Refractory Installation Quality Control—Inspection and Testing of AES/RCF Fiber Linings and Materials

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Contents

Figures

Tables

Important Information Concerning Use of Asbestos or Alternative Materials

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been extremely useful in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* Sections 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products (Sections 763.160-179).

There are currently a number of substitute materials in use and under development to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

Safety and health information with respect to particular products or materials can be obtained from the employer, the manufacturer, or supplier of that product or material, or the material safety datasheet.

Refractory Installation Quality Control—Inspection and Testing of AES/RCF Fiber Linings

1 Scope

This standard provides installation quality control procedures and lining system design requirements for AES/RCF fiber linings, and may be used to supplement owner specifications. Materials, equipment, and personnel are qualified by the methods described, and applied refractory quality is closely monitored, based on defined procedures and acceptance criteria. The responsibilities of inspection personnel who monitor and direct the quality control process are also defined.

The lining described in this standard is for internal refractory linings on the process side of the equipment. External insulation and jacketing are not covered in this standard.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Standard 560, *Fired Heaters for General Refinery Service*

API Standard 936, *Refractory Installation Quality Control – Inspection and Testing of Monolithic*s

ASTM C1771 [1], *Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus*

ASTM E1172, *Standard Practice for Describing and Specifying a Wavelength-Dispersive X-Ray Spectrometer*

ASTM E1361, *Standard Guide for Correction of Interelement Effects in X-Ray Spectrometric Analysis*

ASTM C201, *Standard Test Method for Thermal Conductivity of Refractories*

ASTM C612, *Standard Specification for Mineral Fiber Block and Board Thermal Insulation*

ASTM C680, *Standard Practice for Estimate of the Heat Gain or Loss and the Surface Temperatures of Insulated Flat, Cylindrical, and Spherical Systems by Use of Computer Programs*

ASTM C892, *Standard Specification for High-Temperature Fiber Blanket Thermal Insulation*

ASTM C1113, *Standard Test Method for Thermal Conductivity of Refractories by Hot Wire (Platinum Resistance Thermometer Technique)*

BS EN 1094-1 [2], *Insulating refractory products. Terminology, classification and methods of test for high temperature insulation wool products*

SSPC-SP 3 [3], *Power Tool Cleaning*

SSPC-SP 7/NACE No. 4, *Brush-Off Blast Cleaning*

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[1] ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.
[2] BSI, 389 Chiswick High Road, London, W4 4AL, United Kingdom, www.bsigroup.com.
[3] The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1
alkaline earth silicate fiber (AES)
Manmade vitreous fiber (MMVF) composed of at least 18 % alkali earth oxides developed to meet the fiber exemption requirements spelled out in 97/69/EC of the Dangerous Substances Initiative in the European Union (EU). These fibers are exonerated from the EU carcinogen classification on the basis of their low bio-persistence. They also may be known as bio-fiber, bio-soluble, or low bio-persistence fiber.

3.2
anchor [4]
Metallic or refractory device that holds the refractory or insulation in place.

3.3
ash [4]
The noncombustible residue that remains after burning a fuel or other combustible material. This residue can potentially foul the exterior of heater tubes.

NOTE Ash may be corrosive to steel or the refractory lining, depending on the composition and metals content of the fuel.

3.4
batten strip
A single or folded layer of fiber blanket placed and compressed between courses of fiber modules.

3.5
casing [4]
Metal plate used to enclose the fired heater.

3.6
ceramic fiber
Fibrous refractory insulation that can be in the form of refractory ceramic fiber or manmade vitreous fiber (MMVF).

NOTE Applicable forms include bulk, blanket, board, modules, paper, coatings, pumpables, cements, moldables, and vacuum-formed shapes.

3.7
classification temperature
The temperature at which MMVF has a linear shrinkage (measured as per ASTM C892) not exceeding 4 % (for blanket, paper) and 2 % (for vacuum form, boards) after 24-hour heat treatment and in a neutral (not oxidizing or reducing) atmosphere.

NOTE In the field, the continuous application temperature is typically 167 °C (300 °F) below the classification temperature. Above that temperature, crystallization can occur and shrinkage increases. Polycrystalline PCW fiber can generally be used at up to classification temperature.

Fiber materials are available in three grades (classification temperature):

— Alkaline Earth Silicate (AES) fiber up to 1450 °C (2642 °F),

— Refractory Ceramic (RCF) fiber up to 1426 °C (2600 °F),

— Polycrystalline Wool (PCW) fiber > 1426 °C (2600 °F).

[4] Definition from API Standard 560, *Fired Heaters for General Refinery Service*.

3.8
cold-face [4]
The surface of a refractory lining against the metal casing surface.

3.9
compliance datasheet [5]
A list of mechanical and chemical properties for a specified refractory material that are warranted by the manufacturer to be met if and when the product is tested by the listed procedure.

3.10
dual layer [4]
Refractory construction comprised of two refractory materials wherein each material performs a separate function (e.g. ceramic fiber over insulating monolithic layer).

3.11
EM [4]
Original equipment manufacturer or equipment supplier with overall responsibility for design, fabrication, and delivery of a finished product.

3.12
expansion joint
A non-bonded joint in a lining system with a gap designed to accommodate thermal expansion of adjoining materials; commonly packed with a temperature-resistant, compressible material, such as ceramic fiber.

3.13
fabricator
Company responsible for the overall fabrication of the fired equipment in which refractory is installed.

3.14
fiberboard
Rigidized fiber, vacuum formed using bulk fiber, fillers, and binder (usually colloidal silica). Once formed and dried, it is supplied in a rigid board form.

3.15
fiber component fabricator
A third party separate from the refractory manufacturer and the installation contractor engaged in a business of purchasing fiber and anchor materials that are fabricated into modular lining components. These components are then purchased and installed by the installation contractor.

3.16
form [4]
— Shaped: sold as finished units, installed as building blocks.

— Monolithic (unshaped): final shape formed upon application.

— MMVF/AES/RCF fiber.

3.17
fuels fired [4]
The type of fuels fired in the heater. Corrosive ash and impurities in the fuel (e.g. sulfur, alkali, and heavy metals) will guide selection of the type or form of refractory and the method of construction for refractory linings.

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[5] Definition from API Standard 936, *Refractory Installation Quality Control – Inspection and Testing of Monolithics*.

3.18
high-temperature insulating wool
An accumulation of fibers of different lengths and diameters, produced synthetically from mineral raw materials. This group of fibers includes alkaline earth silicate (AES) and aluminum-silicate, as well as polycrystalline (PCW) with a classification temperature >1000 °C (1830 °F).

3.19
hot-face layer [4]
Refractory layer exposed to the highest temperatures in a multilayer or multicomponent lining.

3.20
hot-face temperature [4]
Temperature of the refractory surface in contact with the flue gas, ~~or~~ heated combustion air, process gas or external metal shell. This is the temperature used for thermal calculations for operating cold-face temperature and heat loss.

3.21
inspector
The party or individual with whom the owner has contracted or otherwise designated to monitor refractory installation work.

3.22
installer [4]
Company or individual responsible for installing the refractory lining.

3.23
interface temperature [4]
Calculated temperature between any two adjacent layers of a multi-layer or multicomponent refractory construction.

3.24
low bio-persistence [4]
Materials having solubility in body fluids and designed to be cleared from the lungs very quickly if they are inhaled. Clearance occurs through the body's natural defense mechanisms.

3.25
manmade vitreous fiber (MMVF)
A class of insulating materials made primarily from glass, rock, slag, clay, or high-purity oxides. The four general categories included as MMVF are fiberglass, mineral wool, alkaline earth silicate fiber, and refractory ceramic fiber.

NOTE MMVF is also referred to as synthetic vitreous fiber (SVF).

3.26
manufacturer (refractory)
The party or parties manufacturing the refractory products at the refractory manufacturing plant.

3.27
maximum continuous use temperature [4]
Maximum temperature to which a refractory may be continuously exposed without excessive shrinkage or mechanical breakdown. It is also sometimes referred to as the "recommended use limit" or "continuous-use temperature."

NOTE This may not be the same as the "Maximum Service Temperature" quoted on the manufacturer's product datasheet.

3.28
module [4]
Construction of fibrous refractory insulation in stacked/folded blankets or monolithic form, commonly with an integrated attachment system.

3.29
mineral wool block [4]
Block insulation composed of mineral wool fiber and an organic binder.

3.30
multicomponent lining [5]
Refractory system consisting of two or more layers of different refractory types.

NOTE Examples of refractory types are castable, insulating firebrick, firebrick, block, board, and ceramic fiber.

3.31
multilayer lining
Refractory system consisting of two or more layers of the same refractory type.

3.32
Needled [5]
An adjective describing a mechanically knitted structure of fibers to enhance handling and mechanical strength.

3.33
owner [5]
The proprietor of the lined equipment who has engaged one or more parties to install or repair refractory.

3.34
parquet [4]
A module lining design where module support anchoring is aligned perpendicular for each adjacent module (see Figure 5).

3.35
permanent linear change [5]
A measure of a refractory's physical property that defines the change in dimensions as a result of initial heating to a specific temperature.

3.36
Polycrystalline Wool (PCW) Fiber
Fibers containing greater than 70 wt % Al_2O_3 that are produced by a "sol-gel method" from aqueous spinning solutions.

NOTE Generally used at application temperatures greater than 1426 °C (2600 °F) or in critical chemical and physical application conditions.

3.37
protective coating [4]
Corrosion-resistant material applied to a metal surface.

EXAMPLE Coating on casing plates behind porous refractory materials to protect against sulfur in flue gases.

3.38
purchaser (refractory)
Party responsible for purchasing the refractory component from the refractory manufacturer.

3.39
qualification test
Pre-installation evaluation of materials and/or applicators to verify that materials purchased and equipment/personnel that will be engaged for the refractory material(s) installation are capable of meeting specified quality standards.

3.40
Refractory Ceramic Fibers (RCF) [4]
MMVF whose chemical constituents are predominantly alumina and silica.

3.41
rigidizer [4]
A liquid applied to AES/RCF that produces a rigid lining surface when dried.

3.42
shot
Un-fiberized, sphere-shaped material in MMVF fibers that does not contribute to the insulating capability of fibrous insulation.

3.43
soldier course [4]
A module lining design where module support anchoring is aligned (parallel) similarly for all modules in a row (see Figure 5).

3.44
sprayable/pumpable fibers [4]
Mixture of bulk fiber and wet binder suitable for pumping or spraying.

3.45
staples
Anchor hooks to secure the batten strip to the module (mandatory in arches)

3.46
supplier (refractory) [5]
The party supplying the refractory and other materials to the contractor.

NOTE The supplier may (or may not) be the manufacturer.

3.47
thermal resistance [4]
Ability of insulation to resist heat flow from the hot face to the cold face. A wide range of thermal resistance is possible by selecting refractories with different thermal conductivities and/or lining thicknesses.

3.48
vacuum formed
A manufacturing process combining fibers and binder components and using a vacuum to form a rigid, densified shape when dried.

3.49
vapor barrier [4]
Metallic foil placed between layers of refractory as a barrier to flue gas flow. This barrier protects the steel shell from corrosion caused by condensing acids.

3.50
wet blanket (refractory) [4]
Flexible, formable, RCF blanket saturated with wet binder that sets on heat exposure, forming a rigid, durable structure.

4 Responsibilities

4.1 Owner

4.1.1 The owner shall provide a detailed specification based on owner or process licensor design technology. The specification shall include the following design details:

— lining products with potential QA/QC test requirements,

— lining construction,

— coating and/or vapor barrier requirements,

— method of application,

— extent of coverage,

— anchor and pin materials including PMI requirements,

— geometry of the unit,

— layout,

— weld details and

— Operating environment (peak temperature, internal gas velocity, chemical environment, etc.)

The owner shall approve the engineering drawings and project execution plan prior to any installation activity. The Owner shall distribute all the final approved design, quality and installation documentation to the Installer and the Inspector.

The owner shall clearly define mock-up requirements to be completed before work is to be executed.

4.1.2 The owner shall provide an inspector(s) for the refractory installation work who has minimum competencies that are appropriate for the required work scope.

NOTE Referenced in API 936

4.1.3 The owner shall resolve the following items:

a) exceptions, substitutions, and deviations to the requirements of any execution plan, this standard, and other referenced documents, and

b) work deficiencies discovered and submitted by the inspector.

4.2 Installer

4.2.1 The installer shall prepare detailed execution and quality plans in accordance with this standard and the requirements of the owner specification and quality standard. The execution plan shall be submitted for the owner approval, and agreed to in full before work starts. The installer shall:

a) designate inspection hold points and the required advance notification to be given to the inspector,

b) prepare and submit ITPs for owner's approval,

c) document procedures for surface preparation, anchor layout, and welding (when anchor welding is within installer's work scope),

d) document procedures for material storage, installation, and quality control,

e) a plan for stiffening and protecting installed linings during the handling and transport of pre-lined components subject to the owner's approval,

f) document field records for design/procedures with the actual layout drawing shown in the execution plan, and

g) execute all work in compliance with the approved ITP, procedures and specifications.

4.2.2 The installer shall submit an installation procedure that include the prequalification of materials, , and equipment to be used to the Owner. The installer shall be responsible for completing the qualifications prior to the start of installation and informing the inspector of when and where the work will take place so that the inspector can witness and document the results.

4.2.3 The installer shall clearly identify to the Owner all exceptions, substitutions, and deviations to the requirements of the execution plan, this standard, and other referenced documents. Owner approval shall be secured before implementation of the changes.

4.2.4 The installer shall give advance notification to the owner of all times and locations where work will take place so that this information can be passed on to the inspector.

4.2.5 The installer shall provide the inspector verified documentation of installation records, including:

a) product(s) being applied;
b) ITPs and test results

c) pallet code numbers and location where applied;

d) installation crew members~~;~~

e) weather conditions and any other unusual conditions or occurrences,

4.2.6
The installer shall store materials according to the manufacturer's recommendations.

4.3 Inspector

4.3.1 The inspector shall monitor production work to ensure compliance with job specifications and agreed-to quality practices.

4.3.2 The inspector shall notify the owner and the contractor of any work deficiencies. Notification shall be made according to the job-specific requirements outlined in the procedures. All communications should be provided to all affected parties as soon as possible to prevent project delays or re-work

4.3.3 The inspector shall not make engineering decisions unless approved by the owner. Conflicts between the specified execution plan and the actual installation procedures shall be submitted to the owner for resolution.

4.3.4 The inspector shall verify the style, layout, and composition of anchors, and that the anchors are installed in accordance with the project requirements and that welds are sound.

4.3.5 The inspector shall check and verify that accurate installation records are being documented by the installer.

4.3.6 the Inspector shall, prior to installation, check that materials have been properly stored in accordance to Manufacturer's recommendations, and that all damaged materials have been properly identified.

4.4 Refractory Manufacturer

4.4.1 The manufacturer shall provide safety datasheets (SDS) to allow for the establishment of effective storage, handling, and environmental controls, as required by applicable federal, state, and local codes.

4.4.2 The manufacturer shall provide compliance datasheets to the purchaser.

4.4.3 The manufacturer shall provide materials, with test documentation, that meet the approved compliance datasheet.

4.4.4 The manufacturer shall provide recommended guidelines for weather protection and storage of products.

4.4.5 The manufacturer shall provide installation instructions to the purchaser if applicable.

4.5 Fiber Component Fabricator

The fiber component fabricator shall provide details of component construction to the owner~~/EM.~~

5 Inspector Qualifications

5.1 The inspector shall have no commercial affiliations with the installer or manufacturer(s).

5.2 The inspector(s) monitoring the refractory installation work shall have minimum competencies that are appropriate for the required work scope.

NOTE ~~-~~ Referenced in API 936

5.3 The inspector shall possess this standard, owner specifications, the project execution plan, the inspection and test plan, and other job-specific requirements outlined by the owner, installer, and/or manufacturer. The inspector shall have working knowledge of these documents.

6 Materials

6.1 Physical Property Requirements for Refractory

Refractory materials shall be selected based on physical properties specified by the purchaser as defined in Table 1.

Table 1—Documentation Required for Fiber per ASTM C892

Properties	Required
Chemical composition	X
Maximum continuous use temperature	X

Tensile strength (fiber)	X
Density	X
Thermal conductivity at mean use temperature	X
Shrinkage	On request

6.2 Anchors

6.2.1 Anchor and pin material shall be selected based on the maximum service temperature at the hottest point of the anchor. Selection criteria shall be based upon Table 2.

Table 2—Maximum Temperature of Anchor Tips*

Anchor Material	Maximum Anchor Temperature	
	°C	°F
Carbon steel	455	850
TP 304 stainless steel	760	1400
TP 316 stainless steel	760	1400
TP 309 stainless steel	815	1500
TP 310 stainless steel	927	1700
TP 330 stainless steel	1038	1900
Alloy 601 (UNS N06601)	1093	2000
Ceramic studs and washers	>1093	>2000
* Additional materials considerations may apply when fuels fired contain significant quantities of corrosive impurities, such as sulfur.		

6.2.2 Selection, installation, inspection, and testing of anchors shall be in accordance with the design drawings and specifications.

6.2.3 All weld procedures and welders provided by the installer for anchor installation shall be approved by the owner.

6.2.4 The anchor shall be welded to a clean surface per SSPC-SP 7 or SSPC-SP 3 (for spot cleaning).

6.2.5 All individual anchors shall be subject to 100 % visual inspection and physical testing per 9.1.

6.3 Packaging

6.3.1 Refractories shall be packaged and stored to prevent physical (weight) and chemical damage from water. Mechanical protection shall be provided by cardboard, rigid plastic, or metal outside containers.

6.3.2 Each alloy anchor shall be stamped, laser etched, or supplied in sealed, traceable packaging to identify alloy and forming manufacturer. Anchors from open packaging that is not stamped/etched, or being installed from a freshly opened package, shall be confirmed by 100 % positive materials identification (PMI) before installation.

6.3.3 The classification of all welding consumables shall be identified on the package and/or spool or welding rod.

6.4 Marking

6.4.1 Refractory bags or containers shall be marked with the product name, batch number, hazards identification label, and date of manufacture.

6.4.2 Packages or containers shall be marked with form, density, temperature rating, and chemistry grade (e.g. HP, ZR, Kaolin, AES) of the fiber product contained within them.

6.4.3 Packaging for anchors shall be marked for alloy composition and the physical dimensions of the anchors.

6.4.4). At least one visible surface of blanket, board, or module of fiber with rating other than 1260°C (2300°F) shall be marked to indicate it's classification temperature.

6.5 Weather Protection

Refractory materials shall be stored in an area protected from weather. The storage facility shall prevent moisture from making contact with the refractory. Storage shall be on an elevated above floor or grade on a platform or skid allowing free ventilation. Moisture shall be directed away from the refractory.

6.6 Shelf Life

The fiber manufacturer's shelf life restrictions shall apply.

6.7 Discarding Criteria

Packages of refractory with broken seals, ~~or~~ that have become damp or wet or have obvious defects, shall be subject to discard. The manufacturer shall be involved to assess and gauge the usability of the material for reevaluation after the expiration of shelf life or for damages that may have occurred during transport and/or storage.

7 Lining Design

7.1 Ceramic fiber shall not be used as the hot-face layer if the design hot-face temperature exceeds

704 °C (1300 °F) when the fuel's combined sodium and vanadium content exceed 100 parts per million (weight basis) in the fuel being fired.

7.2

In layered construction,

a) the hot-face layer shall be a needled blanket with a 25 mm (1 in.) thickness for overlap construction.

b) Blanket hot face layer shall be minimum 25mm (1") for butt joint construction.

c)

128 kg/m^3 (8 lb/ft^3) density.

a) In layered blanket system, hot-face blanket layers should be installed in lengths no less than ~~1219~~ 1220 mm (4 ft) and no greater than 3810 mm (12.5 ft).

Fiberboard, if applied as a hot-face layer, shall not be less than 38 mm (1.5 in.) thick, nor have a density less than 240 kg/m^3 (15 lb/ft^3). A backup layer(s) of fiber blanket shall be needled material with a minimum density of 96 kg/m^3 (6 lb/ft^3). The blanket shall have a maximum width of 600 mm (24 in.) and be applied using an anchoring system approved by the Owner.

7.3 Maximum dimensions for fiberboard used on the hot face shall be:

a) 610 mm x 610 mm (24 in. x 24 in.) if the design hot-face temperature is below 1093 °C (2000 °F) on sidewalls;

b) overhead (arch, hip roof, etc.)—450 mm x 450 mm (18 in. x 18 in.)—if the design hot-face temperature exceeds 1093 °C (2000 °F) or if used on the roof at any temperature.

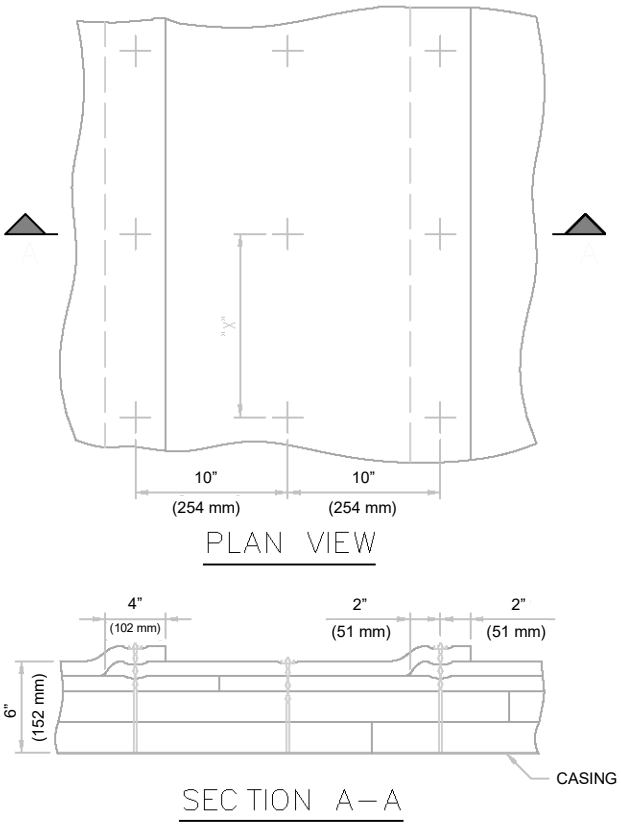
7.4 The hot-face blanket layer shall be overlap design [typically 100 mm (4 in.)], as shown in Figure 1, and

shall use a fiber blanket size of 610 mm (24 in.) wide x 25 mm (1 in.) thick. Anchor retaining clips (Figure 2) shall be installed with 12 mm to 25 mm (½ in. to 1 in.) compression.

7.5 Anchor spacing shall be as follows.

a) Vertical walls: Spacing across the blanket width shall be on 254 mm (10 in.) centers. Spacing along the blanket length shall be 254 mm to 305 mm (10 in. to 12 in.). In more extreme conditions (vibration or other), tighter centers of less than 254 mm (10 in.) are acceptable and advisable.

b) Overhead (arch, hip roof, etc.): Spacing across the blanket width shall be on 254 mm (10 in.) centers. Spacing along the blanket length shall be 229 mm to 254 mm (9 in. to 10 in.). In more extreme conditions (vibration or other), tighter centers of less than 229 mm (9 in.) are acceptable and advisable.



"x"	Studs Per Square Meter (SF)
254 mm (10")	15.49 (1.44)
305 mm (12")	12.91 (1.2)
356 mm (14")	11.84 (1.10)

Figure 1—Typical Stud Layout for Overlap Blanket Systems

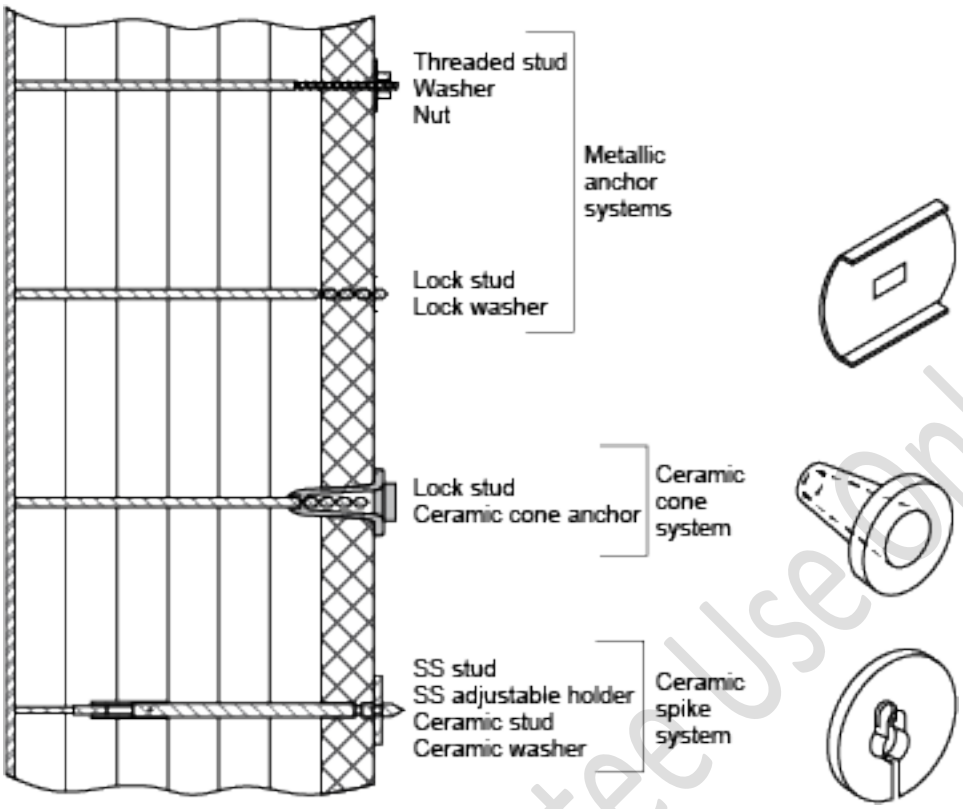


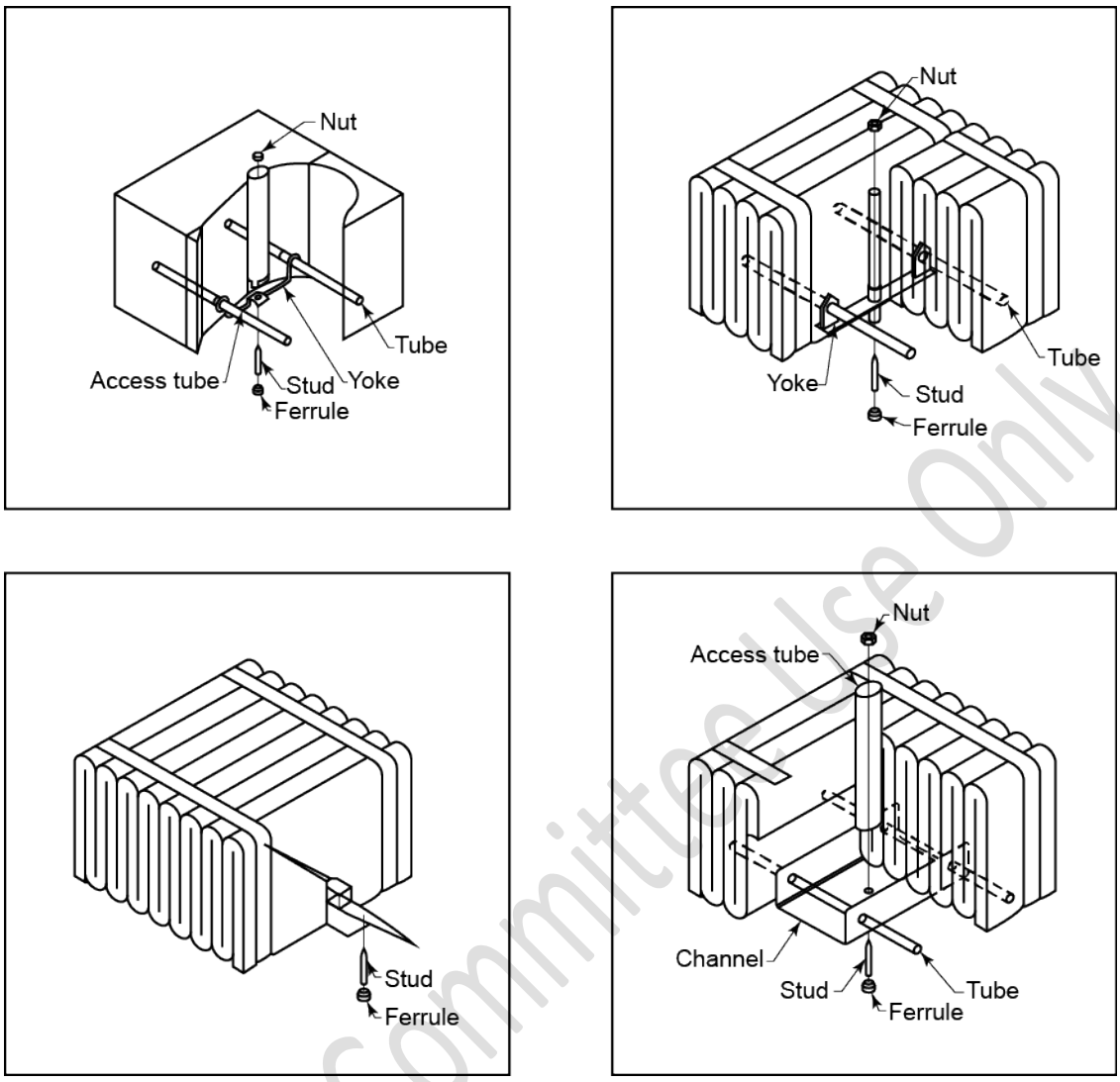
Figure 2—Typical Layered Fiber Lining Anchoring Systems

7.5.1 Fiber blanket shall not be used as the hot-face layer when gas velocities are in excess of 12 m/s (40 ft/s). Wet blanket, fiberboard, or modules are normally not used on the hot face when velocities are greater than 30 m/s (100 ft/s).

7.5.2 Fiber blanket shall be installed with its longest dimension in the direction of gas flow. The hot-face layer of blanket shall be constructed with all joints overlapped. Overlaps shall be in the direction of gas flow. Hot-face layers of fiberboard shall be constructed with tight butt joints.

7.5.3 Fiber blanket used in backup layers shall be installed with butt joints with at least 12 mm (½ in.) compression on the joints. All joints in successive layers of blanket shall be staggered minimum 50mm (2”).

7.5.4 Module systems (Figure 3) shall be installed so that joints at each edge are compressed to avoid gaps due to shrinkage.



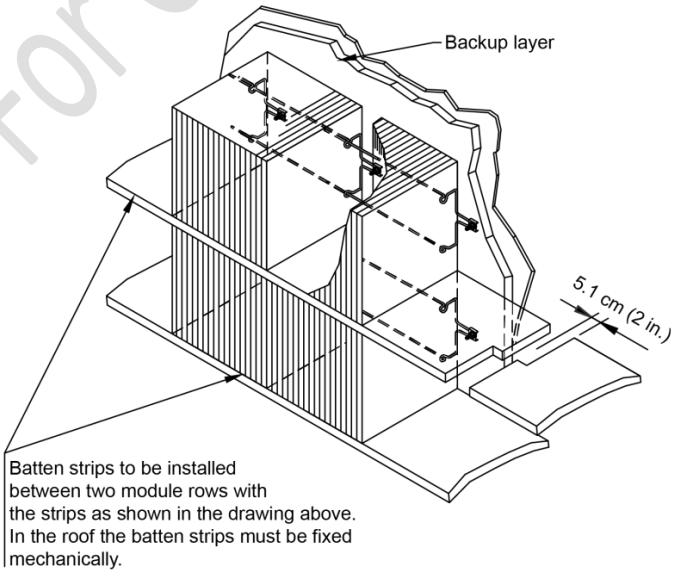


Figure 3—Examples of Modular Fiber Systems

7.5.5 Modules shall be designed so that support hardware spans over at least 80 % of the module width (Figure 4).

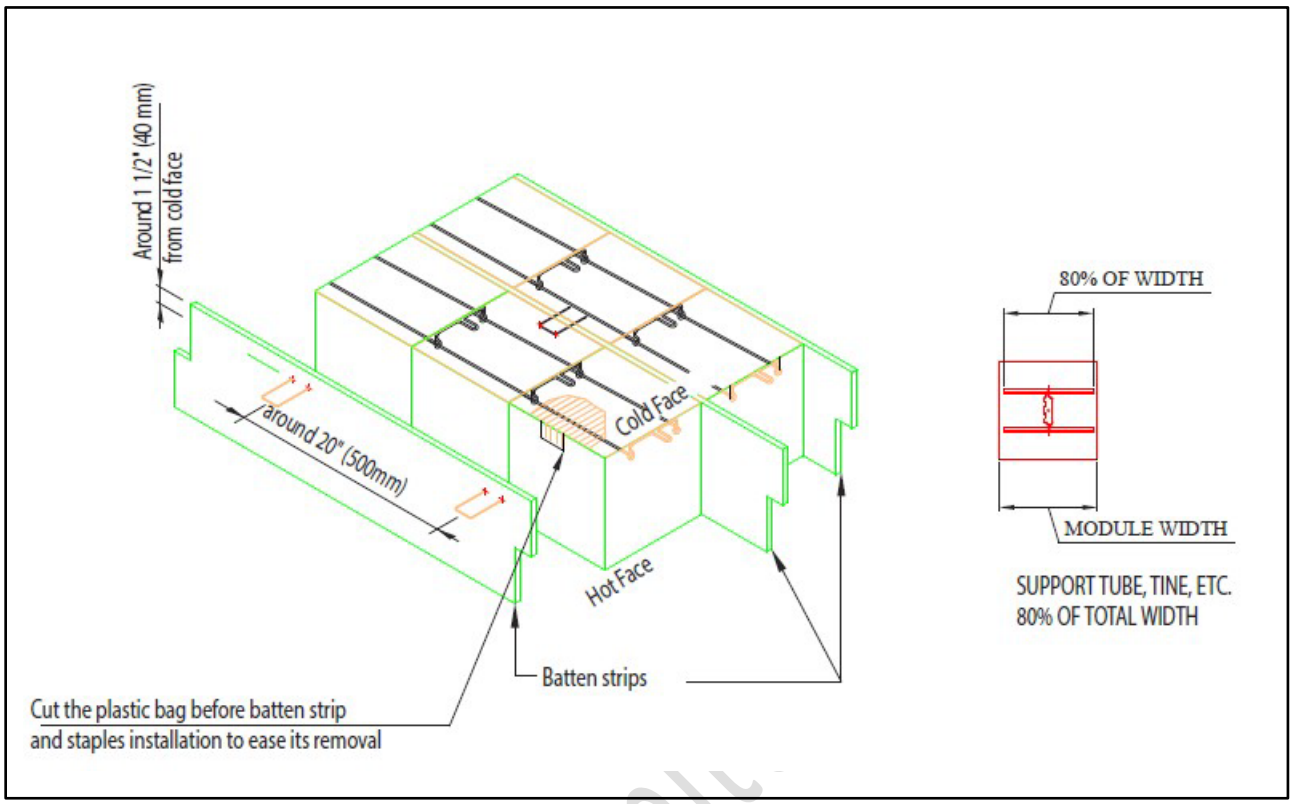


Figure 4—Hardware Span Required for Overhead Section Modules and Typical Staples to Secure Batten Strip to Module in Overhead Installations

7.5.6 Modules shall be installed in soldier-course with batten strips. A parquet pattern is only acceptable on flat arches and typically does not require batten strips. See Figure 5 for an example of each. Figure 6 shows angled and shiplap joint details for single batten strip joints.

a) Overhead and sloped applications shall have batten strips anchored to the adjacent module by means of staples, U-pins, or J-pins for overhead and sloped applications.

b) Batten strips shall be of the same grade as the hot-face material.

Batten strip length shall be cut at regular intervals, between 1.2-2.5 m (4-8.33 ft) depending on temperature, to account for in-service shrinkage by using a shiplap joint (Figure 6) or cutting the hot face surface 25mm (1") deep on the same regular

c) A layer of impermeable material shall be applied at all locations where green or wet castable comes in contact with ceramic fibers.

d) Dimensional tolerances shall be defined for the module.

e) Dimensional tolerances shall be defined for blanket width.

f) Modules shall be installed such that ~~two~~ adjacent modules are NOT edge on edge (they must be separated by a compressed single layer or folded blanket/batten strip).

Batten strips shall be installed to full lining thickness of the module.

g) Batten strips shall be compressed per the manufacturer's instructions.

h) Anchors shall be attached to the casing before modules are installed

i) Threaded studs for module systems shall be protected from physical damage, weld splatter and or overspray of any casing protective coating

j) If back up layer of blanket is required, it shall be applied to studs insuring joints are offset at least 1” from the module joints.”

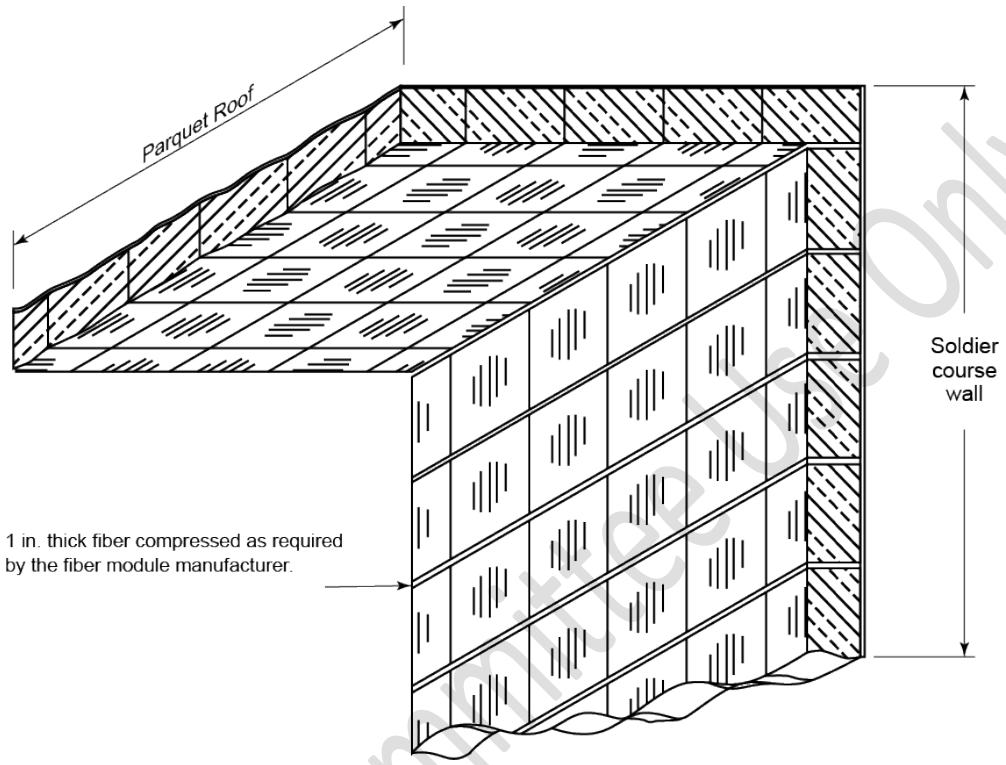


Figure 5—Typical Module Orientations

7.5.7 Internal hardware and anchors shall comply with the maximum tip temperature defined for studs in Table 2 based on the highest calculated temperature for each of the components.

7.5.8 Full-thickness fiber linings shall not be used for the lining of floors where maintenance traffic and scaffolding construction are anticipated.

7.5.9 Fiber shall not be used in convection sections where soot blowers, steam lances, or water wash facilities are used**.**

7.5.10 Anchors shall be installed before applying protective coating to the casing. The coating shall cover the attachment studs and anchors so that uncoated parts are above the acid dew-point temperature.

— For fuels that have a sulfur content exceeding 200 mg/kg (200 ppm by mass), the casing and carbon steel anchor components that will be operating below acid dew-point temperature shall be coated to prevent corrosion. The protective coating shall have a maximum continuous use temperature of 175 °C (350 °F) or greater, and it shall be applied after the anchors are welded to the casing. Threaded tips of anchors are typically protected using caps/tape while the coating is being applied.

7.5.11 For fuels that have a sulfur content exceeding 500 mg/kg (500 ppm by mass), a 2 mil (50 micron) vapor barrier of austenitic stainless steel foil shall be provided in addition to coating. The vapor barrier shall be installed in soldier course and located so that the exposed temperature is at least 55 °C (100 °F) above the calculated acid dew point for all operating cases. Vapor barrier edges shall be overlapped by at least 175 mm (7 in.). Edges and punctures shall be overlapped and sealed with sodium silicate, fiber cement, mortar, or moldable.

7.5.12 Mineral wool block shall not be used.

7.5.13 Typical patch repairs [e.g. less than 0.465 m^2 (5 ft^2)] are shown in Figure 7 and Figure 8 for blanket lining systems, and Figure 9 for a modular system. Blanket overlaps counter to the gas flow direction should be avoided.

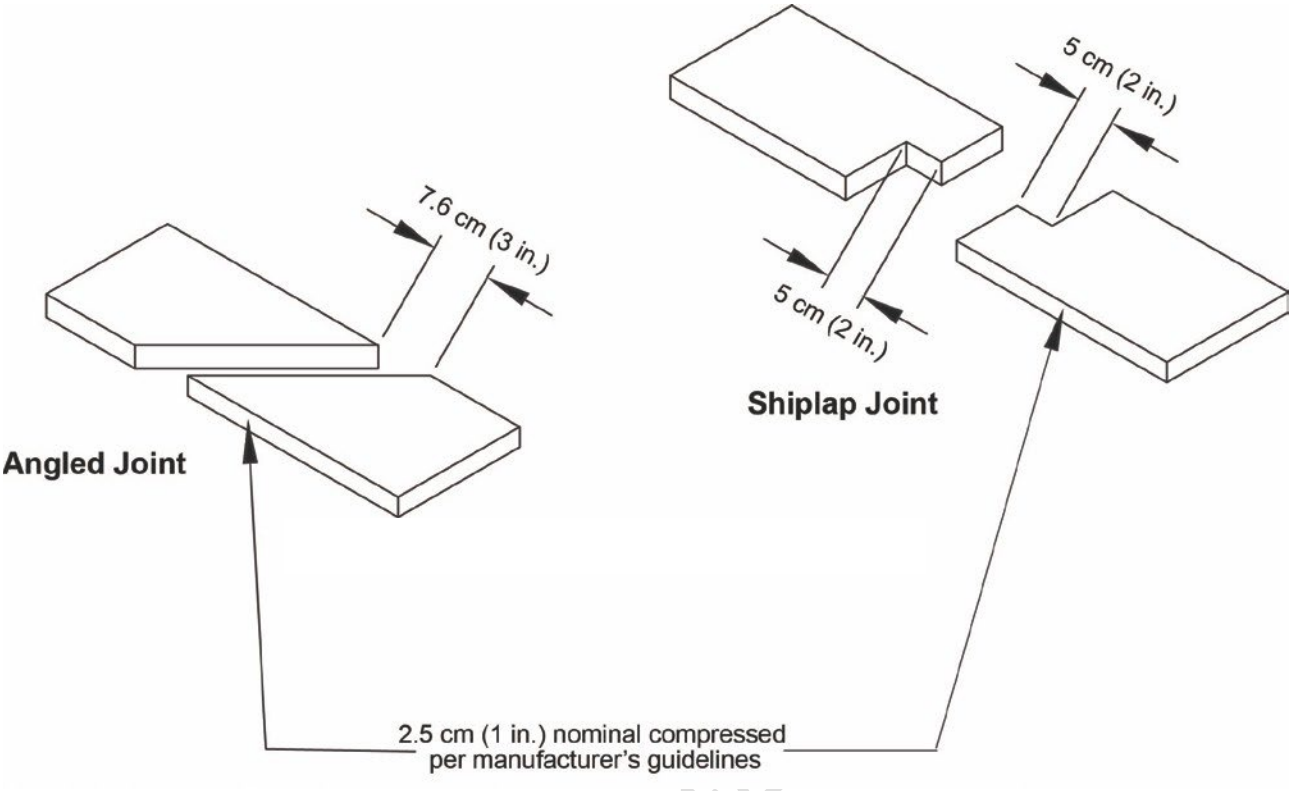


Figure 6—Typical Joint Details for Single Batten Strips

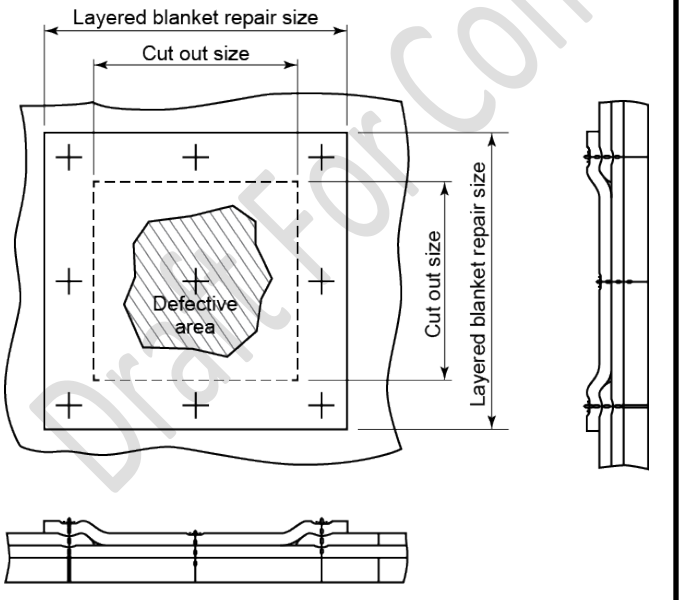


Figure 7—Typical Blanket Lining Repair of Hot-face Layer

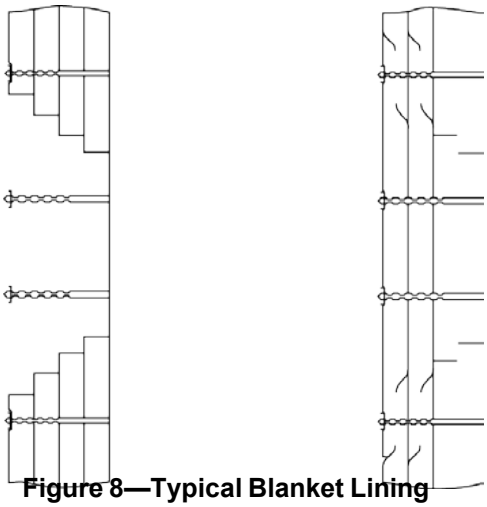
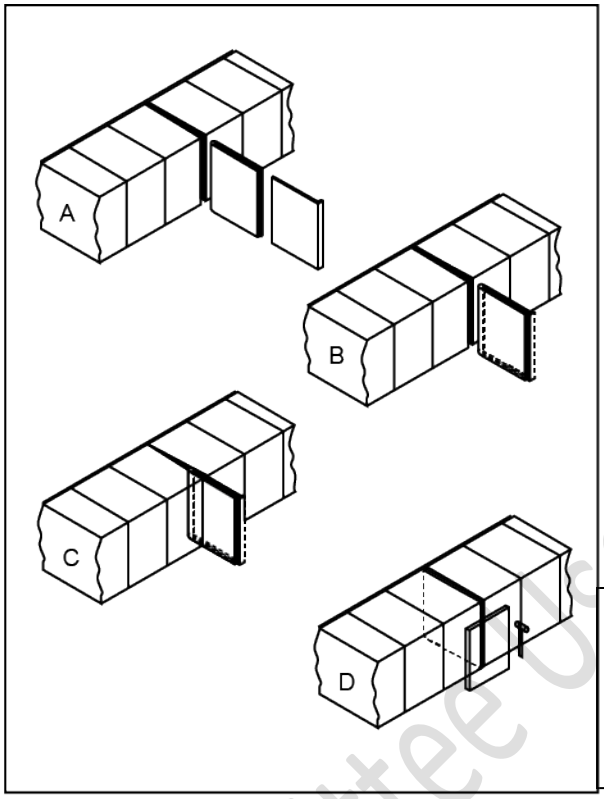
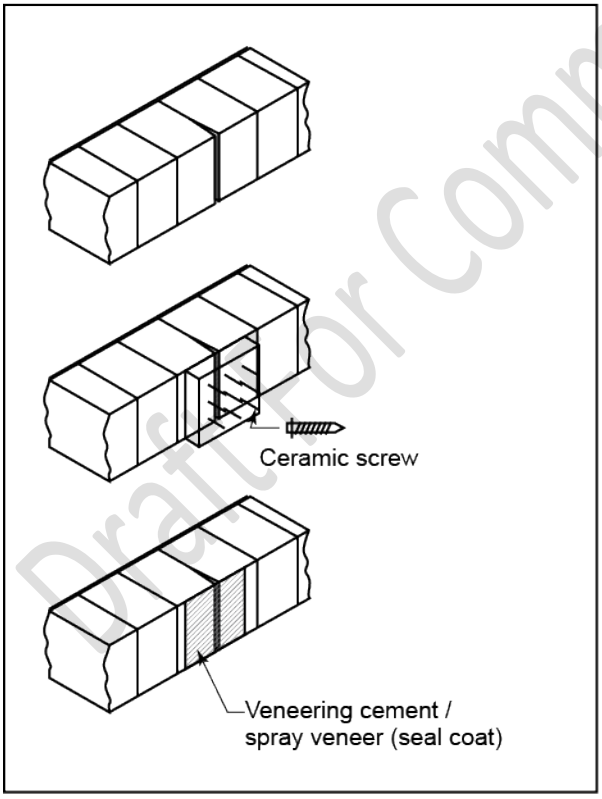


Figure 8—Typical Blanket Lining Repair of Multiple Layers



Folded blanket pleat used to fill large gaps in between modules after they have been installed.



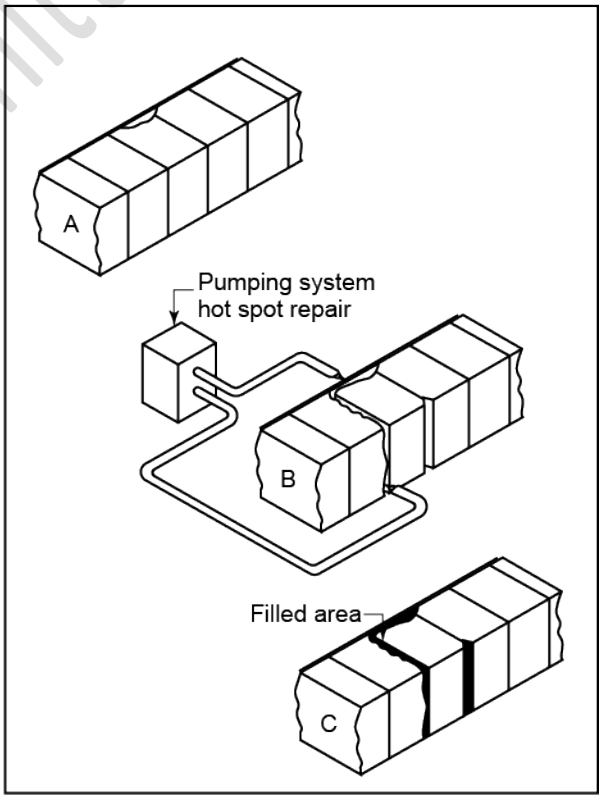


Figure 9—Typical Repair of Modular Fiber Linings

8 Rigidized and Surface-treated Fiber

8.1 Rigidized and surface-treated fiber shall be colloidal silica/alumina based. Sodium silicate or potassium silica shall not be used. Others shall be subject to owner approval.

8.2 Application of rigidizer shall be in accordance with manufacturer's guidelines.

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9 QA/QC, Examination, and Testing

9.1 Anchor Inspection and Testing

a) Surface preparation and weld attachment quality shall be confirmed. The minimum hammer and/or bend test frequency for anchor weld attachments shall be per Table 3

Table 3—Minimum Hammer and/or Bend Test Frequency

Anchor Count	Hammer/Bend Test
<25	100%
25 to 50	50%
50 to 500	25%
>500	5%
NOTE Count per type/installation/welder.	

b) Layout and spacing shall be verified as meeting specified requirements before refractory installation.

c) **7.4.2** Selection, installation, inspection, and testing of anchors shall be in accordance with the design drawings and specifications.

9.2 Anchor Stud Welding

a) At the start of each shift, sample test welds shall be performed by each welder to confirm weld quality and that the machine is set correctly. A prequalification test shall entail stud welding five anchors on a piece of plate in similar condition as anchor location or on the prepared shell. Excess anchors from weld testing on prepared shell shall be removed prior to refractory installation. The bend test shall be performed for each sample to ensure a sound full weld. The bend test shall involve bending the anchor tine in the vicinity of the weld 15 degrees from vertical and back without cracking.

Note: Prequalification of weld procedure for blind welds is especially important because you cannot visually inspect the quality of the stud weld after the weld is completed.

b) All equipment settings shall be checked and noted prior to each work shift.

9.3 Fiber Lining Inspection and Testing

a) The manufacturer shall prepare in advance standard compliance datasheets per Annex A, Figure A.1, and keep them on file for immediate transmission to the purchaser. Each compliance datasheet shall include a statement of identification as a compliance datasheet. The compliance datasheet shall include a list of the test methods used for each value listed.

b) Prior to installation, fiber materials shall be reviewed and inspected to confirm properties as outlined in the

Compliance Data Sheets.

c) Sample/testing frequency at the installation site per material to be installed shall be the following:

1) three samples for greater than 1000 pieces (e.g. module or blanket roll),

2) one sample for less than 1000 pieces.

d) Additionally for AES fiber, the manufacturer shall provide evidence that the fiber is exempt from carcinogenic classification per Note Q of EU Commission Directive 97/69/EC.

9.4 Installation Workmanship for Fiber Linings

b) Installation drawings and procedures shall be available at the job site and reviewed by installation personnel prior to start of work.

c) Anchors, hardware, and materials shall be dimensionally checked and material composition verified by the inspector to confirm compliance with the work specification.

d) Layout of anchors and hardware shall be plumb, level, and compliant with specification tolerances.

e) Special geometries (i.e. corners, burner blocks, view ports, penetrations through the lining, and terminations with other refractory systems) shall be confirmed to be constructed according to manufacturer's (or other's) design drawings .

f) The anchor or stud pattern layout shall account for the hot-face layer anchor requirements.

g) In a layered blanket system, joints shall be tight or overlapped, as specified. Overlap in the hot-face layer shall be in the direction of gas flow.

h) Prior to shell coating application, the surface shall be prepared per specification. Coating application shall be expedited to avoid flash rusting.

i) Prior to shell coating application, anchors and anchor threads shall be protected from overspray.

j) Blankets shall not be stretched.

k) Butt joints between blankets shall have specified compression.

l) In board and blanket systems, the hot-face board shall be tight against the underlying blanket with 12 mm to 25 mm (½ in. to 1 in.) compression in the blanket.

m) Anchor retaining washers shall be installed and locked. When specified, the washers shall be protected with wrapped blanket covers.

n) Hot-face layers of board shall be installed with tight butt joints.

o) Modules shall be tightly installed per design before the banding is removed (if applicable).

p) Modules shall be tamped per manufacturer's specification, with no gaps at the joints.

q) Module batten strips shall be cut in a single layer or folded as per Manufacturer's procedures

r) Module orientation shall be correct per specification/drawings (parquet versus soldier course).

s) Only specified cements and rigidizers shall be used.

t) Small and irregular openings found after tamping shall be filled with blanket or pumpable AES/RCF fiber.

10 Preparation for Shipment

10.1 For shop and field-applied linings, packaging shall prevent damage to lining due to physical abuse, rain, and wind effects during transportation and storage.

10.2 For shop-lined fiber refractory sections, shrink wrapping or an owner-approved equivalent shall be used to prevent water from penetrating the fiber.

10.3 The vendor shall identify on the drawings the maximum number of shop-lined sections that can be stacked and the orientation of sections for shipping and storage purposes.

10.4 Prior to shipment, the Owner and Inspector shall inspect the lining.

Annex A
(normative)

Refractory Compliance Datasheet

A.1 Scope

This annex describes the contents of and the requirements for compliance datasheets produced by refractory manufacturers.

A.2 Definition

A compliance datasheet lists physical and chemical properties for a specified refractory material that are warranted by the manufacturer to be met if and when the product is tested by the listed procedure.

A.3 Application

Compliance datasheets are applicable to certification and qualification testing of refractory materials. They may also be used as a part of laboratory and technician qualification procedures.

A.4 Requirements

A.4.1 Compliance datasheets shall be developed for any refractory material commonly used in or marketed to the refining and petrochemical Industry. They may be developed for any refractory material. Each compliance datasheet shall include a statement of identification as a compliance datasheet.

A.4.2 Standard compliance datasheets shall include values for a minimum of 2 property tests as defined in Table A.1 for fiber refractories.

Table A.1—Test Methods to Determine RCF/AES Properties

Properties	Test Method	Conditions	Range
Density	ASTM C892	As-received condition (unfired)	Provide an upper and lower limit
Linear shrinkage	ASTM C892	Values to include testing at these temperatures: • manufacturer's recommended operating temperature limit or continuous use temperature limit; and • maximum use temperature as defined by ASTM C892 for classification of types	Provide an upper limit for each temperature
Chemical analysis	ASTM E1172		Provide an upper and/or lower limit
Thermal conductivity	ASTM C177 or C201		Provide an upper limit
Tensile strength	ASTM C892	As-received condition (unfired)	Provide a minimum limit

DATE SUBMITTED_____

EQUIP. NO._____ EQUIP. NAME _____

REFRACTORY MATERIAL

REFRACTORY MANUFACTURER_____

REFRACTORY SUPPLIER _____

DENSITY (kg/m^3) (lb/ft^3)

Manufacturer's guarantee_____min._____max.

LINEAR SHRINKAGE (%)

At manufacturer's recommended operating temperature limit or continuous use temperature limit

Manufacturer's guarantee_____max.

At maximum use temperature as defined by ASTM C892 for classification of types

Manufacturer's guarantee_____max.

TENSILE STRENGTH (lb/ft^3)

Manufacturer's guarantee_____min.

THERMAL CONDUCTIVITY FACTOR "K" AT 538 °C (1000 °F) MEAN ($BTU*in/hr*ft^{2}*°F$)

Manufacturer's guarantee_____max.

CHEMICAL ANALYSIS (min/max)

Alumina (Al_2O_3) _____Silica (SiO_2) _____

Calcia (CaO)_____Magnesia (MgO)_____

Iron Oxide (Fe_2O_3) _____Others _____

Figure A.1—Compliance Datasheet: Fiber Materials

Note – not all tests are required to ensure quality of fiber. This should be an agreed upon set of criteria. However, if an owner has a critical application or may not have history with specific manufacturers, they may wish to include more than typical testing

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