PIP RFSF2000
Ceramic Fiber Refractory Installation Specification
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1. **Scope**

This Practice provides procedures for installing ceramic fiber refractory linings in fired heaters and other process equipment. Installation includes steel surface preparation and coating, ceramic fiber installation, and repair of ceramic fiber linings. Ceramic fiber refractories in this Practice include:

a. Refractory ceramic fiber  
b. Bio-soluble ceramic fiber

This Practice does not include installation of mineral wool, fiberglass, or other non-refractory fiber insulation materials.

2. **References**

Applicable parts of the following Practices and industry codes and standards shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 **Process Industry Practices (PIP)**

- PIP CTSL1000 - Application of Internal Linings  
- PIP RFIA1000 - Refractory Anchor and Accessory Installation Details  
- PIP RFSA1000 - Refractory Anchor and Accessory Specification  
- PIP RFSF1000 - Ceramic Fiber Refractory Material Specification  
- PIP RFSM2000 - Installation of Monolithic Refractories  
- PIP RFTA1000 - Refractory Anchor and Accessory Installation Qualification, Inspection, and Testing  
- PIP RFTF1000 - Ceramic Fiber Refractory Installation Qualification, Inspection, and Testing  
- PIP RFTM1000 - Monolithic Refractory Installation Qualification, Inspection, and Testing

2.2 **Industry Codes and Standards**

American Petroleum Institute (API)

- API Standard 560 - Fired Heaters for General Refinery Service

3. **Definitions**

*back-up*: The layer or layers of insulating material that are located between the hot face layer and the casing or shell

*batten strip*: Folded and compressed strip of ceramic fiber blanket placed in gaps between two courses of ceramic fiber refractory modules

*bio-soluble ceramic fiber*: Ceramic fiber refractory material that contains greater than 18 weight percent CaO+MgO, dissolves in bodily fluids and is in accordance with the European Union’s regulatory health, safety, and environmental requirements for bio-solubility. This is also known as low bio-persistence fiber or alkaline earth silicate (AES) fiber.

*blanket*: Flexible ceramic fibrous insulating material of determinate dimension and without binder

*board*: Substantially rigid flat sheet developed from bulk fiber and binder
bulk fiber: Loose form of ceramic fiber refractory

butt joint: Ceramic fiber joint where edges of adjacent blankets meet with or without compression or boards meet without compression

ceramic fiber refractory: Refractory made of either refractory ceramic fiber or bio-soluble ceramic fiber materials

compliance data sheet: Data sheet provided by the manufacturer listing physical and chemical property values that the manufacturer certifies or guarantees will be met by each sample tested using the specified procedures in Appendix A of PIP RFSF1000

continuous use limit temperature: A temperature provided by the manufacture for long-term use, based upon a defined amount of shrinkage in a defined period

dge-grain: The orientation of a ceramic fiber refractory system in which strips of ceramic fiber blanket or felt are oriented perpendicular to the plane of the surface casing

felt: Flexible sheet product formed from bulk ceramic fiber bonded with an organic binder and pressed into shape

hot face: The refractory surface exposed to the process temperature

installer: Party responsible for installing the ceramic fiber refractory lining

interface: The common boundary between the surfaces of two layers

lock washers: Washers used in conjunction with pin-studs to hold blanket lining into place

manufacturer: The party or parties that produce(s) the ceramic fiber refractory material and/or the final product form (e.g., blanket, modules, etc)

mat: Blanket fabricated without needling. It typically does not contain a binder.

module: A prefabricated ceramic fiber refractory unit that can be installed as an individual lining block

overlap: A construction method in which the edge of a blanket is lapped over the edge of an adjacent blanket and shares a common pin-stud and lock-washer. Also known as overlap joint. Where used in vertical strips it may be referred to as wallpaper construction.

needled: Interlacing (i.e., weaving) of the fibers when fabricating blanket ceramic fiber refractory. This technique greatly improves the durability of the blanket.

owner: Party who owns the facility wherein the refractory lining is to be used

paper: A flexible, flat, sheet developed from chopped ceramic fiber refractory mixed with an organic binder and formed into thin sheets on a paper roll machine

pin-studs: Metallic flat studs with notches used as anchors to hold blanket lining by locking with a lock washer

purchaser: Party who awards the contract to the supplier or installer. The purchaser may be the owner or the owner’s authorized agent.
**purchaser’s inspector:** Purchaser’s authorized representative with authority to act in the interest of, and on behalf of, the purchaser in all quality assurance matters

**refractory:** A non-metallic material that has a high melting point and ability to retain its physical shape and chemical identity where subjected to environmental conditions

**refractory ceramic fiber:** Ceramic fiber made of alumino-silicate materials

**rigidizing:** The practice of applying an inorganic hardening agent to the ceramic fiber hot face to improve its resistance to gas flow

**rope:** Long ceramic fibers spun into a flexible, braided or twisted, rope-like form

**supplier:** Party responsible for furnishing the ceramic fiber refractory lining materials. The supplier may or may not be the same as the manufacturer.

**textile:** Cloth, tape, sleeve, or other forms manufactured from ceramic fiber yarn

**vapor barrier:** A thin, corrosion resistant, foil placed in the ceramic fiber refractory lining parallel to the shell to inhibit exposure of the shell to corrodents from condensed process gasses

**veneer:** Layer of ceramic fiber in blanket or module form which is attached to the hot face of an existing ceramic fiber, brick or monolithic refractory lining

4. **Requirements**

4.1 **General**

4.1.1 **Conflicts, Exceptions, Substitutions, and Deviations**

4.1.1.1 All conflicts between the referenced documents and this Practice shall be submitted in writing to the purchaser for clarification and resolution before proceeding.

4.1.1.2 All exceptions, substitutions, and deviations to the requirements of this Practice and in referenced documents shall be approved by the purchaser.

4.1.2 **Regulations and Safety Data Sheets (SDS)**

4.1.2.1 Ceramic fiber refractory materials shall be in accordance with all applicable federal, state, and local codes and regulations on storage, handling, safety, and environmental requirements.

4.1.2.2 The latest issue of the manufacturer’s product data sheets, compliance data sheets (conforming to the requirements of PIP RFSF1000 and including any more stringent requirements agreed upon by the manufacturer and purchaser), installation instructions, and SDS for each product shall be available at the installation site and complied with during the installation of ceramic fiber refractory linings.

4.1.3 **Notification**

Purchaser’s inspector shall be given adequate notice before the start of work and before all hold points, so the inspector can witness the work.
4.1.4 Preinstallation

The installer shall submit a complete installation procedure including surface preparation, coatings, and vapor barrier (if specified), to the purchaser for review and approval before the start of the installation. This procedure shall be in accordance with the manufacturer’s requirements and shall constitute an inspection hold point in accordance with PIP RFTF1000-F.

4.2 Ceramic Fiber Refractory Lining Accessories

4.2.1 Anchors

Selection, installation, and inspection and testing of anchors shall be in accordance with PIP RFSA1000, PIP RFIA1000, and PIP RFTA1000, respectively.

4.2.2 Vapor Barrier

4.2.2.1 If installation of a vapor barrier is specified in the contract documents, stainless steel or other alloy foil suitable for the atmosphere (e.g., temperature, chemistry, moisture) shall be placed in the ceramic fiber refractory lining parallel to the shell or casing surface at a distance from the shell or casing such that the temperature of the foil shall always be above the dew point of the process gas condensate (API 560 calls for a minimum of 56°C (100 °F)).

4.2.2.2 The foil material and its distance from the shell or casing is specified on the contract documents.

4.2.2.3 The foil material shall be compatible with the components (e.g., refractory ceramic fiber) it may contact.

4.2.2.4 The anchor penetrations through the foil and lap joints between the foil shall be overlapped and sealed with an inorganic sealant (e.g., sodium silicate or colloidal silica), adequate for the interface temperature. (API 560 calls for vapor barrier edges to be overlapped by a minimum of 175 millimeters (7 inches)).

4.3 Steel Shell Coating

4.3.1 General

4.3.1.1 Interior steel shell surfaces underneath a ceramic fiber lining shall be coated with a corrosion resistant coating. The coating material is specified on the contract documents. It shall be applied in accordance with PIP CTSL1000.

4.3.1.2 The coating shall not be detrimental to the shell, anchors, accessories, ceramic fiber refractory or any other components to which it may be exposed.

4.3.1.3 The coating shall be suitable for the fluids (liquid and gas) to which it may be exposed.

4.3.1.4 The maximum temperature limit of the coating shall be above the steel shell temperature.
4.3.1.5 The coating shall withstand a continuous temperature of a minimum of 28°C (50°F) above the dew point temperature of the gas but greater than 177°C (350°F).

4.3.1.6 The coating shall be applied after completion of anchor installation and any required heat treatment.

4.3.1.7 The coating shall be applied as close as practical to the ceramic fiber refractory installation to minimize the potential for damage before the ceramic fiber refractory is installed.

4.3.2 Surface Preparation

4.3.2.1 Inspections and tests that are necessary to assure that surface preparation and coating application are in accordance with the requirements of PIP CTSL1000 shall be completed before ceramic fiber refractory installation.

4.3.2.2 Completion of surface preparation and coating application shall each constitute an inspection hold point in accordance with PIP RFTF1000-F.

4.3.3 Coating Installation

4.3.3.1 The coating shall cover the steel shell including attachment welds and entire base of the anchor.

4.3.3.2 The coating shall cover all parts of the anchor operating below the acid dew point temperature.

4.3.3.3 Unless dew point considerations require greater coverage, the coating shall not interfere with the installation of the lining or extend more than 25 millimeters (1 inch) up the leg of the anchor.

4.4 Materials

Ceramic fiber refractory materials shall have been prequalified in accordance with the requirements of PIP RFSF1000 and, if applicable, shall be in accordance with the requirements of API Standard 560. This shall constitute an inspection hold point in accordance with PIP RFTF1000-F.

4.5 Prequalification of Installation Personnel

Ceramic fiber refractory installation personnel shall be prequalified in accordance with PIP RFTF1000. Personnel prequalification shall constitute an inspection hold point in accordance with PIP RFTF1000-F.

4.6 Water-Contaminated Ceramic Fiber Refractory

4.6.1 Ceramic fiber material that has not been installed and exhibits evidence of water contamination shall be discarded.

4.6.2 Ceramic fiber material that has been installed and exhibits evidence of water contamination that cannot be restored to its original condition and dimension by air and/or thermal drying or has been chemically contaminated (e.g., exposure to sea water) shall be discarded and replaced.
4.7 Preparation for Lining Installation

4.7.1 Materials shall be kept in their original and unopened packaging and kept dry until immediately before installation.

4.7.2 Work areas shall be kept clean and protected to ensure that lining installation can proceed in an orderly manner without incorporating dirt, debris, moisture, or other deleterious material into the lining.

4.8 Ceramic Fiber Refractory Installation

4.8.1 General

4.8.1.1 Openings through the ceramic fiber refractory lining shall be cut perpendicular to the lining surface. If design requires otherwise (e.g., burner openings), preformed shapes shall be used.

4.8.1.2 Anchors for the hot face layer of a lining shall be 50 millimeters (2 inches) from any edge of the blanket or board.

4.8.1.3 Layout of the ceramic fiber lining shall eliminate straight through joints (i.e., direct flow paths from the surface to the casing).

4.8.1.4 Joints in layers of a lining (including surface board, if used) shall be staggered a minimum of 75 millimeters (3 inches) from joints in adjacent layers.

4.8.1.5 The design hot face temperature shall be the calculated hot face temperature plus 165°C (300°F).

4.8.1.6 The design interface temperature shall be the calculated interface temperature plus 165°C (300°F).

4.8.2 Nozzles and Manways

4.8.2.1 For ceramic fiber refractory-lined nozzles, excluding manways, the intersection of the nozzle lining and the main lining shall be designed to ensure that back-up layers are not exposed to hot face temperature. See Figure 1a or 1b.

4.8.2.2 For manways, the shell lining shall stop at the perimeter of the opening and be protected by a high alloy (e.g., stainless steel) retaining ring or plate. See Figure 2a or 2b.

4.8.2.3 Manways shall be protected by internal ceramic fiber plugs. A wrap of hot face blanket shall cover the perimeter edge of the lining. See Figure 2a or 2b.

4.8.3 Blanket and Board Lining Construction

4.8.3.1 Blanket Lining

1. Back-up ceramic fiber blanket layers shall be compressed edge to edge 25 millimeters (1 inch), 13 millimeters (1/2 inch) on each side, at all joints to protect against shrinkage. See Figure 3.

2. Joints for the installed surface layer shall be overlapped. See Figure 4.

3. The maximum length of hot face blanket segments shall be 4 meters (12.5 feet).
Comment: This requirement prevents shrinkage tears from developing along the length of the blanket.

4. Hot face layer components of a blanket lining shall be oriented with the long edge in the direction of the gas flow.

5. Overlap joints in the hot face layer of a blanket lining construction shall be oriented relative to the direction of gas flow as shown in Figure 4. Any component of the gas flow towards the overlap edge is not permitted.

6. The hot face layer of a blanket lining shall be needled, 128 kg/cm³ (8 pcf) ceramic fiber refractory, a minimum of 25 millimeters (1 inch) thick and not be greater than 600 millimeters (24 inches) in width.

7. The pin washer shall be installed to compress the ceramic fiber refractory lining approximately 13 – 25 millimeters (1/2 to 1 inch).

8. For corners and at changes in direction, the hot face blanket joints shall be in accordance with Figure 5a or 5b for an inside corner and Figure 1a or 1b for an outside corner.

4.8.3.2 Blanket/Board Lining

1. For a blanket/board lining, the hot face layer shall be board and back-up layers shall be blanket.

   Comment: Board is used as hot face layer to provide increased resistance to abrasion and elevated gas velocity.

2. The blanket layer immediately behind the board shall have the same continuous use limit temperature as the board material.

3. Back-up ceramic fiber blanket layers shall be compressed edge to edge 25 millimeters (1 inch), 13 millimeters (1/2 inch) on each side, at all joints to protect against shrinkage. See Figure 3.

4. Fiber board stud holes shall be drilled into board before installation.

5. Unless manufacturer requires open joints to accommodate thermal expansion of the board material and Purchaser approves, adjacent boards shall be tightly butted.

6. Boards shall be installed such that back-up blanket layer(s) is (are) slightly compressed by the washers.

7. The hot face layer board shall be in accordance with the following:

   a. For a wall design hot face temperature equal to or greater than 1100°C (2000°F), or overhead at any temperature the maximum dimensions are 450 x 450 millimeters (18 x 18 inches).

   b. For a wall design hot face temperature less than 1100°C (2000°F) the maximum dimensions are 600 x 600 millimeters (24 x 24 inches).

   c. The board material shall be no less than 38 millimeters (1½ inches) in thickness, and no less than 240 kg/m³ (15 lb/ft³) in density.
4.8.4 Module Lining

4.8.4.1 Modules shall be installed in accordance with the manufacturer’s approved installation procedure, using the manufacturer’s proprietary anchor system.

4.8.4.2 If a back-up safety lining is specified in the project documents, the safety lining shall be 25 millimeters (1 inch) thick, 128 kg/m³ (8 lb/ft³) blanket installed using compressed butt joints in accordance with Section 4.8.3.1.1.

Comment: For a module lining, a back-up safety blanket is installed for protection of the casing should a module be damaged or dislodged during operation.

4.8.4.3 Unless not required by the manufacturer, installation of the module shall be unidirectional (i.e., soldier, not parquet, pattern) with folded batten strips between each row.

4.8.4.4 In areas where an installed module butts up to brick or monolithic refractory (e.g., common with fired heater floor-wall interfaces), the joint between them shall be packed with a folded blanket batten strip.

4.8.4.5 The continuous use limit temperature of batten strips shall be equal to or greater than the module.

4.8.4.6 The maximum length of batten strips shall be 4 meters (12.5 feet).

4.8.4.7 The joints at the end of the batten strips shall be offset from the module joint and compressed 13 millimeters (1/2 inch) at each end.

4.8.4.8 Modules shall be installed in a compressed condition to prevent gaps due to shrinkage.

Comment: Manufacturer may provide modules in a pre-compressed condition.

4.8.4.9 Modules shall be no more than 300 x 300 millimeters (12 x 12 inches) and a minimum of 100 millimeters (4 inches) thick.

Comment: Modules of larger dimensions (e.g., irregular shapes or outside bends) may be considered in accordance with design of the manufacturer and approval of the Purchaser.

4.8.4.10 For spaces smaller than 300 x 300 millimeters (12 x 12 inches), modules shall be cut to fit, but shall not be less than half of the original face area and shall retain the original anchoring system.

4.8.4.11 Where ceramic fiber modules are installed around manways, folded blanket modules shall be used. The modules that edge the manway shall be oriented such that the folds are perpendicular to the manway frame or jamb.

Comment: Orienting the folds in this manner minimizes the wear of the module at the manway edge.
4.8.5 **Rigidizing**

4.8.5.1 If one or more applications of a rigidizing agent are specified in the project documents, the manufacturer’s recommended method of application shall be used to completely saturate the hot face surface of the ceramic fiber lining. Application by spraying is typically preferred.

4.8.5.2 The physical and chemical properties of the rigidizing agent shall be compatible with the hot face ceramic fiber to which it is applied and the atmosphere to which it may be exposed.

4.8.5.3 The rigidizing agent service temperature shall be equal to or greater than the continuous use limit temperature of the hot face ceramic fiber to which it is applied.

4.8.6 **Hot Face Coatings**

4.8.6.1 Hot face coatings, if specified in the project documents, shall be applied only on module linings.

*Comment:* A hot face coating improves erosion and chemical resistance, reduces the permeability of the fibrous surface, and acts to encapsulate the fibers within the lining.

4.8.6.2 Coatings shall be inorganic, suitable for the materials (e.g., ceramic fiber refractory) and atmosphere (e.g., temperature, chemistry, moisture) to which it may be exposed.

4.8.6.3 The coating shall be applied in a single coat by spraying and shall completely cover the hot face surface of the module lining.

4.8.6.4 The application of a coating shall be in accordance with the coating manufacturer’s approved procedure.

4.8.7 **Bulk Fiber**

Bulk fiber shall be installed by ramming or packing into the designated, confined space to the density specified in the contract documents.

*Comment:* Installation method shall ensure a uniform fiber density, (e.g., installed in lifts or layers).

4.8.8 **Veneer Lining**

4.8.8.1 Veneer linings shall be used only for temporary repairs and only if specifically required by the repair procedure.

4.8.8.2 Veneer lining shall be adhered to the existing hot face surface in accordance with the manufacturer’s recommended procedure.

4.8.8.3 Thickness of the veneer lining shall not be greater than 75 millimeters (3 inches).

4.8.9 **Miscellaneous Ceramic Fiber**

4.8.9.1 Ceramic fiber paper, rope, felt, mat and textile shall be utilized as auxiliary lining components (e.g., tube seal, door seal, expansion joints, and other packing applications).
4.8.9.2 Installation shall be in accordance with the manufacturer’s design and installation procedures.

4.9 Repairs

4.9.1 General

4.9.1.1 Ceramic fiber lining deemed defective in accordance with PIP RFTF1000 shall be repaired.

4.9.1.2 Non-ceramic fiber parts of the lining (e.g., monolithics, brick or shapes) shall be evaluated and repaired in accordance with applicable PIP Practices (e.g., monolithics in accordance with PIP RFSM2000 and PIP RFTM1000).

4.9.2 Repair Procedures

4.9.2.1 Materials and methods of repair shall be approved by the owner before a repair is made.

4.9.2.2 For a multilayer-lining, if only the hot face is damaged, the defective part of the hot face shall be removed and repaired without disturbing the back-up. If additional layers are determined to be damaged, the same removal and repair procedure shall be followed without disturbing the remaining back-up.

4.9.2.3 The size and shape of the replaced hot-face ceramic fiber refractory shall ensure that the replaced and the retained original fiber are each anchored in accordance with RFIA1000 (e.g., 50 millimeters (2 inches) from the blanket edge).

Comment: To avoid adding new anchors, replacement of full sheets of hot face board or full modules is required. It may be possible to replace partial sections of hot face blanket with overlap construction using the existing anchor layout.

4.9.2.4 Consider a means to minimize the release of respirable fibers if the fiber is cut and removed. Dampening the fiber or covering with plastic are two possibilities.

4.9.2.5 If anchors or anchor attachment welds are damaged, the anchors shall be replaced in accordance with PIP RFIA1000. The steel shell, attachment weld and anchor shall be coated as needed using original specification.

4.9.2.6 Immediately before placement of new ceramic fiber, the undamaged material adjacent to a repair area shall be cleaned of debris by high efficiency particulate air (HEPA) vacuuming. Do not use blowing, sweeping or any means that may cause respirable fibers to become airborne. It is the small particles that cannot be seen that are of the most concern.

4.10 Shipping and Storage of Equipment

4.10.1 Openings in the equipment that expose a lining shall be sealed during shipment and storage.

4.10.2 Linings shall be kept dry at all times.

4.10.3 Proper support, external bracing, rigging, and lifting techniques shall be used to prevent damage to the lining during handling, shipping, and erection.
FIGURE 1A – OUTSIDE CORNER: NO FLOW
FIGURE 1B – OUTSIDE CORNER: FLOW OR NO FLOW
FIGURE 2A - MANWAY DETAIL WITH BLANKET LINING
RINGS OF COMPRESSED CERAMIC FIBER BLANKET
25 MM (1") COMPRESSED TO 13 MM (1/2")

3 MM (1/8") MINIMUM METAL RETAINER

MANWAY COVER SAME AS LINING (MINIMUM)

CERAMIC FIBER MODULE

CERAMIC FIBER MODULE

GAP—NOMINAL 3 MM (1/8")

CASING OR SHELL

MANWAY FLANGE AND COVER

SLOTS SPACED AT 300 MM (12")

3 MM (1/8")

R = THICKNESS OF THE SHELL OR CASING INSULATION

R/2

INSULATION COLD FACE

6 MM (1/4") DIAMETER

FIGURE 2B — MANWAY DETAIL WITH MODULE LINING
FIGURE 3 - COMPRESSION JOINTS FOR BACKUP BLANKET LINING

NOTE: BACKUP CERAMIC FIBER BLANKET SHALL BE COMPRESSED EDGE-TO-EDGE 25 MM (1 INCH) AT ALL JOINTS TO PROTECT AGAINST SHRINKAGE COMPRESSION. SHALL BE EVEN, I.E., 13 MM (1/2 INCH) EACH SIDE.

LENGTH BEFORE INSTALLATION

LENGTH MINUS 25 MM (1")

WIDTH BEFORE INSTALLATION

WIDTH MINUS 25 MM (1")

APPROXIMATELY 13 MM (1/2") TYP.
FIGURE 4 — HOT FACE LINING JOINT OVERLAP
FIGURE 5A – INSIDE CORNER: NO FLOW
FIGURE 5B – INSIDE CORNER: FLOW OR NO FLOW