

2300 Lining Systems for Fired Heaters and Boilers

Interim results from animal toxicity studies conducted by TIMA, Inc. on laboratory animals were released in October 1990. The studies indicate that when inhaled, the health effects of unfired refractory ceramic fibers (RCF) are similar to those for asbestos.

Continued developments regarding RCF health issues will be incorporated in Section 500 "Safe Handling." Questions on the suitability of RCF for your application, or for updates on possible alternative materials, should be directed to the Materials and Equipment Engineering Unit.

Abstract

Due to its excellent insulating properties and its light weight, refractory ceramic fiber (RCF) is used as the main refractory lining in about 75% of all process furnaces. There are, however, some instances where other types of refractories are more suitable. Insulating firebrick (IFB) is sometimes used as the lining on the bottom 6 feet of a furnace wall and in other areas where increased durability is needed. Castable refractories provide increased erosion resistance in convection sections, breechings, and stacks, around door frames, and in areas where soot blowers are used. Plastic refractories and special refractory shapes are also used to a small extent in some fired heaters and boilers. These systems, their properties, advantages, limitations, and recommended use are discussed in this section.

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2310 Refractory Ceramic Fiber (RCF)

RCF is becoming the primary lining for fired heater applications. Because RCF is considered a probable carcinogen by OSHA, CRTC's HE&S Team has developed some handling guidelines. These are discussed in Section 500 and specified in IRM-MS-4775.

RCF lining systems consist of an anchoring system, a vapor barrier coating (to protect the shell from corrosion), and the RCF product itself. The RCF can be in several forms, the most common being either modules or layered blankets ("wall-paper"). Layered blankets are generally used at lower temperatures (to 2000°F), and modules at higher temperatures. Blanket with a hot face board layer and modules with blanket back-up layers are also used, but less often.

2311 Anchors

This section discusses anchor material and the anchor systems used for both RCF modules, blankets, and blanket/boards.

Anchor Material

The type of material used for both module and layered blanket anchors depends on the operating temperature and atmosphere of the furnace.

For furnaces burning "clean" fuels (less than 0.5% sulfur), use Table 1A on Standard Drawing GD-N1262 to choose the anchor material. This table gives oxidation limits for anchor materials. These limits should be followed closely, because even a small amount of oxidation cannot be tolerated. If the fuel is "dirty" (over 0.5% sulfur), the potential for sulfidation lowers the temperature limits of the anchor materials. In these cases, use anchor materials based on Table 1B of Standard Drawing GD-N1262.

For blanket and blanket/board systems, the hot face temperature will determine which anchor material to use. In module systems, the anchor material is buried deep within the module and will not normally experience hot face temperatures. It is a good idea, however, to choose anchor material on the basis of hot face temperature. If just one module failed, the anchor system could be exposed to hot face temperatures, and widespread damage could result. Generally the *cost increment is small* for this metallurgical upgrade, relative to the entire job.

Anchors for Modules

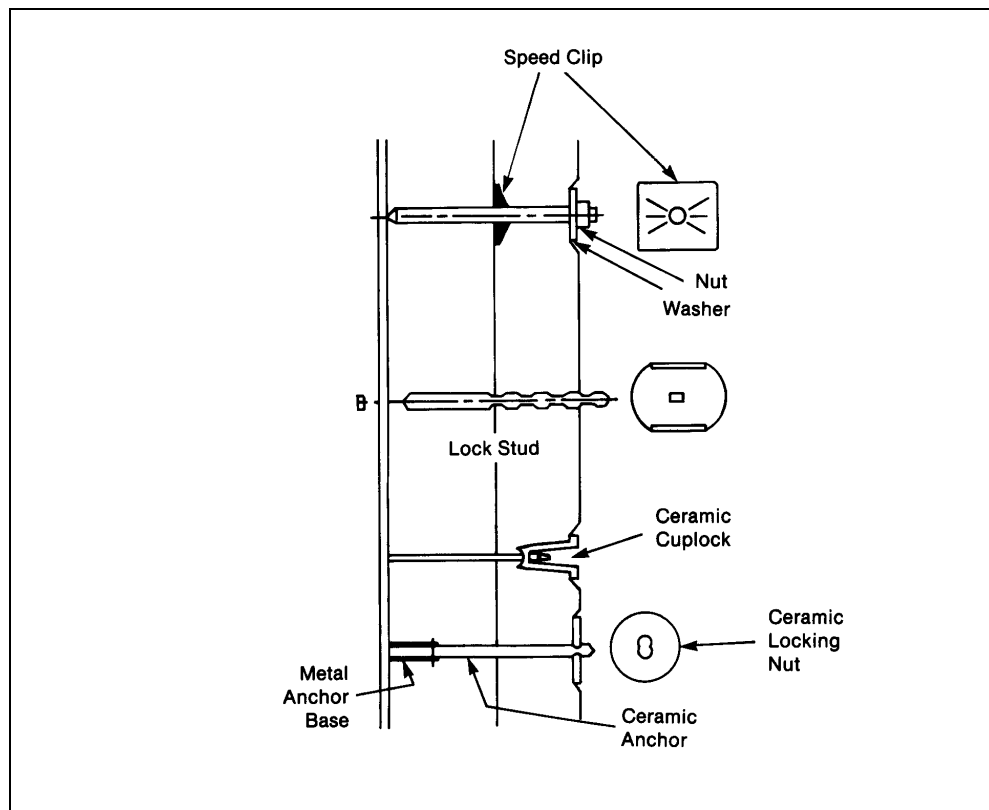
The key to a good module installation is the reliability of the attachment to the furnace shell. Some anchors attach by welding, some by bolting through the shell. We recommend only those types that are welded. We further limit our recommendation to those systems that require the anchors to be welded in place *before* the modules are installed. This allows us to check the weld integrity (visually and mechanically). These systems also require anchor welds to be made before the vapor barrier coating is applied. This is very important because welds made through a vapor barrier coating would be unreliable. Each RCF manufacturer has several

types of module anchoring systems. Most systems have proven to work well in a variety of applications.

Anchors for Blanket and Blanket/Board Systems

There are several types of blanket anchors although some are more common than others. Figure 2300-1 shows examples of some common types.

Fig. 2300-1 Some Types of Blanket and Blanket/Board Anchoring Systems *Courtesy of Isolite Insulating Products Co., Ltd.*



2312 Vapor Barriers

A vapor barrier is needed to protect the steel furnace casing from corrosion due to acidic condensation. This is especially important in furnaces which burn fuel containing sulfur. Otherwise, sulfur acids can condense on the shell and cause severe corrosion. Two types of protection can be used, an asphaltic coating on the wall or stainless steel foil between RCF layers.

We recommend using an asphaltic mastic coating called Stalastic in *all* furnaces. It is made by Witco Corporation and comes in sprayable and trowelable grades. Asphaltic coatings are inexpensive insurance against corrosion problems. It is especially important to use Stalastic in furnaces that burn sulfur- or vanadium-containing fuels, due to the potential for acid condensation. Tests are currently being run to determine if there are suitable alternatives to Stalastic.

The vapor barrier coating can be sprayed or troweled on. Stalastic 61031 is the trowelable grade; Stalastic 61036 is sprayable. The finished thickness should be a minimum of 1/8 inch for either grade. Both grades are rated to 500°F maximum.

Stainless steel foil has been used in the past as a vapor barrier. The foil is positioned so that its temperature is above the dew point of the condensing acid (about 350° to 450°F). The foil does not offer an advantage over Stalastic and has several limitations. The foil cannot be used if modules are chosen. Also, anchor puncture holes and seams in the foil can allow corrosive condensate to reach the shell and anchor attachments, defeating the purpose of the foil. Some users try to seal up all the holes and seams, but this is time-consuming and of questionable reliability. We do not recommend the use of foil.

2313 RCF Products

Refractory Ceramic Fibers (RCF) are produced by melting an aluminosilicate composition in an electric arc furnace at temperatures above 3500°F. Fiber production is by a spun or a blown method, and the method used depends entirely upon the manufacturer. A spinning rotor or a jet of air breaks up a stream of molten material into very small droplets. The droplets are rapidly accelerated and they elongate into fibers as they cool.

The average diameter of spun fibers ranges from 80 to 195 micro-inches (2.0-5.0 μm). Blown fibers are usually about half the diameter of spun fibers. The finer blown fibers reduce the thermal conductivity of the resultant product. On the other hand, spun fibers tend to be slightly longer and produce materials with greater tensile strengths and end products with better handling strengths. However, these differences have little significance for most applications.

RCF fibers generally come in five grades which, combined with the manufacturing process, determine the product temperature limit and use. The most commonly used grades are:

1. Low Purity “standard” RCF kaolin clay-based (approximately 50% Al_2O_3 - 50% SiO_2 , with TiO_2 and Fe_2O_3 impurities)
2. High Purity used for reducing atmospheres (lower amounts of TiO_2 and Fe_2O_3)
3. Specialty (10-20% ZrO_2 or Cr_2O_3 added to increase use temperature)

Manufacturers also make a low-quality grade used only in mold services. It has higher shot content than “standard” RCF. A high Al_2O_3 (approximately 95%) RCF is made for use at high temperatures. This material has the trade name Saffil. It is marketed in the U.S. by Thermal Ceramics. See Section 2317. The most significant difference among their different grades is temperature limits. Thermal conductivity is similar for all the grades except the high Al_2O_3 grade, which has higher thermal conductivity. Figure 2300-2 gives thermal conductivity and temperature limits for the five grades of RCF at 6 lb/ft³ and 8 lb/ft³ densities.

Nearly all RCF sold in the United States today is made by the manufacturers listed in Section 2317.

Fig. 2300-2 Thermal Conductivities and Temperature Limits for Five RCF Grades *Courtesy of Isolite Insulating Products Co., Ltd.*

Grade RCF	Approximate Temperature Limit Based on 3% Shrinkage, °F	Thermal Conductivity, K, at 1000°F Mean Temperature, Btu in/ft ² hr °F	
		6 lb/ft ³	8 lb/ft ³
Low quality, high shot	1800	0.92	0.83
Low purity "standard"	2000	0.92	0.83
High purity	2100	0.92	0.83
Specialty (Zr ₂ O ₃ added)	2600	0.84	0.78
High Al ₂ O ₃ ⁽¹⁾	2800	1.51	

(1) Only made in 6 lb/ft³ material.

2314 Advantages and Limitations of RCF

The physical properties of RCF can significantly impact the performance of fired equipment. The advantages are numerous, but RCF is not right for all applications. Operating parameters of the equipment must be reviewed thoroughly before deciding to use RCF.

Advantages

The advantages of RCF are: low thermal conductivity, low heat storage, and excellent thermal shock resistance. In addition, it is easy to fabricate and install, no time is needed for curing and dryout, it is easy to repair, and it is cost-effective.

Low Thermal Conductivity. Figure 2300-3 shows how the K factor of RCF changes with mean temperature and blanket density. This example is for standard grade blankets. Other grades are similar, but K factors do vary slightly with grade and manufacturer.

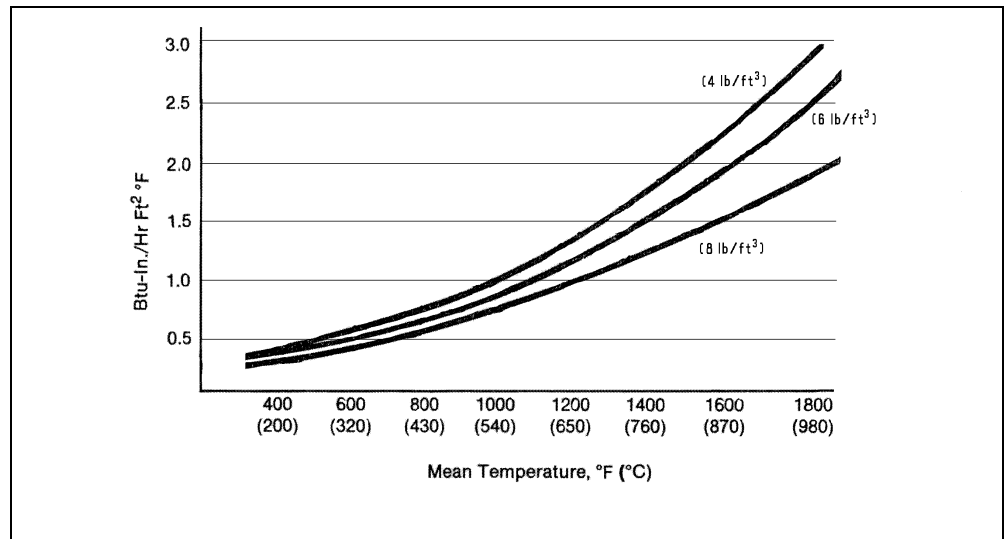
Because of the low thermal conductivity:

- Heat losses can be greatly reduced.
- Furnace refractory walls can be thinner, thereby increasing the available space in a process heater or reducing the overall outside dimensions of the equipment while maintaining the same level of activity.
- Fuel costs are lower.

Low Heat Storage. Since heat storage is proportional to the mass or density of the refractory material, heat stored in the lining is greatly reduced with ceramic fiber.

- RCF can change temperature rapidly. The rate of change will be a function of the process, not of the refractory as with conventional refractory linings. This feature results in shorter shutdowns because entry time is much reduced, which improves productivity.

Fig. 2300-3 Example of K Factor versus Mean Temperature and Blanket Density for One Manufacturer *Courtesy of Isolite Insulating Products Co., Ltd.*



- Furnace control improves. Lower heat storage means that the furnace will respond to controls more quickly than with conventional refractories. Equipment with linings having higher heat storage responds very slowly to changes in operation, which can affect efficiency and safe operation.
- Emergency shutdowns are less time-consuming. Because shutdowns are less time-consuming, they are not postponed, and serious damage to equipment may be avoided.

Good Thermal Shock Resistance. The lightweight and fibrous nature of this material helps make it virtually unaffected by rapid heating and cooling. This means fewer repairs, longer use, and faster startups.

Easy to Fabricate and Install. No special skills are required to properly install ceramic fiber linings.

- Because RCF is resilient and light weight, furnace structures can be designed with lighter gage metals.
- RCF can be shipped with less and lighter bracing, which lowers shipping cost. Prefabricated panels are also easy to construct, ship and erect in the field.

No Time Needed for Curing or Dryout. Since ceramic fiber products are generally dry, the linings require no curing time. They can also be fired immediately at any rate desirable. (With conventional refractories, heat-up temperature rate is limited by the refractory, not the process.)

Easy to Repair. Because RCF is simple to install, plant personnel can and do perform repairs. The old or damaged areas can be removed, a new lining installed, and the equipment put back on line before a contractor's crew can arrive on site.

Cost Effective. RCF systems provide very real savings. In many cases the installed price will be lower than conventional refractory. In other cases, the improved

efficiency and shorter down times will provide the savings. As an example, the cost for lining steam generators at Bakersfield with RCF was about 30% less than that for a castable lining (\$45,000 versus \$65,000 for a 1380 square-foot area). Also, the generators now run on 130 barrels of oil per day (BOPD) instead of 160 BOPD. Figure 2300-4 shows how heat loss for an RCF lining is much lower than that for a castable lining or an IFB-block insulation lining of the same thickness.

Fig. 2300-4 Heat Loss and Cold Face Temperature Comparison, RCF versus Castable and IFB Linings *Courtesy of Isolite Insulating Products Co., Ltd.*

Lining Description	Heat Loss ⁽¹⁾ , Btu/hr ft ²	Cold Face Temp ⁽¹⁾ , °F
9-inch castable (75 lb ft ³)	379	233
7-inch IFB + 2-inch block insulation	151	154
9-inch RCF modules	103	134

(1) J. T. Thorpe computer calculations. Assumes 1700°F hot face temperature, 80°F ambient temperature, and zero mph wind velocity.

Limitations

RCF lining systems have several limitations: they have low mechanical strength, they are susceptible to corrosives, are affected badly by reducing atmospheres, they shrink if used above their temperature limits, and they are considered a probable carcinogen.

Mechanical Abuse. Because RCF is lightweight it cannot take mechanical abuse. Examples of mechanical abuse include:

- Walking on the fiber. This problem may occur when workers perform mechanical projects adjacent to RCF linings. (Brick is sometimes used for the bottom 6 feet of wall to minimize damage in furnaces that require extensive inspection.)
- High gas velocities and/or turbulence. Turbulence can create a pressure drop across the RCF that can tear it off the wall. RCF cannot be used if the furnace tubes are to be externally water-washed, or if soot blowers are used. (Section 2315 gives velocity limits for the types of RCF discussed there.)
- Low mass. Processes must have good controls because there is very little heat stored in the lining to compensate for poor controls or operating inconsistencies.
- RCF is a carcinogen similar to asbestos fiber, according to recent animal studies by TIMA. The fibers are carcinogenic in the unfired state as well as in the aged state. (See Section 500, "Safe Handling.")
- Aged RCF. RCF can become brittle with age at temperatures higher than 1800°F. This brittleness creates a hazard to workers and special precautions need to be taken during repairs (see Section 500 on Safe Handling).

High Susceptibility to Corrosives. Ceramic fiber linings are also very permeable. Furnace atmospheres of a corrosive nature can penetrate fiber linings quickly and

corrode the shell and anchor base. For this reason a vapor barrier is needed to keep corrosives from condensing on the furnace shell and anchor attachments. See Section 2312 for information on vapor barriers.

Reducing Atmospheres. When RCF is used in hydrogen or other reducing atmospheres, the iron and titanium oxides (and sometimes the silica) in the RCF can be reduced and cause the RCF to be more friable. Manufacturers have developed high purity RCF (low in TiO_2 and Fe_2O_3) for use in reducing atmospheres. However, RCF is generally not cost-effective as a lining in hydrogen atmospheres, because its thermal conductivity increases significantly and most H_2 applications require stronger materials.

Temperature Limits/Shrinkage. RCF shrinks at elevated temperatures due to crystallization or devitrification of the “glassy” fiber. The material undergoes irreversible thermal shrinkage of up to 5% in the plane of the lining and 10% in the through-thickness direction. Based on experience, the maximum use temperature of RCF products from an engineering standpoint is reached when shrinkage reaches approximately 3%. This usually corresponds to a temperature about 300°F **below** the manufacturer's recommended temperature limits. The maximum use temperature of these fibers can be raised by increasing the alumina content or by adding ZrO_2 or Cr_2O_3 .

Safe Handling Procedures. As a probable carcinogen, RCF must be handled differently from the way other types of refractory are handled. It generally must be kept wet when it is being removed and it requires stricter respiratory protection. These procedures add to the cost of the work. Section 500 and IRM-MS-4775 give the Company's guidelines on handling RCF.

2315 Forms of RCF Products

All grades of RCF are available in a wide variety of sizes and product forms with densities ranging from 3 to 50 lb/ft³ and continuous use temperatures up to 2800°F. RCF product forms include the following:

Bulk Fiber

Bulk fiber is the raw, unprocessed material as it comes out of the electric arc furnace after being spun or blown. Bulk fiber is used to fill expansion joints in linings made from castable or brick products and to fill narrow openings, such as those between RCF modules (if gaps open up), around entry ports in process furnaces, and around tubes. Using bulk fiber around tubes still allows for tube thermal expansion while maintaining an air-tight fit around tubes.

Typical published use temperature limits are 1800°F for low quality, high shot content RCF, 2300°F for standard and high purity RCF, 2600°F for specialty RCF, and 3000°F for high Al_2O_3 fibers. Actual limits based on a maximum of 3% shrinkage are about 300°F lower in most cases.

Blankets

Blankets are produced from bulk fiber using a needling process which interweaves the fibers and increases tear strength. For a fired heater lining, one or more layers of blanket are impaled onto metallic or ceramic studs, often over existing castable or brick linings to help cut energy consumption.

Where Used. This layer or “wallpaper” construction is used quite successfully in the enhanced oil recovery fields to line steam generators. Very thin (about ¼-inch) blankets have also been used in rheniformer reactors to fill expansion joints between the metal shrouds and castable refractory.

Limitations. Layer construction has been less successful in turbulent areas such as around corners and in convection sections where gas velocities exceed 30 ft/sec. Blankets have inadequate tear strength to resist velocity above 30 ft/sec.

Properties. Typical blanket properties are densities of 3 to 12 lb/ft³ and temperature use limits up to 2700°F.

Modules

Modules are either folded blankets or edge-stacked strips of blanket, with each manufacturer and installer having a proprietary fold and anchoring system. Both types of modules are pre-compressed to ensure a tight fit in service.

The folded layer construction is preferred because it is more durable and gaps are less likely to occur. When the fiber shrinks in edge-stacked modules, cracks can open up.

Advantages of the modules over blankets are:

- They are easier to install and replace if damaged in service
- They can be precompressed when installed to produce linings with greater density and greater tear strength so they can handle higher gas velocities
- Anchors in modules are less likely to fail by oxidation since they are buried in RCF
- The module precompression compensates for some of the fiber shrinkage in fired linings

Where Used. Modules are used to line a variety of cabin-type heaters, ammonia primary reformer furnaces, crude unit furnaces, hydrogen reformers, ethylene furnaces and air preheaters. The method of lining is similar to that explained for layer construction; however, the precompression allows them to be used in turbulent services with gas velocities up to 60 ft/sec.

Properties. Typical module properties are densities of 6 to 15 lb/ft³ and temperature use limits up to 2700°F.

Boards and Other Vacuum-Formed Shapes

RCF boards are made from RCF fibers mixed with an organic/inorganic binder and formed into a rigid product by a process called vacuum-forming. The organic

portion of the binder is sacrificial in that it burns out in service but it reduces handling damage during installation. Other shapes are also made by this process, including furnace burner blocks. Vacuum-formed (V-F) boards and other products have high thermal shock and velocity resistance.

Where Used. Possible uses for boards are: 1) over layered blanket for higher velocity resistance, and 2) under castable refractory for lower thermal conductivity. Other V-F shapes can be used in turbulent high-velocity areas such as ductwork and flueways, and as burner blocks. V-F modules are also used at corners (bullnoses) in module installations.

Properties. Typical properties of V-F boards and shapes are densities of 10 to 50 lb/ft³, velocity resistance up to 80 ft/sec, and temperature use limits up to 2700°F.

Sprayable RCF

As of 1988, the Company has very little experience with sprayable RCF. It is the newest material to enter the RCF product line and consists of RCF fibers and inorganic binders. Although it can be used as the primary refractory lining, it was designed mainly for retrofit and repair over existing hot face firebrick or castable linings.

Where Used. Areas of application include furnace linings and process heater and reformers. The material is pneumatically applied (gunned).

Properties. Typical properties of a sprayable RCF lining that has been fired by being placed in service are densities of 6 to 10 lb/ft³ density and 2400°F temperature limit.

Moldable RCF

Moldable RCF is bulk RCF with an organic binder. It has the consistency of putty. Moldable RCF can be used to cover exposed anchor ends or for small repairs. It has a dried density of 40 to 50 lb/ft³ and a maximum temperature limit of 2300°F.

Wet Blanket

We have little experience with wet blanket RCF but believe it can be useful for small repairs. Wet blanket RCF is simply RCF blanket soaked in a colloidal silica binder. The blanket is flexible and formable until it dries and hardens. It dries quickly and can be put in service even before it is dried. Its maximum continuous use limit is 1900°F and its density is 12 to 24 lb/ft³ dry.

Rigidizers

We generally recommend against using rigidizers. Rigidizers are not actually an RCF product. They are a colloidal silica or alumina coating used over RCF to harden the surface and make it more resistant to mechanical damage and velocity. They can be used up to 1900°F. We have little experience with rigidizers, but we have heard some reports of their peeling off in sheets and damaging downstream equipment.

RCF Mortars and Cements

RCF manufacturers also supply high-temperature mortars and cements to be used with their RCF products. The mortars and cements are usually Al_2O_3 -based and air-setting. They are used to bond RCF to itself or to other refractory types, such as brick or castable (as long as the surface is sound and free of oxide scale). The products come in different consistencies and/or can be diluted to the desired consistency. They can be troweled, sprayed, or painted on, or the surface to be protected can be dipped in the mortar. Cements and mortars do not require controlled dryout; they can be put in service immediately. Products are usually limited to 2300°F, although some manufacturers claim temperature resistance to 2800°F.

2316 Choosing the RCF System

This section discusses the major design parameters that determine the type of RCF system to use in a given furnace and describes how these parameters come into play in choosing an RCF system. These design parameters, which the contractor must know, are as follows.

Design Parameters

- Normal operating temperature
- Maximum operating temperature
- Desired cold face temperature
- Ambient temperature
- Exterior wind speed
- Maximum gas velocity
- Type of fuel
- Furnace atmosphere
- Furnace operation (continuous/cyclic)
- Lining thickness limits imposed by furnace geometry

RCF Temperature Limits

We recommend staying at least 300°F below the manufacturer's maximum continuous use temperature. As an alternative, you could require the manufacturer to give data that show less than 3% shrinkage at the intended maximum use temperature.

Thickness of RCF

The operating temperature, cold face temperature, and RCF thermal conductivity (K factor) are used to determine what thickness of RCF is needed. K factors vary depending on the product chosen. More dense products generally have lower K factors. The K factors also depend on the environment (e.g., K factors in hydrogen are higher than they are in air). Manufacturers and RCF installation contractors have computer programs that can determine the most cost-effective system based on the design considerations for a specific job. Section 2100 of this manual presents heat flow calculations.

Density of RCF

Layered Blanket Systems. The top two layers should be 8 lb/ft³. Below that 6 lb/ft³ blanket can be used. We do not recommend using blankets with density lower than 6 lb/ft³.

Blanket/board Systems. Board density should be at least 10 lb/ft³, followed by one 8 lb/ft³ blanket layer, and the rest of the layers 6 lb/ft³ blanket.

Modules. They should be made from 8 lb/ft³ blanket. When the modules are compressed, the density will be about 9 lb/ft³.

Type of RCF to Use

The choice of the type of RCF to use (blanket, modules, board) will depend on several factors:

Velocity Resistance and Durability. Blanket systems are limited to velocities less than 30 ft/sec; modules can be used up to 60 ft/sec. Blankets with board on top can be used to about 80 ft/sec maximum. Modules are most resistant to mechanical damage, followed by boards, and finally by blankets, which are least resistant.

Maximum Operating Temperature. At high temperatures (above 2000°F) layered blanket installation is not recommended because shrinkage affects layered blankets more than it does modules or blanket/board systems. Modules or blanket/board systems should be considered where the temperature exceeds 2000°F.

Economics. In new construction (furnace being built in shop), layered blanket construction is usually less expensive and more common than modules. In the field where plant downtime must be taken into account, modules are usually more cost-effective because they can be installed more quickly. At temperatures where ceramic anchors are required (above 2100°F), modular systems are often more cost-effective than blanket/board systems. Both should be considered and their costs compared. Being more rugged, modules will generally last longer than a layered blanket system. They are also easier to repair.

Sometimes a combination system is the best choice, with blanket back-up layers and modules. The combination system can be cost-effective since lower density, less expensive blanket is used as the back-up layer for thinner modules of high temperature, higher density (more expensive) material. Bakersfield has used this design in many of its steam generators.

2317 Manufacturers of RCF Systems and Vapor Barrier

See Figure 2300-5 for manufacturers of RCF and Stalastic.

Fig. 2300-5 RCF and Vapor Barrier Manufacturers

Manufacturer and Location	Product Name	Phone Number
Harbison-Walker Pryor, OK	Inswool	(918) 825-1044
Premier Refractories Valley Forge, PA	Cer-wool	(610) 337-1100
Johns-Manville Denver, CO	Cerafiber	(303) 978-2000
Thermal Ceramics Augusta, GA	Kaowool	(706) 796-4200
NUTEC	FiberTec	(215) 493-0131

2318 Chevron RCF Installations

Figure 2300-6 shows examples of where Chevron has used RCF.

2320 Insulating Firebrick (IFB)

There is still a place for IFB in fired heaters and furnaces. Although RCF linings can be used successfully in a number of areas and applications, there are some places where IFB and other types of refractories are the better choice.

IFB are available in different thicknesses (2½ inches and 3 inches) and in different sizes. With use of standard IFB, the brick portion of the wall can be 4½ inches, 6¾ inches, or 9 inches thick. Linings using IFB thicker than 9 inches would be very rare in our applications.

Where Used

IFB are often used as the hot face lining for the bottom 6 feet of accessible vertical walls in furnaces which require extensive inspection during a shutdown. In certain types of reformer furnaces, IFB should also be used for 4 to 6 feet of lining above terrace or flower box-type burners. Other applications for IFB are areas of flame impingement and around burner blocks. Selsas ethylene furnaces (that have a number of radiant-type burners in the sidewalls) use IFB as the primary sidewall lining material. Figure 2300-7 gives temperature limits for common brick types.

Construction Method

As a general rule, a large wall area having IFB lining and block insulation backup will use sectionally supported wall construction. An example of this design is shown in Figure 2300-8. Note that the IFB are supported in rectangular sections on horizontal steel angles welded to the wall structure. This allows for thermal expansion in both directions (vertical and horizontal) and minimizes weight load on the IFB at the bottom of each section. Other types of anchors are also used in these lining systems; e.g., hooks with points that are embedded in the IFB and attached to shell at other end. The metals selected for anchors and tie-back in these systems

Fig. 2300-6 Chevron RCF Installations

Location	Plant/Equipment	Type RCF	Date First Installed
Pascagoula	Rheniformer I/F-1501, 02, 03	Layered Blanket	1974
	H2 II/F-6410	Layered Blanket	1976
	Ammonia/F-2501	Layered Blanket	1977-8
	H2 I/F-1401	Layered Blanket	1979
	Crude Unit I/F-1101, 02	Layered Blanket	1980
	Crude Unit II/F-6101, 02	Layered Blanket	1983
	H2 III/F-8610	Layered Blanket	1983
Richmond	3 Battery Crude/F-1, F-2	Modules	5-87
	10 Battery Crude/ F-1	Modules	10-87
	H2 III/F-8610	Modules	3-88
El Segundo	Isomax H2/F-301 roof only	Modules	—
	Isocracker/F-610A	Layered blanket	1977
	#2 Cat Reformer/F-440	Modules	1986
Port Arthur	AVU 146/H-101, 102A+B new construction, heater walls	Blanket	1981
	AVU 141/H-1, 2 new construction, heater walls	Blanket	1982
	AVU 142/H-1, 2 new construction, heater walls	Blanket	1982
	DCU 1994/F-1 new construction, heater walls	Blanket	1982
	CRU 1342/PH-400, 401 refractory replacement, heater walls	Blanket	1982
	GFU 244/F-101, 102 new construction, heater walls	Blanket	1982
	GFU 2141/F-102 new construction heater walls	Blanket	1984
	DCU 841-1B refractory replacement, convection walls	Blanket	1987
	FCCU 1242/B-102 refractory replacement, external walls	Chopped RCF sprayed	1987
	FCCU 1242/precipitator refractory replacement, external walls	Blanket	1987
Bakersfield	Steam generators ⁽¹⁾		1981

(1) Currently, a combination system of blanket/modules. Previously used modules alone.

Fig. 2300-7 Temperature Limits⁽¹⁾ of Various Brick

Brick	Temperature, °F
2300 IFB	2200
2600 IFB	2500
2800 IFB ⁽²⁾	2700
High-duty Fireclay	2800 ⁽³⁾
Super-duty Fireclay	2900 ⁽³⁾

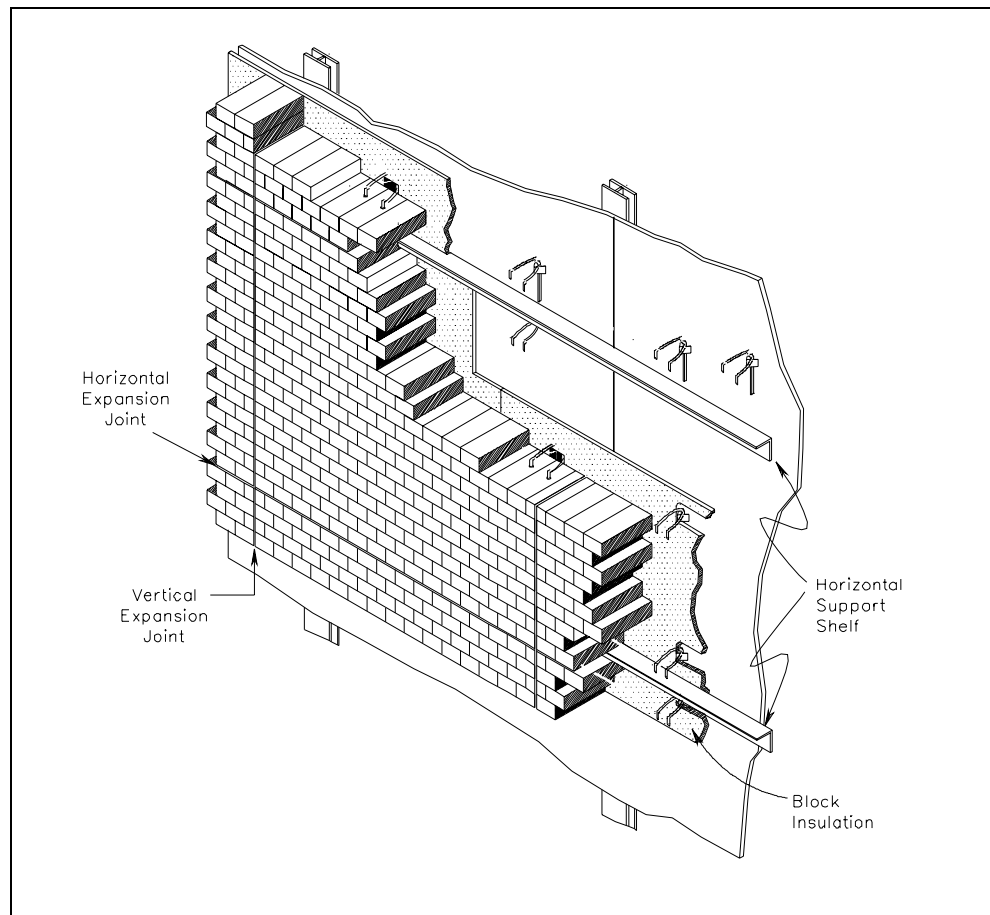
(1) This Chevron rating is based on shrinkage, etc., at elevated temperatures.

(2) There are also 3000, 3200, and 3300 IFB on the market. These three classes are used very rarely in fired heaters and other equipment in refineries and petrochemical plants.

(3) These values are for applications where brick are heated from one side only. Use hot load test data when designing bridge walls.

must be adequate to withstand temperatures and other exposure conditions of the specific application. (Use Tables 1A and 1B on Standard Drawing GD-N1262 to choose anchor materials).

Fig. 2300-8 Insulating Firebrick—Sectionally Supported Wall Construction



Expansion Joints

Expansion joints must be carefully designed. The width of an expansion joint should be a function of 1) anticipated maximum temperature, 2) the type (temperature use limit) of IFB being laid, and 3) whether or not the joint will be left open or filled with a compressible insulating material.

Calculation Method. Use the following steps to design expansion joints for IFB linings:

1. Calculate (expected) temperatures of the lining's hot face and of the shell.
2. Use Equation 2300-1 to calculate gross thermal expansion of the lining for a length (L) between expansion joints. Example values for the lining's hot face temperature, construction temperature, and distance between expansion joints are given in parentheses.

$$X_G = \alpha (T_h - T_c) L \quad (\text{Eq. 2300-1})$$

where:

- X_G = Gross width of expansion joint (cold), inches
- α = Thermal coefficient for most IFB $\approx 3.0 \times 10^{-6}$ in/in $^{\circ}$ F
- T_h = Hot face temperature of the lining, $^{\circ}$ F (= 2300)
- T_c = Construction temperature, $^{\circ}$ F (= 70)
- L = Length between expansion joints, inches (= 78)

Putting numerical values in the equation:

$$X_G = 3.0 \times 10^{-6} (2300 - 70) 78$$

$$X_G = 0.52 \text{ inches}$$

3. Calculate thermal expansion of the steel for the same length.
4. Subtract the results of step 3 from those of step 2. The final result is the required (net) width of the joint every 6.5 feet.

How Expansion Joint Filler Affects Joint Width. If the expansion joint is to be filled with a compressible material (for example, 6 lb/ft³ RCF blanket) the width of the joint should be about two times the calculated (net) value. This is based on 50% compressibility of blanket. Some RCF products are specifically designed for use in expansion joints. Staggered expansion joints are sometimes used with IFB. When used, they must be kept free of mortar.

Mortar

A good grade of wet-type air-set mortar is used to lay the IFB in place. This type of mortar takes a rigid set after air drying. It is prepared from fireclay and (sometimes) high alumina materials. Some of the finely-divided raw materials used in mortars have been calcined. Chemical binders (often sodium silicate) impart air-setting properties and maintain the strength of the bond up to the temperature at which ceramic bond takes effect. Air-setting mortars form mechanically strong joints and bond the wall the whole way through. Specify a mortar with adequate plasticity and workability suitable for laying IFB.

The wet-type mortars are easier to use than the dry-type. Even so, some mixing (and/or thinning, if dip joints are to be used) is often required at the job site.

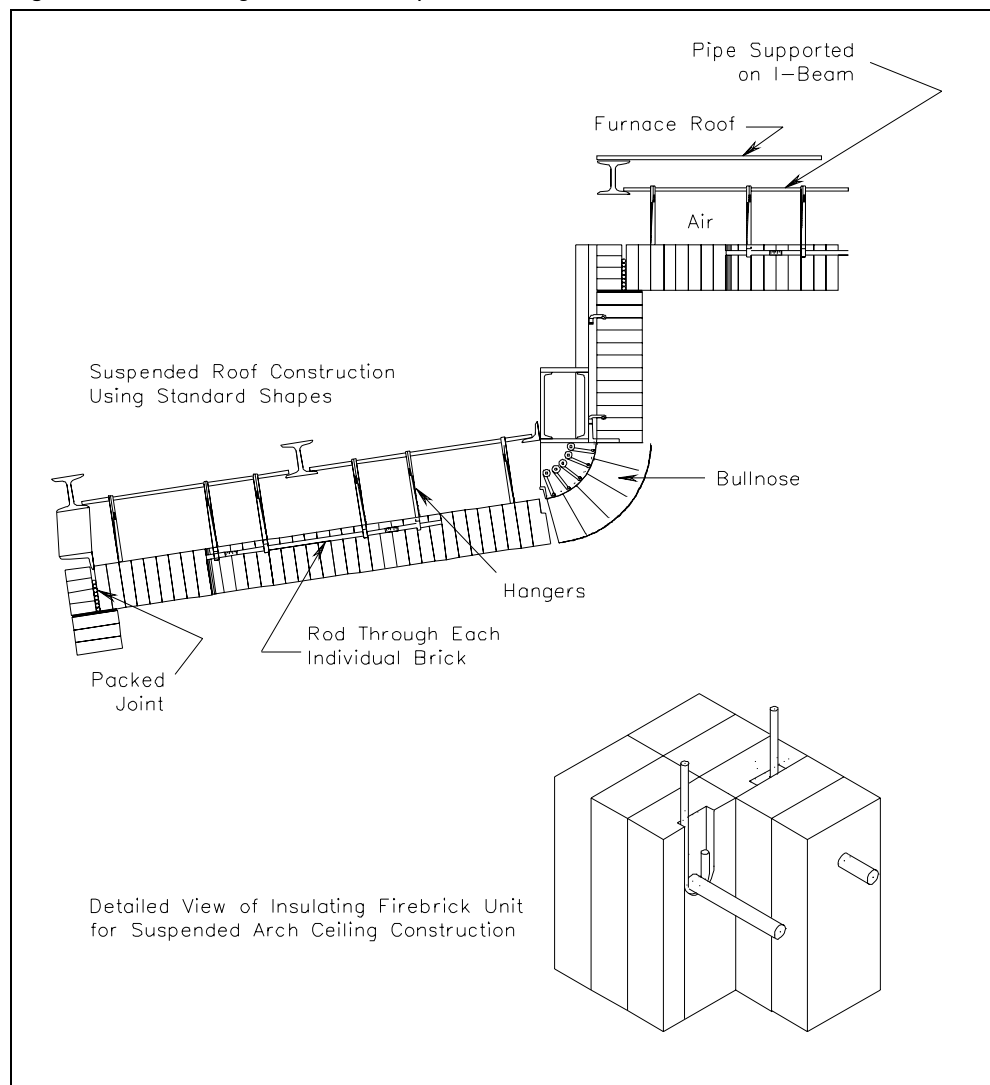
Do not use block insulation as the back-up lining when fuel high in sulfur (0.3%) is being burned. In this case, a less porous castable should be substituted.

Normally, the design of sectionally supported walls and suspended arches (Figure 2300-9) is handled by the supplier of the furnace. Repairs and maintenance of these linings are facilitated when design and maintenance specialists understand the basic concepts. There are only a few major manufacturers of IFB in the United States.

Quite often these producers have specialists who can advise on system design and/or maintenance problems.

A well-designed and installed IFB system is probably more rugged and reliable than an RCF lining system. It is also more expensive, however, so a choice will usually be based on cost effectiveness.

Fig. 2300-9 Insulating Firebrick—Suspended Arch Construction



2330 Castables

2331 Where Used

Insulating and semi-insulating castables are used in a number of applications in most fired heaters. Much of the convection section can be lined with insulating castable. Breechings and stacks are applications where either insulating or semi-

insulating castable is the best choice. These linings are often only 2 inches or 3 inches thick.

Two-layer castable linings are used in the radiant section of some fired heaters. These linings consist of a semi-insulating castable, perhaps 4 inches thick at the hot face, plus a 3-inch to 5-inch thickness of insulating castable as back-up. Anchors suitable for two-layer linings must be used with this design. This two-layer lining design places the more temperature-resistant castable closer to the fire.

A two-layer castable lining is sometimes used on the floor of fired heaters and process furnaces. In this case, a castable denser and stronger than an insulating castable is preferred for the hot surface to resist impact and mechanical wear. A more common design involves dense fireclay brick (laid loose, no mortar) on top of a cast-in-place insulating castable backup lining.

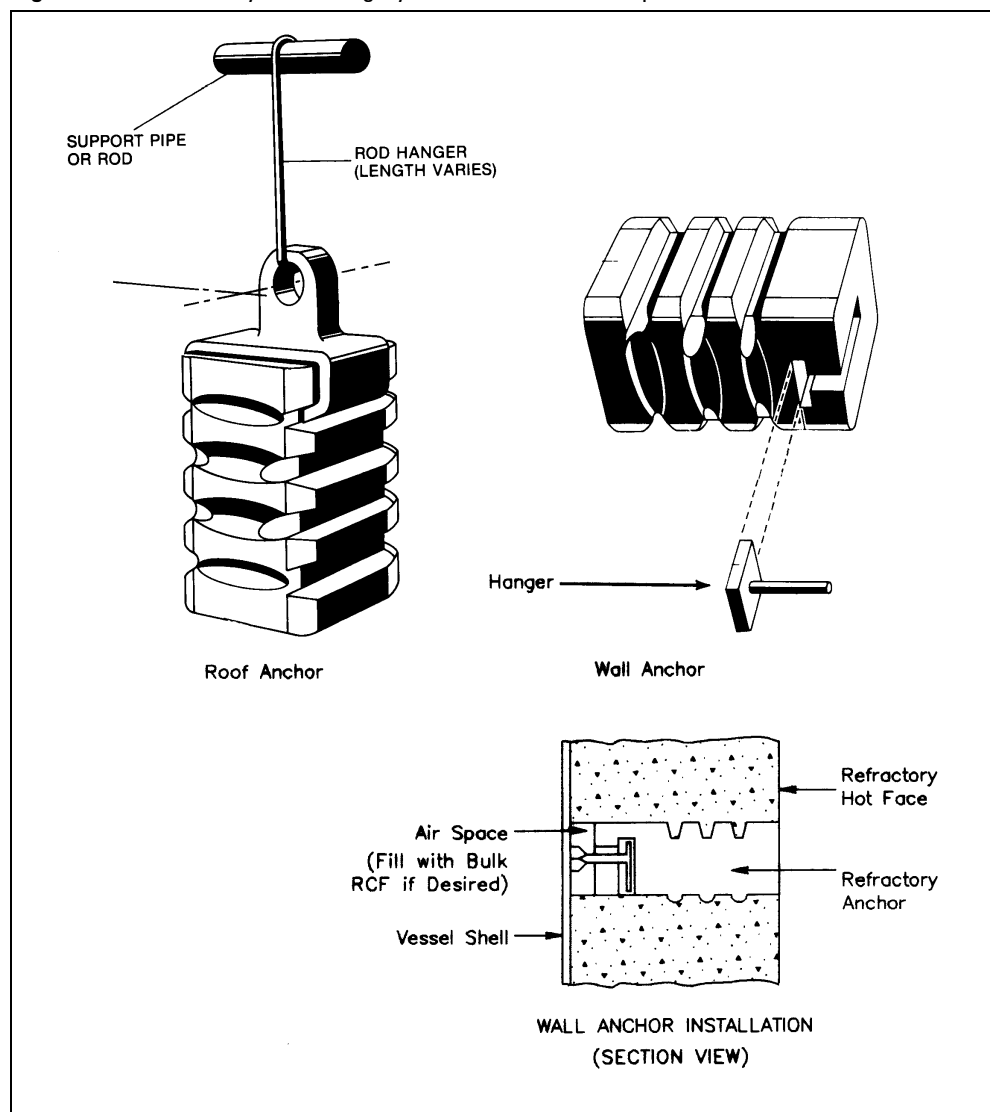
2332 L-H-V Insulating Castable

Lumnite-Haydite-Vermiculite (L-H-V) concrete is only acceptable for use where service temperatures will not exceed 1600°F. It consists of one volume of calcium aluminate (e.g., Ciment Fondu or Lumnite) cement, two volumes of expanded shale (Haydite), and four volumes of expanded vermiculite. This inexpensive field-mix refractory has been used often in fired heaters.

The major drawbacks to L-H-V are 1) uncertainty as to its quality and 2) its low cement content. In addition, the expanded shale and vermiculite are trucked to the job site in bulk form; control of raw material quality is a major concern. Some manufacturers offer pre-mixed (dry constituents), tested and bagged L-H-V or L-H-P (perlite) mixes. Raw material quality is less of a concern with these materials. Consider using L-H-V mixes only where the size of the project justifies the inspection level required to assure a quality lining. Increasing the calcium aluminate cement content of normal mix L-H-V by 50% improves overall quality.

2333 Anchors

If the castable lining will experience temperatures greater than 2000°F, a ceramic anchor (Figure 2300-10) should be used. For additional information on anchorage for castable linings, see Section 2210.

Fig. 2300-10 Refractory Anchoring Systems for Service Temperatures Greater than 2000°F

2340 Firebrick and Special Shapes

Although refractory material in existing furnaces is still mostly IFB, only minor quantities of IFB are installed in modern fired heaters. Major uses are:

2341 Divider Walls

These walls are used to "divide" a furnace in half with each half having a different function or operation. In some ethylene furnaces, divider walls are also used to produce different horizontal zones. This arrangement improves the overall thermal cracking process by independently controlling the heat input to each zone. Either super-duty or high-duty fireclay brick is used depending on firebox temperature and height of the wall. Some walls are designed with super-duty brick for the lower half of the wall and high-duty brick for the remainder. Such walls must rise from a solid

foundation. They require expansion joints (unless very narrow), good design, and good construction. Brick for divider walls must have good “hot load strength” in addition to good dimensional tolerances.

2342 Floors

High duty fireclay brick are often laid dry (without mortar) as the working floor of fired heaters.

2343 Use of Special Shapes

Special shapes are used to form burner rings, burner blocks, bullnoses, peep sight openings and doors. Such shapes are often made from super-duty fireclay or vacuum-formed (V-F) ceramic fiber modules.

2350 Plastic Refractories

Plastic refractories find only limited use in fired heaters because of their density, low thermal insulating value, and their heat-set bonding characteristic. They are sometimes used to form burner blocks (in place) and occasionally to construct a burner wall containing a number of burners. Super-duty and 50% Al_2O_3 plastics are good choices for these applications. Sometimes, an air-set plastic is advantageous for burner blocks. Contraction cut lines are required to control shrinkage cracking, and small vent holes are required to allow steam venting during dryout.

Since plastic refractory is dense (approximately 150 lb/ft^3) and has a fairly high K factor, a back-up layer is normally used to reduce heat loss and shell temperature. The back-up layer may be block insulation or insulating castable which is gun-applied.

These plastic refractories normally are held in place by special anchors made of refractory material (rather than stainless steel). These refractory anchors (Figures 2300-11 and 2300-12) are much larger than metal anchors, extend to the hot face of the plastic lining, and are located on wider spacings than (metal) anchors used with castables. They normally are tapered and contain corrugations to improve holding power. Various types of metal linkages are used to connect anchors to the shell.

Use of plastic linings is generally confined to incinerators, boilers, and burner walls in some fired heaters where the lining should be rugged and should resist slag attack and thermal spalling.

Fig. 2300-11 Typical Anchor and Connecting Links (Hangers) for Plastic Refractory Wall Installations

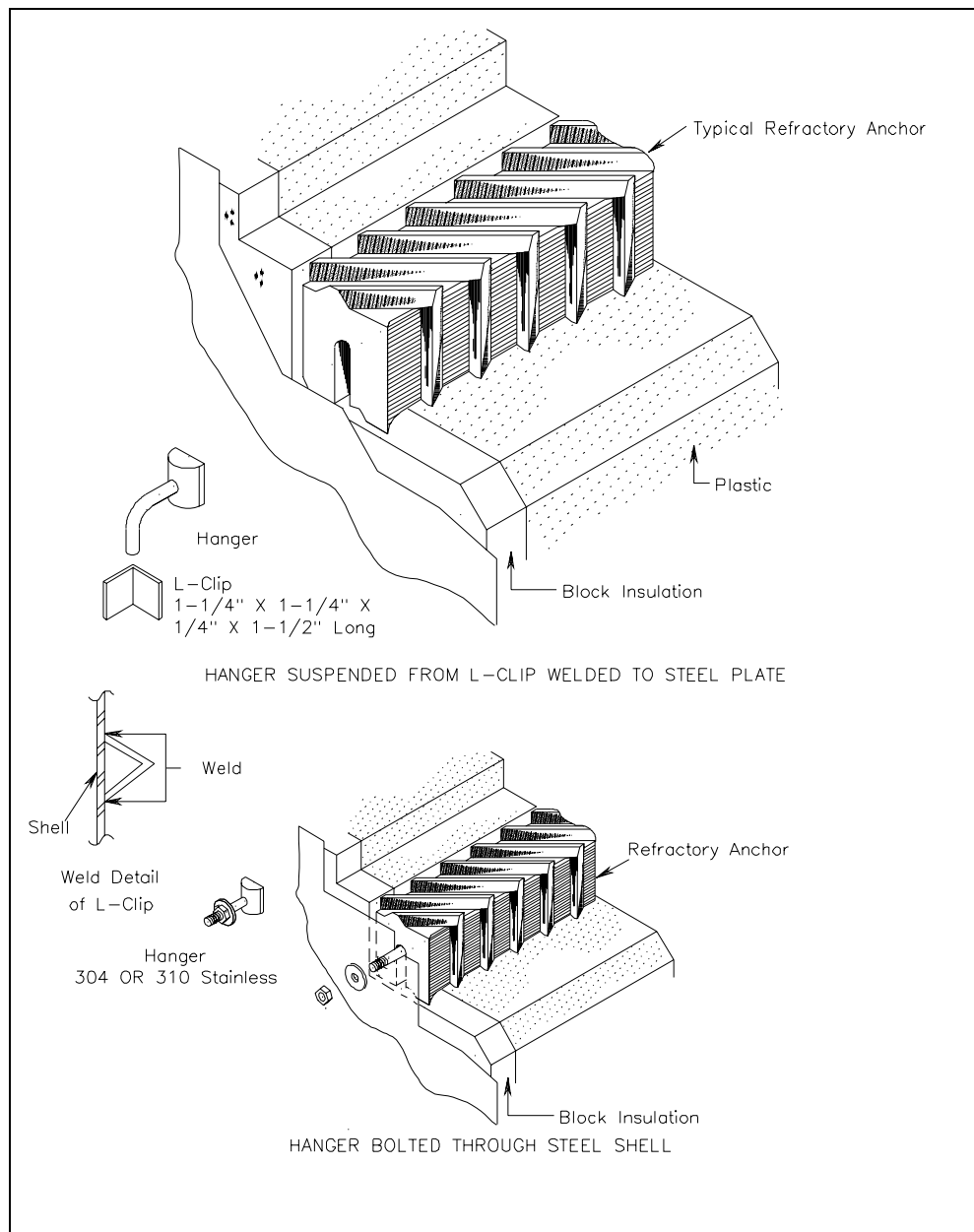


Fig. 2300-12 Metal Wall Anchor Assemblies (Supplement Refractory Anchors)