Engineering Standard

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Installation Requirements - Castable Refractories

Document Responsibility: Heat Transfer Equipment Standards Committee

Saudi Aramco DeskTop Standards

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Primary contact: Mansour, Khalid Mohammad on 966-3-8809575

1 Scope

1.1 This standard establishes the minimum mandatory requirements for installation, testing and inspection of castable refractory systems for pressure vessels, boilers, process fired heaters, heat exchangers, flare tips, sulfur recovery unit 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 installation of new castable refractory and the repair of existing castable 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*

Saudi Aramco Standard Drawings

AB-036396	*Hexsteel Details*
AC-036397	*Anchoring Details for Castable Refractory*
AB-036914	*Support Details at Nozzles and Manways for Castable Refractory*
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	*Refractories: Castable Systems*

3.2 Industry Codes and Standards

American Petroleum Institute

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

American Society of Mechanical Engineers Boiler and Pressure Vessel Codes

ASME SEC IX	*Welding and Brazing Qualifications*

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 C113	*Standard Test Method for Reheat Change of Refractory Brick*
ASTM C133	*Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories*
ASTM C134	*Test Methods for Size and Bulk Density of Refractory Brick and Insulating Firebrick*
ASTM C860	*Standard Practices for Determining and Measuring Consistency of Refractory Concretes*

ASTM C862	*Practice for Preparing Refractory Concrete Specimens by Casting*

Steel Structures Painting Council

SSPC SP 3	*Power Tool Cleaning*
SSPC SP 7	*Brush Blasting*

4 Definitions

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.

Metal Fiber Reinforcement: Needles added to refractory castables.

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 monitor 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 resist process conditions.

Saudi Aramco Engineer: The responsible HTE Standards Committee Chairman.

Coating: A high-temperature coating that is applied to the shell of equipment to protect the steel from condensing corrosive gases.

Vapor Stops: A metal ring that is welded to the shell of equipment to prevent gas bypassing.

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 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 Refractory Designer.

5.2 The Refractory Installer is also responsible for preparing a complete installation procedure in accordance with the requirements of Refractory Designer and this standard.

5.3 The Refractory Designer is responsible for preparing fully detailed construction drawings of the refractory system. As a minimum, the drawings shall include anchorage design including spacing, orientation, and welding details, refractory thickness, all materials, and surface preparation.

5.4 The Refractory Inspector is responsible for monitoting qualification and production work. The Inspector shall not make any engineering decision.

5.5 The Refractory Manufacturer is responsible to supply materials in accordance with their compliance data sheets.

6 Welding

6.1 General

6.1.1 All refractory anchors shall be welded in accordance with welding procedures that are written and qualified in accordance with ASME SEC IX.

6.1.2 All welders for refractory anchors shall be qualified in accordance with the requirements of ASME SEC IX.

6.1.3 All refractory anchorage system for the support of castable refractory materials shall be made only with the shielded metal arc welding

(SMAW) or gas tungsten arc welding (GTAW) welding processes and shall be welded all around. For other welding techniques, it shall be reviewed by Refractory Inspector.

6.1.4 The Refractory Designer shall prepare and have available the detailed anchor welding design.

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 anchors shall not be welded less than 20 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 at Site

7.1 Prior to placement, all refractory shall be protected from water and moisture.

7.2 Materials shall be stored according to the refractory manufacturer's specifications.

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 For application not requiring coating, all metallic surfaces shall be blasted in accordance with Refractory Designer/Manufacturer.

8.3 Surfaces that were previously coated with a vapor barrier or that are heavily corroded shall be brush blasted in accordance with SSPC SP 7.

8.4 Surface cleaning in accordance with SSPC SP 3 shall be acceptable only for limited area such as spot grinding for repairs.

9 Installation

9.1 General

9.1.1 Application of castable refractory shall be by the Refractory Manufacturer's guidelines.

9.1.2 Test panels must be made prior to the application of castable refractory. The testing procedures are to be performed in accordance with the requirements of Section 11.

9.1.3 Surfaces to be lined shall be inspected and approved prior to refractory installation by Refractory Inspector.

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

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

9.1.6 In order to achieve the temperature limitations specified in paragraphs 9.1.4 and 9.1.5, installers shall take necessary precautions.

9.1.7 The liquid used to mix refractory shall comply with the manufacturers' guidelines.

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

9.1.9 The liquid ratios as specified by the Refractory Manufacturer shall be used.

9.1.10 The temperature of the liquid and refractory shall be controlled so that the mixed refractory is between 10°C and 25°C.

9.1.11 Piping and equipment shall be adequately supported to prevent distortion during lining.

9.1.12 Threaded attachments on equipment shall be protected from the lining during application. Protection shall not interfere with the application of the lining.

9.1.13 Equipment nozzle extensions shall be protected to prevent refractory from bonding to them.

9.1.14 All openings in equipment shall be closed by any means that are long enough to extend beyond the final thickness of the lining.

9.1.15 Refractory that shows signs of having set (lumps or hardness throughout) prior to installation shall be rejected. All refractory shall be placed within the Refractory Manufacturer's recommended time limits. Refractory that is not used within specified time limit shall be discarded.

9.1.16 If refractory is installed in piping or vessel sections prior to their being connected by welding a minimum gap of 100 mm at the ends of each section shall be left unlined until the sections have been welded. At least one row of anchors shall be left in each side of the weld and in compliance with paragraph 6.2.1.

9.1.17 The second layer in double-layer linings shall not be applied until the first layer has been cured. Prior to installing the second layer precautions shall be taken to prevent dehydration of this layer.

9.1.18 Linings of each type of refractory shall be installed to the full thickness. If it is necessary to apply lining in sections to achieve full thickness, edges shall be beveled to provide for keying of adjoining sections.

9.2 Installation of Anchors and Supports

9.2.1 Anchors and T studs shall be installed in accordance with AC-036397.

9.2.2 Details of nozzle and manway openings in refractory lined pressure vessels and piping shall be in accordance with AB-036914. (Further review and modification shall be done on this drawing and the previous one above).

9.2.3 Hexsteel shall be installed in accordance with AB-036396.

9.3 Mixing Refractory for Pneumatic Applications

9.3.1 Mixing of refractory materials when required, shall be done in a paddle type mixer.

9.3.2 Only full contents of refractory bags or drums shall be placed in the mixer. Fractional parts of a bag or drum shall not be used.

9.3.3 Dry gunning application method shall be used. Shotcreting application is acceptable but requires approval of Saudi Aramco Engineer.

9.3.4 When fiber reinforcement is added in the field, the fibers shall, be added to the mixer through a wire mesh screen with approximately 12 mm

openings in order to obtain proper fiber distribution.

9.4 Application of Pneumatically Applied Refractory

9.4.1 Only prequalified personnel as per Section 11.2 shall be employed for this work.

9.4.2 Minimum air pressure at the nozzle, consistent with Manufacturer's guidelines, shall be used.

9.4.3 Gun nozzles are to be sized to enable the "nozzleman" to maintain effective control of the application and to allow maneuverability in confined spaces.

9.4.4 The "nozzleman" shall shoot at right angles with a maximum of 30° below horizontal to the surface that is being lined.

9.4.5 The liquid supply and air pressure must remain constant during application.

9.4.6 All rebound material ahead of the "nozzleman" shall be removed to prevent inclusion in the lining.

9.4.7 Under no circumstances shall rebound material be reused.

9.4.8 For a specific band all rebound and loose material shall be removed from the surface before application of the next band is started. No rebound material shall be allowed to accumulate at any point where the lining has already been applied.

9.4.9 In vertical vessels and piping, the lining shall be applied circumferentially in narrow bands. Application is to start at the bottom and is to proceed upwards. The full final thickness shall be permitted to develop in each band before the next band is applied. In no case shall a thickness be applied that is less than the thickness that is specified to allow the applied lining to develop into initial set. The required thickness shall not be built up in layers.

9.4.10 In large vessels and piping, where the height of the bands needed to provide effective bonding would be too small to be practical, multiple crews or sectionalizing may be used.

9.4.11 When guide boards are not used, the edges of each band shall be cut back to the shell with a steel trowelat right angles to the shell, where full thickness of refractory is applied. All refractory beyond this location shall be removed and discarded. The edge of each successive band shall

be securely bonded to the adjacent band before the latter has developed an initial set.

9.4.12 The same general procedures shall be used for horizontal equipment.

9.4.13 The lining shall be screeded to the final required thickness after placement and any deficiencies shall be immediately corrected. Smoothing, trowelling, and floating are not permitted.

9.4.14 When application is interrupted before completion of the entire lining, any refractory section that is applied at a thickness less than the full thickness shall be completely removed by cutting back to the shell with a steel trowel at right angle. And all material beyond the line shall be discarded.

9.4.15 During a period of interruption in application, the lining that has already been applied shall be completed.

9.4.16 Immediately prior to resuming application, the exposed surface of lining to which a bond must be made shall be thoroughly wetted with liquid of a quality as outlined in 9.1.7.

9.4.17 The gunning application downward is not allowed.

9.5 Mixing Refractory for Casting Applications

9.5.1 Mixing of refractory materials shall be done in a paddle type mixer.

9.5.2 Only full contents of refractory bags or drums shall be placed in the mixer. Fractional parts of a bag or drum shall not be used.

9.5.3 When fiber reinforcement is added in the field, the fibers shall, be added to the mixer through a wire mesh screen with approximately 12 mm openings in order to obtain proper fiber distribution.

9.5.4 All refractory shall be placed within the Refractory Manufacturer's recommended time limits. Refractory that is not used within specified time limit shall be discarded.

9.5.5 The amount of liquid shall be as per the Refractory Manufacturer's specified amount.

9.6 Application of Cast Refractory

9.6.1 Forms shall be rigidly constructed and sufficiently tight to prevent excessive leakage. The surfaces that are in contact with the lining shall

be uniform, reasonably smooth, and suitably coated to prevent bonding of refractory to the forms. Forms shall be designed to facilitate their removal without damage to the refractory.

9.6.2 Refractory shall be compacted by spading or vibrating. Compacting shall be done with care to avoid segregation, damage to previously applied portions of the lining, and damage to the equipment.

9.6.3 Work shall not be terminated until a panel or section is complete. When work is resumed, the contact surface of the lining that is in place shall be thoroughly cleaned, roughened, and wetted with liquid of a quality as outlined in 9.1.7. Any excess liquid shall be removed.

9.6.4 Curing shall be carried out whenever the application is interrupted

9.7 Application of Vibration Casting

9.7.1 The refractory materials to be used shall be manufactured specifically for vibration casting.

9.7.2 Additives to promote flow shall not be used in the field.

9.7.3 Forms used shall be rigidly constructed.

10 Curing and Dryout

10.1 General

10.1.1 All new linings shall be cured and dried out in accordance with the Refractory Manufacturer's recommendations and the standard procedures as defined in 10.2 and 10.3 below.

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

10.2 Curing

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

10.2.2 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 onetime application of a membrane-curing compound.

10.2.3 Lined equipment shall not be moved during curing.

10.3 Dryout

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

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

10.3.3 Thermocouples shall be installed on the refractory side and on the external surfaces of equipment to indicate differentials between metal and refractory temperatures.

10.3.4 Unless otherwise specified by the Refractory Manufacturer, the dryout procedure shall be in accordance with Table 5 API 936 and Section 10.2.2.

11 Inspection, Testing and Repairs

11.1 General

11.1.1 All inspection shall be carried out in accordance with Saudi Aramco Inspection Requirement Form 175-328110 and the requirements of this standard.

11.1.2 All testing shall be done in accordance with the ASTM standards as referenced in this standard.

11.1.3 All testing shall be conducted by a fully qualified independent laboratory.

11.2 Prequalification Testing

11.2.1 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.

11.2.2 Documented evidence of the application crew's prequalification shall be made available to the Refractory Inspector prior to production.

11.2.3 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).

11.2.4 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.

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

11.2.6 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.

11.2.7 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.

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

11.3 Pre-qualification Testing

11.3.1 Material Qualification Testing

11.3.2 Applicator Qualification Testing

11.3 Production Testing

11.3.1 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.

11.3.2 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.

11.3.3 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.

11.3.4 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.

11.3.5 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.

11.3.6 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.

11.3.7 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.

11.4 Inspection of Anchors and Supports

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

11.4.2 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 11.4.3 and 11.4.4.

11.4.3 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.

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

11.5 Repairs

11.5.1 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.

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

11.5.3 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.

11.5.4 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.

11.6 Checklist for Refractory Installation

For any castable refractory application the below checklist shall be used by the Refractory Installer to ensure the final lining.

Revision Summary

22 July 2012 Major revision after conducting Value Engineering.

Refractory Installation Checklist

A. **Prior To Installation**

Materials
( ) Verify the types of materials supplied, data sheets and] mixing instructions
( ) Verify availability of MSDS sheets conditions Verify shelf life.

Documents
( ) Verify approved detail drawings

Inspection
( ) Inspect surface preparation
( ) Inspect anchor layout and welding
( ) Review welding procedures

Weather Protection
( ) Verify that materials are properly stored
( ) Verify that equipment to be lined is prepared for inclement weather

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

Gunnite Rig
( ) Number of Rigs
( ) Type
( ) Operating Condition
( ) Cleanliness
( ) Sufficient Hose
( ) Nozzle type

Vibrators
( ) Number of vibrators
( ) Type
( ) Attachment method
( ) Operating condition
( ) Backup

Curing Compound Applicators
( ) Type and size
( ) Cleanliness
( ) Number
( ) Working conditions

Air Compressors
( ) Size
( ) Operating Condition
( ) Contingencies

Sample Molds
( ) Cubes
( ) Gunnited

B. **Installation**

Condition
( ) Ambient
( ) Weather protection

Forming
( ) Strength
( ) Form release
( ) Position of forms for proper thickness
( ) Sealed
( ) Bracing
( ) Secured

Mixing
( ) Water source
( ) Storage container
( ) Introduction of metallic fiber reinforcement
( ) Percentage of metallic fibers
( ) Cleanliness
( ) Method of adding water
( ) Water quality
( ) Water temperature
( ) Mixing time
( ) Mix temperature
( ) Water percentage

Inspection after Dryout
( ) Cracking
( ) hammer testing

Surface Preparation and Anchorage
( ) Surface preparation meets spec
( ) Welding procedures
( ) Anchor welds. Bend tests, cracks
( ) Squaring of old refractory
( ) Anchor layout
( ) Hammer testing

Gunniting
( ) Competence of operator
( ) Pre-qualification of gun operator
( ) Material feed rate
( ) Sampling
( ) Rebound
( ) Curing compound application
( ) Maintenance of gun
( ) Gunning technique
( ) Air pressure
( ) Thickness
( ) Cut back
( ) Construction joints
( ) Prewet

Inspection after Curing
( ) Cracking
( ) Construction joints
( ) Hammer testing

Casting and Vibration Casting
( ) Vibrator frequency
( ) Movement of material
( ) Time between mixing and placement
( ) Mixing per checklist
( ) Forms per checklist
( ) Curing compound applied
( ) Total casting time
( ) Water content
( ) Vibration arrangement
( ) Batch size
( ) Anchor loss

Production Sampling
( ) Proper molds and size
( ) Frequency of samples
( ) Sampling procedure matches installation procedure
( ) Curing
( ) Handling

Dryout
( ) Firing equipment
( ) Burner locations relative to refractory
( ) Dryout schedule
( ) Thermocouple locations
( ) Recording equipment