

CERAMIC FIBER LININGS

GENERAL INFORMATION AND DESIGN CRITERIA

INTRODUCTION

The use of ceramic fibers as insulation and lining material for high-temperature equipment has established itself as an efficient alternative to conventional refractory systems, particularly in applications where energy efficiency, rapid commissioning, weight reduction, and the ability to undergo faster thermal cycling are critical.

However, the proper performance of a ceramic fiber lining depends on more than just the quality of the selected material. Factors such as operating temperature, permissible cold-face temperature, required heat loss limits, gas velocity and turbulence, equipment atmosphere, fuel type, anchoring systems, and layer configuration must all be analyzed in conjunction.

This bulletin outlines the primary ceramic fiber lining systems, their characteristics and advantages, and the fundamental design criteria. It specifically addresses multi-layer and modular systems, the selection of hot-face and backup materials, insulation thickness calculations, the choice of anchors and retainers, and basic guidelines for joint layout and installation.

The aim is to provide engineers, maintenance managers, and thermal equipment users with a technical resource that facilitates proper lining specification, thereby ensuring safe and efficient equipment operation.

As with any high-temperature insulation system, the final selection of materials, thicknesses, and anchoring systems must be tailored to actual operating conditions and supported by appropriate thermal and mechanical analysis.

GENERAL INFORMATION ON CERAMIC FIBER LININGS

There are different types of ceramic fiber linings, depending on the installation method:

1. Multi-layer lining.
2. Modular lining with integrated anchoring systems.
3. Bonded modular lining.
4. Fiber lining installed over an existing refractory lining.
5. Fiber lining installed over another fiber lining

1. MULTILAYER LINING

Multi-layer linings generally consist of a ceramic fiber blanket or board layer forming the hot face, supplemented by one or more layers of backup insulation material.

The system is attached to the equipment casing using metal or ceramic studs or anchors, employing suitable retainers to hold the fiber in place.

The number and thickness of the insulation layers must be determined based on operating conditions and the required cold-face temperature.

2. R MODULAR LINING WITH INTEGRATED ANCHORING SYSTEM

Ceramic fiber modules consist of folded and compressed fiber blankets, incorporating anchoring elements that allow for their installation onto the equipment casing.

This system creates a continuous ceramic fiber surface with a high capacity to recover from any shrinkage that may occur during service.

3. ADHERED MODULAR LINING

In this system, ceramic fiber modules are attached to the surface using adhesives or cements suitable for the temperature and service conditions.

Surface preparation and correct adhesive application are important factors in ensuring the adhesion and stability of the lining.

4. CERAMIC FIBER OVER A PRE-EXISTING REFRACTORY LINING

Ceramic fiber can be installed over an existing refractory lining.

One alternative is to use modules bonded to the refractory surface.

Another option is to drill holes in the existing lining, install stainless steel or ceramic studs, and use them to secure the layers of ceramic fiber blanket.

5. CERAMIC FIBER OVER ANOTHER FIBER LINING

It is also possible to install a new layer of ceramic fiber over an existing fiber lining, provided that the condition of the base lining and the service conditions allow for this configuration.

The system must be selected based on the specific operating conditions of the equipment.

ADVANTAGES OF CERAMIC FIBER LININGS

Ceramic fibers have been used industrially since the 1970s. Rising energy costs and the need to reduce fuel consumption and associated emissions have driven the use of these materials in various high-temperature applications.

Their main advantages include:

- Reduced fuel consumption.
- Low lining weight.
- Lower installation costs and time.
- Ease of repair and maintenance.
- Reduced heat storage.
- Shorter heating and cooling times.
- Potential for reduced cycle times.
- Increased productivity in certain applications.

Ceramic fiber linings can achieve significant weight reductions compared to conventional refractory linings. As a general indication, the fiber can be approximately 75% lighter than insulating firebrick and between 90% and 95% lighter than dense refractory material.

A key characteristic of ceramic fiber is its low heat storage capacity. Due to its low thermal mass, less energy is required to bring the lining up to operating temperature. Similarly, less stored energy is released during cooling.

This feature can be particularly advantageous for equipment subject to frequent heating and cooling cycles.

Ceramic fiber also exhibits high thermal shock resistance, primarily due to its low mass and the flexibility of its fibrous structure.

Its low thermal conductivity enables high thermal efficiency and, in certain applications, allows required cold-face temperatures to be achieved with thinner linings than those needed for other systems.

However, the final thickness must be determined through appropriate thermal calculations, taking into account the specific conditions of the equipment.

The fiber's flexibility and low weight also facilitate handling, installation, and repair.

Another important feature is the ability to put the equipment into service quickly after installation is complete, as it does not require the drying and curing periods associated with certain wet refractory linings.

GENERAL DESIGN CRITERIA

To correctly design a ceramic fiber lining, the following factors—among others—must be considered:

- Maximum operating temperature.
- Required cold-face temperature.
- Allowable heat loss.
- Gas velocity.
- Turbulence.
- Atmosphere within the equipment.
- Type of fuel used.
- Chemical characteristics of the atmosphere.
- Anchoring system.
- Configuration and thickness of the various layers.

For multi-layer linings, it is necessary to define both the material directly exposed to the operating temperature and the materials that will serve as back-up insulation.

The selection of these materials must take into account not only their nominal classification temperature but also the actual service temperature and the specific conditions of the application.

SELECTION OF HOT-FACE MATERIAL

The standard ceramic fiber blankets covered in this bulletin have classification temperatures of approximately:

- 1260 °C (2300 °F).
- 1427 °C (2600 °F).

The blankets may experience shrinkage at temperatures above approximately 982 °C; therefore, the operating temperature must be carefully considered when selecting the hot-face material.

For applications with temperatures up to approximately 1149 °C, a 1260 °C-rated blanket may be used as the hot face.

For higher temperatures, it is recommended to consider a 1427 °C-rated blanket.

The specified density for the blankets is approximately **128 kg/m³ (8 lb/ft³)**.

HOT FACE THICKNESS

As a general guideline indicated in the document, the use of a layer approximately 25.4 mm (1") thick is recommended for many applications.

For 1427°C-rated blankets, thicknesses of 38 mm (1.5") or 51 mm (2") may be used.

The final selection must be based on the operating temperature, gas conditions, and the corresponding thermal calculation.

CHEMICAL ATTACK

Ceramic fibers can be affected by specific chemical conditions present in the equipment's atmosphere.

The presence of alkalis and other chemical components can attack the fiber; therefore, material selection must take into account the atmosphere's composition and any potential contaminants present during service.

GAS VELOCITY

Gas velocity is a significant factor in the design of ceramic fiber linings.

As a reference, a gas velocity of approximately **12.2 m/s (40 ft/s)** is considered for certain applications.

Under specific conditions and using suitable materials, higher velocities—in the range of **30.5 m/s (100 ft/s)**—may be considered

Gas temperature must also be taken into account. For example: **2000 °F ≈ 1093 °C**.

When using blankets directly exposed to high-velocity gas streams, measures to protect the fiber surface may be necessary.

In certain applications, the use of a wet blanket or a surface layer approximately 6.4 to 12.7 mm thick has been specified, allowing for gas velocities of up to approximately 30.5 m/s (100 ft/s), depending on specific conditions.

Reference Values

Material	Classification temperature	Reference velocity
Manta de fibra cerámica	1260 °C	12,2 m/s
Manta de fibra cerámica	1427 °C	12,2 m/s
Placa de fibra cerámica	1260 °C	30,5 m/s
Manta húmeda	1260 °C	30,5 m/s

These values should be considered design references and do not replace the evaluation of specific service conditions. La velocidad de los gases constituye un factor importante en el diseño de revestimientos de fibra cerámica

THERMAL HEAT FLOW

The thermal calculation for a ceramic fiber lining must consider various factors, including:

- Thermal conductivity of the materials.
- Thickness of each layer.
- Surface emissivity.
- External air velocity.
- Surface orientation.
- Equipment geometry.
- Operating temperature.
- Ambient temperature.

The following parameters are used for the calculation example:

- Ambient temperature: 22 °C.
- Hot-face temperature: 1250 °C.
- Ambient air velocity: 0.5 m/s.
- Emissivity: 0.80.

For the material and thickness configuration used in the original example, the resulting cold-face temperature is approximately 84 °C.

The calculated heat loss is approximately 884.33 W/m².

The calculated stored energy for the system is approximately 596,174,400 J/m².

The values above apply to the example presented in this bulletin and must be recalculated for each specific application.

VAPOR BARRIER

In facilities where fuels containing more than approximately 0.5% sulfur are used, sulfur dioxide (SO₂) and sulfur trioxide (SO₃) may be generated.

Under certain temperature conditions, these compounds can condense and form products capable of chemically attacking the equipment casing and the welds of the mounting studs.

When operating conditions require it, a vapor barrier—such as a stainless steel sheet—may be installed between the various layers of the lining.

The location of this barrier must be determined by considering the interface temperature and the dew point of the components present in the atmosphere.

The objective is to prevent condensable products from reaching the metal casing and causing corrosion.

ANCHORS AND FASTENING SYSTEMS

Selecting the anchoring system is a fundamental aspect of designing a multilayer ceramic fiber lining. Anchors must keep the various lining layers in position during installation and, crucially, during the equipment's heating, cooling, and operating cycles.

The selection of anchor material, geometry, and length must take into account the temperature the component will reach during service. This temperature does not necessarily match the hot-face temperature, as the thermal gradient across the lining determines the actual temperature to which each part of the anchor will be subjected.

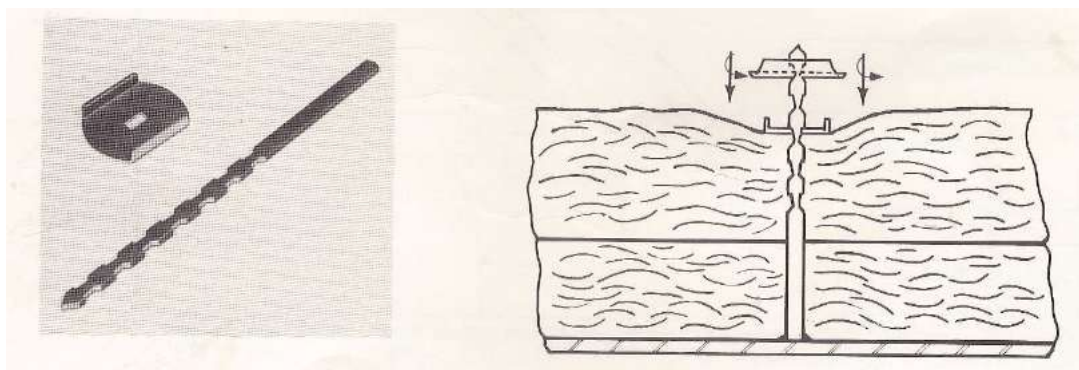
For this reason, the thermal calculation of the lining is an essential tool for the proper selection of fastening elements.

.Metal bolts

Stainless steel or high-temperature alloy studs may be used in multilayer lining systems.

The studs used in the system in question have a rectangular cross-section of approximately $6.4 \times 3.2 \text{ mm}$ ($\frac{1}{4}'' \times \frac{1}{8}''$) with grooved sides. Rectangular washers or retainers, designed to keep the fiber layers compressed, are placed over these studs.

Once the insulation layers are installed, the retainer is placed over the stud and pressed down until the lining is slightly compressed. The retainer is then rotated to lock it into the corresponding groove on the stud.



For the systems in question, AISI 304 and AISI 310 stainless steels are used, among others. Various stud lengths are available, including:

- 88.9 mm ($3\frac{1}{2}''$)
- 114.3 mm ($4\frac{1}{2}''$)
- 152.4 mm (6")
- 203.2 mm (8")

Other lengths and material grades may also be used, depending on the specific requirements of each installation.

Anchor temperature

The maximum service temperature of an anchor must not be determined solely based on the alloy's classification temperature; the actual temperature the element will reach at its installed location must be taken into account.

The thermal gradient across a multi-layer lining is not necessarily linear. The anchor's temperature will depend on the temperature distribution within the various layers, the thermal properties of the materials, and heat transfer conditions.

Consequently, proper anchor selection requires knowledge of the expected temperature in the element's critical zone, particularly at the point where the retainer or cuplock is installed.

Reference temperatures for anchors

Material or configuration	Maxima temperature of use indicated
AISI 304	760 °C (1400 °F)
AISI 310	927 °C (1700 °F)
AISI 330	1038 °C (1900 °F)
Inconel 601	1093 °C (2000 °F)
Inconel 601 + cuplock + mastic	1149 °C (2100 °F)
High alumina ceramic anchor + mullite washer	1482 °C (2700 °F)
High alumina ceramic anchor + SiC washer	1482 °C (2700 °F)

The values above correspond to the operating conditions specified for the reference system and must be verified for each specific application.

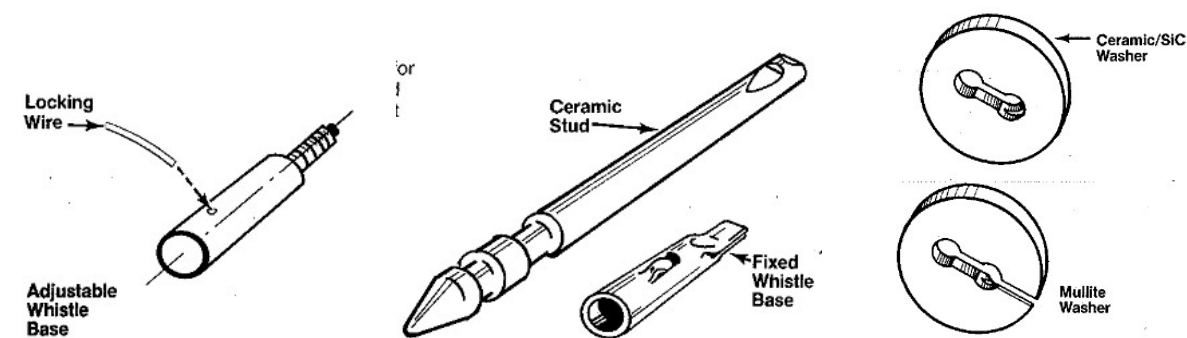
Ceramic Anchors

High-alumina ceramic studs and retainers can be used for high-temperature applications.

These systems extend the lining's operating range when the anchor temperature exceeds the limits of conventional metal components.

Ceramic anchors can be installed using a metal base welded to the equipment casing. The system may feature fixed or adjustable bases, with the latter allowing for the adjustment of the anchor assembly's effective length.

At high temperatures, ceramic retainers keep the fiber in place, preventing direct exposure of metal components to the hottest zones.



Metal anchor Protection

In certain applications, metal elements can be protected using ceramic components and moldable ceramic fiber materials.

One configuration involves a **ceramic cup placed over the end of the stud and filled with moldable mastic**, thereby reducing the temperature to which the metal element is exposed.

To protect the stud and retainer assembly, the reference document specifies an approximate volume of **33 cm³ of moldable material**, whereas a volume in the order of **20 cm³** is indicated for filling and coating a ceramic cuplock.

The mastic must completely fill the interior space of the ceramic component, ensuring thermal continuity and contributing to the protection of the metal element.

A small excess of material on the surface of the retainer further helps protect the assembly against thermal exposure.

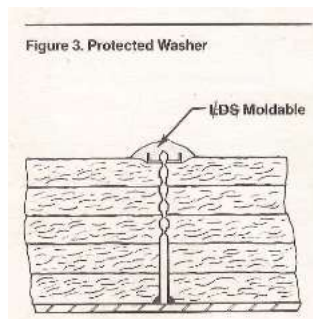
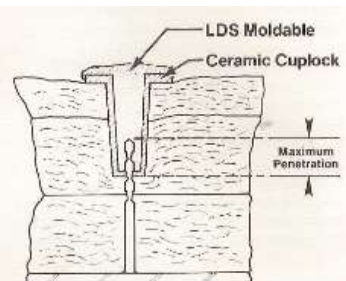
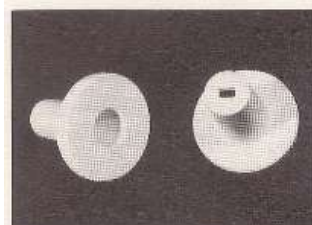


Figure 4. Cuplock



Ceramic Cuplock

For temperatures up to approximately **1149°C (2100°F)**, the system in question utilizes a ceramic retainer or "cuplock."

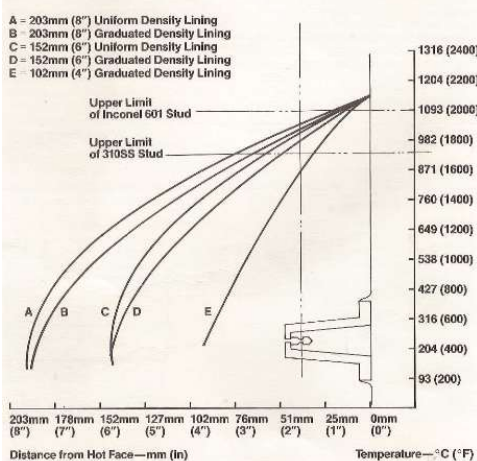
The cuplock operates via a locking mechanism similar to that of the metal washer used in conventional systems. The key difference is that the end of the fastener is protected by a ceramic component and moldable ceramic fiber mastic.

Using this system lowers the temperature to which the bolt end is exposed, thereby expanding the application range for certain metal components.

According to the design criteria specified in the reference document, a ceramic washer properly filled with mastic may allow for an increase of up to approximately 55°C (100°F) in the recommended contact temperature for certain bolt materials.

This value should be understood as a criterion specific to the protection system in question, rather than a general property applicable to any combination of bolt, ceramic, and mastic.

Figure 5. Position of Critical Temperature on Anchor Stud



Protection in corrosive atmospheres

The selection of the anchor material must also take into account the atmosphere within the equipment.

Atmospheres with high carbon potential or significant levels of carbon monoxide—such as those used in certain heat treatment processes—can affect ferrous alloys and promote mechanisms of metallurgical degradation.

Likewise, certain fuels containing vanadium, sodium, nickel, or vanadium-derived compounds can accelerate the corrosion of metal components.

Under these conditions, the reference document recommends considering the use of **Inconel 601 with ceramic retainers**, supplemented by moldable mastic.

The final selection must be made by jointly considering the temperature, atmosphere composition, exposure time, and specific operating conditions.

Ceramic backup rings and ceramic retainers

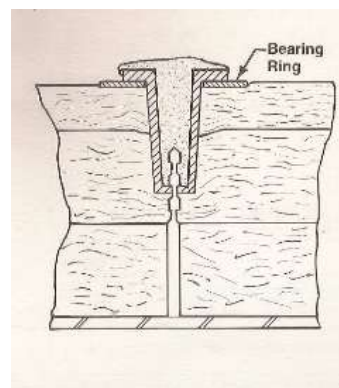
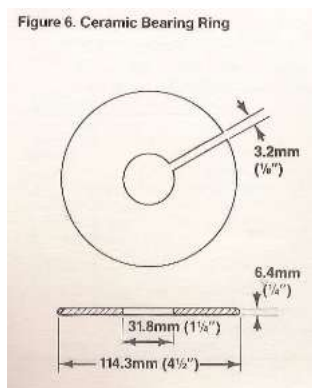
E In high-temperature applications, particularly in roof installations, it may be advisable to incorporate a **ceramic support ring** between the locking or retaining system and the hot face of the insulation.

The objective is to increase the contact area and distribute the load over a larger surface area of the fiber. This reduces the risk of the blanket slipping or being pierced by the retainer due to the load exerted on the lining.

For applications involving a risk of significant thermal shock, **mullite** washers may be used due to their thermal shock resistance properties.

In higher-temperature applications, **SiC** retainers may also be used, depending on the specific system configuration.

Figure 6. Ceramic Bearing Ring



General criterion for the selection of anchors

The selection of the anchoring system must be carried out as an integral part of the lining design, rather than as a decision independent of the fiber layer selection.

The selection process should consider, at a minimum:

1. Equipment operating temperature.
2. Maximum hot-face temperature.
3. Temperature profile within the lining.
4. Anticipated temperature at the critical anchor point.
5. Type and thickness of the fiber layers.
6. Surface orientation: walls, roof, or floor.
7. Weight of the lining to be supported by each anchor.
8. Gas velocity and turbulence.
9. Atmosphere and corrosive potential.
10. Feasibility of using ceramic anchor protection.
11. Type of retainer or locking system.
12. Thermal cycling conditions.

Proper anchor selection ensures the lining maintains its mechanical integrity during operation and prevents the fastening elements from becoming critical failure points due to excessive temperatures, corrosion, or loss of mechanical strength.

When these systems are used, the corresponding spaces may be filled with a suitable mastic.

ANCHOR LAYOUT

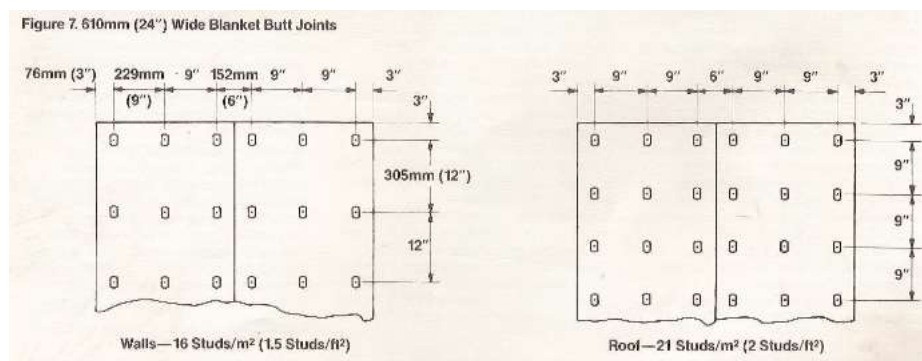
Proper anchor spacing is essential for the successful installation of the multilayer system. The layout pattern is determined based on the furnace's operating conditions. For all patterns, the backup layers are installed in the same manner. Each backup layer is butt-jointed and installed asymmetrically relative to the anchor pattern. Install each layer so that the joints are offset by a minimum of 152 mm (6") from the joints immediately below in the adjacent layer.

On sidewalls, the blankets are generally positioned vertically.

On roofs, the orientation must be adapted to the blanket roll installation direction and the specific equipment configuration.

Stop Joints

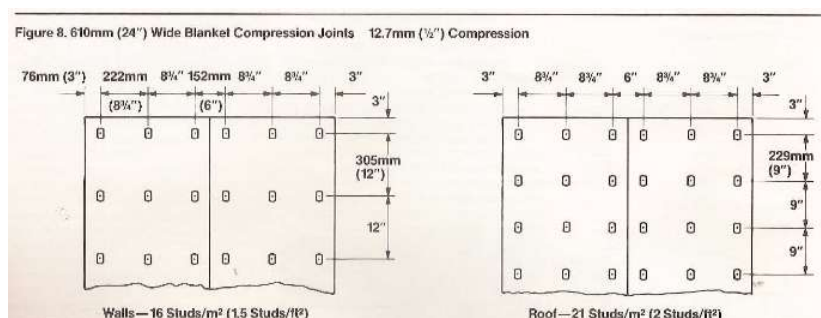
The following figure illustrates the proper mounting pattern for a 610 mm (24") wide blanket when using a butt-joint construction.



Compression Joints

A compression joint is essentially the same as a butt joint, except that the contacting edges of adjacent blankets are subjected to slight compression. Compression joints require a slight adjustment to the anchor spacing. Figure 8 shows the anchor spacing for a compression of 12.7 mm ($\frac{1}{2}$ ").

Compression joints are formed by securing the final layer of hot-face lining onto the studs and overlapping adjacent blankets by an amount equal to the desired compression overlap. Once the retaining clips are in place, the two blanket edges are lifted away from the wall and brought back together, compressing them against each other.

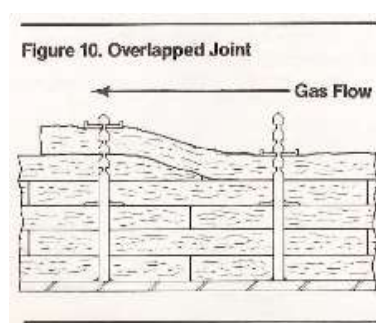
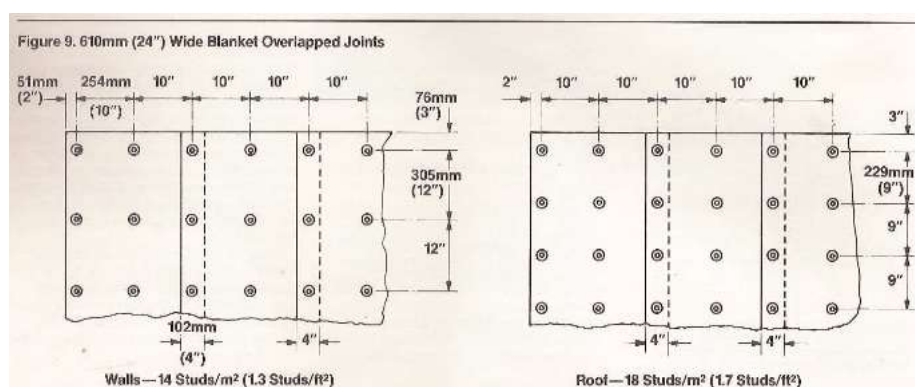


Lap Joints

Another alternative is to use lap joints.

The overlap must be oriented in the direction of gas flow to reduce the likelihood of the gas stream penetrating directly between the fiber layers.

Proper execution of the joints is crucial to ensuring the continuity of the lining.



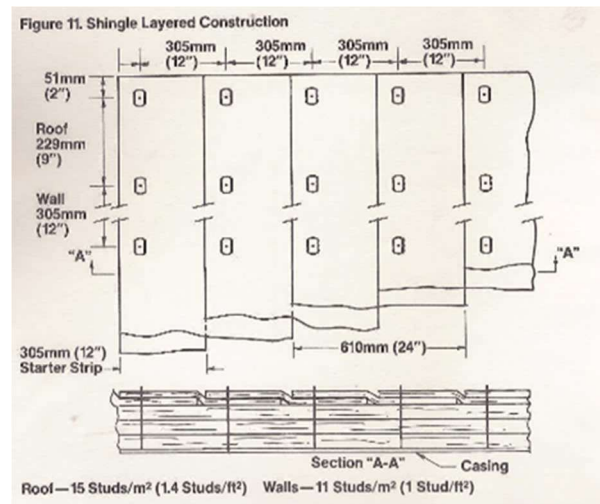
Shingle-style overlap

In certain configurations, the blankets may be arranged in a manner similar to roof tiles.

In this case, the hot-face layer and the first backup layer must be identical.

As a general guideline, a thickness of approximately **25.4 mm (1")** is considered.

To account for trimming, adjustments, and installation losses, it is recommended to allow for approximately **10% additional material**.



MODULAR CONSTRUCTION

Modular linings offer an alternative to traditional systems using blankets installed layer by layer.

The modules are manufactured from folded and compressed ceramic fiber blankets.

Broadly speaking, there are two types of modules: anchored modules and bonded (glued) modules. Anchored module systems come in a wide range of formats, depending on the type of anchor used.

Bonded modules contain no internal or external anchors. They are attached to the furnace wall using a special refractory mortar and can be mounted on metal structures, existing refractory linings, or even previously installed modules. These modules are typically no more than 3 inches thick; for greater thicknesses, one would need to look at the various anchored module options.

Anchored modules are more widely used, and their formats vary significantly across different manufacturers and brands.

Each fold of the blanket within the module is secured by a pair of stainless steel rods and a supporting bracket. This bracket is the component that is ultimately attached to the wall of the furnace or piece of equipment.



Anchored modules can be constructed using blankets with varying maximum service temperatures. Standard grades offer temperature limits of 1204°C (2200°F), 1315°C (2400°F), and 1427°C (2600°F). Each type is available in two densities.

During module fabrication, the "U" folds are compressed by 30%. This compensates for the ceramic fiber's inherent shrinkage at maximum operating temperatures, thereby preventing heat flow toward the casing.

Module thickness is determined by the desired cold-face temperature. Upon request, our engineering department can provide heat flow calculations that take into account both module density and thickness.

INSTALLATION PROCEDURES

Proper installation **determines the thermal performance and service life** of the lining. Factors to consider include surface preparation, module layout and fastening, layer orientation and compression, joints, anchors and their protection, interfaces, and repairs.

These procedures will be detailed in a **future technical bulletin**, covering everything from surface preparation to the equipment's commissioning.