

# Engineering Standard

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SAES-N-110

30 November 2004

## Installation Requirements – Castable Refractories

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### Heat Transfer Equipment Standards Committee Members

*Al-Anizi, S.S., Chairman*

*Al-Anezi, M.A.*

*Al-Bagawi, J.J.*

*Al-Dossary, M.A.*

*Al-Gahtani, M.S.*

*Al-Hamam, I.H.*

*Al-Rumaih, A.M.*

*Fernandez, G.T.*

*Moore, M.A.*

*Naffa'a, M.Y.*

## Saudi Aramco DeskTop Standards

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## 1 Scope

- 1.1 This standard establishes the minimum mandatory requirements for installation, testing and inspection of hydraulic-setting refractory systems for pressure vessels, boilers, process 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 hydraulic-setting castable refractory and the repair of existing hydraulic-setting 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*

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[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 Requirement

*Form 175-328110                      Refractories: Hydraulic-Setting, Castable Systems*

3.2 Industry Codes and Standards

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 C24                      Standard Test Method for Pyrometric Cone  
Equivalent (PCE) of Fireclay and High  
Alumina Refractory Materials*

*ASTM C113                      Standard Test Method for Reheat Change of  
Refractory Brick*

*ASTM C133                      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*

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*ASTM C862*

*Practice for Preparing Refractory Concrete  
Specimens by Casting*

Steel Structures Painting Council

*SSPC SP 6*

*Commercial Blast Cleaning*

*SSPC SP 7*

*Brush 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 raised to temperatures near their service temperature after curing. 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 process heaters, pressure vessels, heat exchangers, piping and flare tips to which refractory is installed.

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

**Metal Fiber Reinforcement:** Stainless steel needles added to monolithic refractory castables to increase strength.

**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.

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

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

**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 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 thickness, 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, as appropriate, for fillet welds or QW-192 for stud welding, 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 welding (SMAW) or gas tungsten arc welding (GTAW) welding processes and shall be welded all around. For anchors, stud welding is an acceptable alternative.
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- 6.1.3 The Equipment Manufacturer shall submit Welding Procedure Specifications and Performance Qualification Records to the Refractory Inspector for review and approval prior to welding.
- 6.1.4 The Equipment Manufacturer 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 at Site

- 7.1 Prior to placement, all refractory shall be protected from water and moisture.
- 7.2 Materials shall be stored off the ground and covered with tarps to protect against water or moisture damage.
- 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 Prior to the application of refractory, all metallic surfaces shall be grit-blasted in accordance with SSPC SP 6, "Commercial Blast Clean".
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- 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, "Brush Blasting".

## 9 Installation

### 9.1 General

- 9.1.1 Application of hydraulic-setting refractory shall be by gunning, casting, or vibration casting.
- 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 paragraph 11.
- 9.1.3 Surfaces to be lined shall be inspected prior to refractory installation. Lining shall not be applied without prior approval of Saudi Aramco's authorized Refractory Inspector.
- 9.1.4 Linings shall not be applied when the temperature of the backing surface exceeds 32°C.
- 9.1.5 Linings must be protected from heat-induced accelerated setting by maintaining the temperature of the backing surface, a maximum of 32°C for a minimum of 24 hours after installation.
- 9.1.6 In order to achieve the temperature limitations specified in paragraphs 9.1.4 and 9.1.5, the backing surface may be shaded from direct sunlight, the refractory lining may be applied indoors, or apply refractory lining at night with proper illumination. Cooling by use of water spraying is prohibited.
- 9.1.7 Linings shall not be applied in freezing weather unless all materials are kept above 10°C during the lining application and for a period 24 hours after the lining application.
- 9.1.8 Linings shall be applied in a manner that will ensure minimal shrinkage. All cracks are subject to repairs.
- 9.1.9 The water used to mix refractory shall comply with the following:
- (1) The pH shall be within a range of 5.8-8.6.
  - (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

- 9.1.10 Admixtures shall not be used.
- 9.1.11 The water ratios as specified by the Refractory Manufacturer shall be used.
- 9.1.12 The temperature of the water and refractory shall be controlled so that the mixed refractory is between 10°C and 32°C.
- 9.1.13 Additives to linings shall not be used unless approved by Saudi Aramco Engineer.
- 9.1.14 Piping and equipment shall be adequately supported to prevent distortion during lining.
- 9.1.15 Threaded attachments on equipment shall be protected from the lining during application. Protection shall not interfere with the application of the lining.
- 9.1.16 Equipment nozzle extensions shall be coated with grease to prevent refractory from bonding to them.
- 9.1.17 All openings in equipment shall be closed by means of tapered hardwood plugs or sheet metal sleeves that are long enough to extend beyond the final thickness of the lining. These plugs or sleeves shall be coated with grease, shall be snugly fitted into openings, and shall not be removed until the refractory has set.
- 9.1.18 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.
- 9.1.19 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.
- 9.1.20 The second layer in double-layer linings shall not be applied until the first layer has been cured for a minimum of 24 hours. Immediately prior to applying the second layer, the first layer must be thoroughly wetted with water of a quality as outlined in 9.1.9.
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9.1.21 Linings of each type of refractory shall be installed to the full thickness in a single application and shall not be built up in layers. If it is necessary to apply lining in sections to achieve full thickness in single application, edge forms shall be beveled 10° to provide for keying of adjoining sections. Appropriate provisions shall be made for construction joints.

## 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](#).

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 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. Wet gunning application requires approval of Saudi Aramco Engineer.

9.3.4 When fiber reinforcement is used, the fibers shall be added to the mixer through a wire mesh screen approximately 12 mm openings to obtain proper fiber distribution.

9.3.5 The refractory shall be used within 15 minutes of mixing.

## 9.4 Application of Pneumatically Applied Refractory

9.4.1 Only qualified personnel who are thoroughly experienced with pneumatic application of refractory lining shall be employed for this work.

9.4.2 Minimum air pressure, consistent with adequate compaction of the refractory, shall be used. The air pressure is to be determined by test prior to application.

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 to the surface that is being lined.
  - 9.4.5 The water 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 The top of each band shall be cut back to the shell with a steel trowel. The cut shall be made at right angles to the shell, at a location where the full thickness of the refractory has been applied. All refractory above this location shall be removed and discarded. The bottom of each successive band shall be securely bonded to the top of the preceding band before the latter has developed an initial set.
  - 9.4.12 The same general procedures shall be used for horizontal equipment with the exception that horizontal equipment can be rotated for either casting or gunning in the flat position.
  - 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 that is applied at a thickness less than the full thickness shall be removed by cutting back to the shell with a steel trowel. The cut
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shall be beveled into the adjacent lining by approximately 10° and all material above the line shall be discarded.

9.4.15 During a period of interruption in application, the curing of the lining that has already been applied may 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 water of a quality as outlined in 9.1.9.

## 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 used, the fibers shall, in order to obtain proper fiber distribution, be added to the mixer through a wire mesh screen with approximately 12 mm openings.

9.5.4 The quantity of refractory material that is mixed in one mixing shall not be greater than the quantity that can be placed prior to initial set or 15 minutes after addition of water, whichever is shorter. Materials not used within this time shall be discarded. Precautions shall be made to prevent the separation of aggregates and cement prior to placement.

9.5.5 The amount of water that is used shall be the minimum amount that will give the proper consistency for placement. This amount is not to exceed the Refractory Manufacturer's specified amount.

9.5.6 The "ball in hand" test described in ASTM C860 shall be used to determine the correct consistency.

## 9.6 Application of Cast Refractory

9.6.1 Only qualified personnel who are thoroughly experienced with cast application of refractory lining shall be employed for this work.

9.6.2 Forms shall be rigidly constructed and sufficiently tight to prevent excessive leakage. The surface 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.

- 9.6.3 Refractory shall be applied in a manner that will minimize section segregation.
- 9.6.4 Refractory shall be compacted by spading or vibrating. Compacting shall be done with care to avoid segregation of materials, damage to previously applied portions of the lining, or damage to the equipment.
- 9.6.5 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 water of a quality as outlined in 9.1.9. Any excess water shall be removed.
- 9.6.6 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 and shall be fine grain and evenly distributed.
  - 9.7.2 Additives used to promote flow shall be used in strict accordance with the Refractory Manufacturer's instructions.
  - 9.7.3 Forms used shall be made of steel sheet and 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/or 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 Castables shall be cured after an initial set of 1 to 3 hours. All exposed lining shall be cured by means of a fine water spray or by the application of a membrane-curing compound. If a water spray is used, the surface shall be kept damp for a minimum of 24 hours.
    - 10.2.2 If forms were used during placement, these forms shall remain in place for a minimum of 24 hours.
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10.2.3 During the curing period, the temperature of the shell and refractory material shall be maintained between 4°C and 32°C.

10.2.4 Lined equipment shall not be moved during curing.

### 10.3 Dryout

10.3.1 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.

10.3.2 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.

10.3.3 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.

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

## 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 Procedure and crew prequalification testing shall 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 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.
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- 11.3.4 Test values for density shall be within 81 kg/m<sup>3</sup> (5 lbs/ft<sup>3</sup>) 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 shows 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.
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## 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. Saudi Aramco 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 water of a quality as outlined in 9.1.9 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.

## 11.6 Checklist for Refractory Installation

Figure 1 is a checklist of activities that shall be used by the Refractory Installer for the installation of castable refractory.

### Revision Summary

30 November, 2004	Revised the "Next Planned Update". Reaffirmed the contents of the document and reissued with no other changes.
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## Figure 1 – Refractory Installation Checklist

### 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 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 conditions

#### 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
- Gunned

### 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

#### Gunning

- 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