-Inspection and Testing Monolithic Refractory Linings and Materials*

Steel Structures Painting Council

SSPC SP 5	*White Metal Blasting*

4 Definitions (Use the definitions of SAES-N-100 and SAES-N-110)

Anchors: Hardware that supports and holds refractory in place.

Curing: The initial ambient temperature holding period following refractory placement.

Dryout: The controlled heating of refractory lining to remove free and chemically bonded water without damaging the lining as per the Refractory Manufacturer procedure.

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.

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.

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.

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

Note: *Saudi Aramco Engineer to review alternatives for erosion resistant anchorage system.*

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^2 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 liquid used to mix refractory shall comply with the manufacturers' guidelines.

10.1.4 Admixtures shall not be used unless approved by the manufacturer and reviewed by Saudi Aramco Engineer.

10.1.5 Linings shall be applied with temperatures of the backing surface between 5°C and 37°C.

10.1.6 Linings must be protected from extreme conditions by maintaining the ambient temperature between 10°C and 32°C for the entire curing period.

10.1.7 In order to achieve the temperature limitations specified in paragraphs 10.1.6 and 10.1.7, installers shall take necessary precautions.

10.1.8 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 type commercial mixer (or equivalent) 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 liquid. 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 (See SAES-N-110 and API RP 936)

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 Section 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/m³.

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.

11 Curing and Dryout

11.1 General

11.1.1 All new linings shall be cured and dried out in accordance with the Refractory Manufacturer's recommendations and the standard procedures as defined in 11.2 and 11.3 below.

11.1.2 During dryout, the equipment must be properly supported to prevent damage to the lining and equipment.

11.2 Curing

11.2.1 If forms were used during placement, these forms shall remain in place for the manufacturer curing period.

11.2.2 During the curing period, the ambient condition shall be maintained between 5°C and 32°C. All exposed lining, except for chemically bonded material, shall be cured by means of a fine water spray, damp cloth, or by the application of a membrane-curing compound.

11.2.3 Lined equipment shall not be moved during curing.

11.3 Dryout

11.3.1 Thermocouples shall be installed 13 mm from the newly installed lining surface to monitor the temperature.

11.3.2 The maximum dryout temperature must be controlled so as to not damage the lining system.

11.3.3 Thermocouples 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 dryout procedure shall be in accordance with Table 5 API RP 936 and Section 11.2.2.

12 Inspection, Testing and Repairs

12.1 General

12.1.1 All inspection shall be carried out in accordance with Saudi Aramco Inspection Requirements 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. (Definition and Responsibility)

12.2 Prequalification Testing (Adopt API RP 936 Prequalification Section)

12.2.1 Refractory Inspector shall monitor crew prequalification testing to be carried out by the Refractory Installer prior to any lining.

This requirement shall apply to gunning, casting or vibration casting a panel to the production thickness.

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 If material is to be gunned, each "nozzleman" shall "gunnite" a test panel that is 1 m x 1 m and that is equal in thickness to the production thickness of lining. The panel position shall be the same as the equipment position during production application (e.g., for a vertical wall application, the test panel shall be in the vertical position).

12.2.4 For vibration cast refractory, a mock up test employing the same prequalified refractory materials, vibrating equipment, and mixing procedure shall be performed prior to placement.

12.2.5 A test panel shall be constructed so that the back may be removed for visual examination of the sample.

12.2.6 The cast or gunned test panels shall be cured for 24 hours and shall then be hammer tested and inspected for correct curing and for voids, cracking, deformation, or honeycombing.

12.2.7 If refractory is metallic-fiber reinforced, the test panel shall be cut into four pieces. The cut edges will be examined for dispersion of metallic fibers, laminations, inclusions, and voids.

12.2.8 Satisfactory results shall qualify both the crew and the application technique.

12.3 Pre-qualification Testing

Both Material Qualification Testing and Applicator Qualification Testing shall be performeed based on API RP 936.

12.4 Production Testing

12.4.1 Production tests shall be conducted during refractory application as specified by the Refractory Inspector. However, two production samples shall be taken at least once per shift or with each change of the "nozzleman" or the installer. One sample shall be sent to a laboratory, and the other sample shall remain on the job site or in the shop for possible future testing.

12.4.2 Samples taken during production shall be tested for cold crushing strength and density in accordance with ASTM C133, ASTM C134

and ASTM C862. Samples from materials being cast shall be taken from the mixer and shall be cast into molds. Samples from refractory being gunned shall be cut from a gunned panel.

12.4.3 Test results shall be compared with the Refractory Manufacturer's product data sheet. Test values that indicate cold crushing strength that is less than 90% of the Refractory Manufacturer's minimum value shall be cause for rejection.

12.4.4 Test values for density shall be within 81 kg/m³ (5 lbs/ft³) of the Refractory Manufacturer's published values. Test values outside this range shall be cause for rejection.

12.4.5 The Refractory Installer shall keep an accurate log of installation so that location of refractory that is presented by the production samples can be determined in case it becomes necessary to remove this refractory.

12.4.6 At the completion of curing and drying, the lining shall be randomly checked for voids or damaged areas. The check shall be conducted by lightly tapping with a 1-pound hammer. It 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.

12.4.7 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.

12.5 Inspection of Anchors and Supports

12.5.1 The strength of each anchor and stud attachment shall be checked with a hammer blow.

12.5.2 All refractory anchors and their attachment welds shall be visually inspected for complete fusion around the base of the anchor and at the "T" stud plate. Any anchor that is not straight or that shows incomplete fusion shall be subjected to a bend test as described in paragraphs 12.5.3 and 12.5.4.

12.5.3 A total of 5% of all anchor welds shall be subjected to a bend test. If any of these samples show cracks or failure at the weld, they shall be rejected. Succeeding and preceding anchors in the same course shall be bend tested until five consecutive welds in each direction are found to be acceptable.

12.5.4 Bend testing shall be accomplished through use of a method that will bend the anchor through approximately 30° and back to the normal position.

12.6 Repairs

12.6.1 The method of repair, curing and retesting shall be in accordance with the original installation procedure. Any part of a single layer lining, except hexmesh or S-bar linings, which is defective, shall be removed for the full thickness of the refractory material. The minimum area removed shall be approximately one square foot. The surface shall be cleaned of all refuse and pre-wet prior to refractory replacement. Refractory Inspector shall determine the extent of the repair.

12.6.2 Where needed, additional refractory anchors shall be installed in accordance with AD-036916.

12.6.3 Refractory that is under repair shall have exposed surfaces of the joint thoroughly wetted with liquid of a quality as outlined in 9.1.7 prior to placement of refractory.

12.6.4 Refractory lining cracks with a width of 3 mm (1/8”) and larger and a depth of more than 20% of refractory thickness shall be repaired as per Refractory Inspector’s recommendation.

12.7 Checklist for Refractory Installation

A checklist of activities that shall be used by the Refractory Installer for the installation of castable refractory.

Revision Summary

11 April 2012	Revised the “Next Planned Update”. Reaffirmed the contents of the document, and reissued with minor changes. Conducted Value Engineering on 20 April 2011.

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
( ) Verify expiration date

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