

2800 Repairs

Abstract

This section will help you identify refractory linings that need repair and choose a successful repair method. A list is given of items to consider before beginning a major repair; causes of lining failures are given; and typical refractory repairs done on refinery and petrochemical equipment are outlined. IRM-MS-4775 is a specification for safe handling of RCF and crystalline silica materials found in most refractories, especially during removal operations.

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2810 Evaluating Existing Linings

The Company often relies on a refractory installation contractor to mark areas for repair. Relying on the contractor's word alone can cause the Company to buy more repair work than is needed. This part of the repair section is designed to show Company engineers what failed refractory linings look like and the repair/replacement needed. The examples shown are limited by the photos currently on file. Although there is usually little time or opportunity to photograph repair areas during a shutdown, such documentation will help those responsible for evaluating existing linings. The red Local Documents section of Part 2 in your manual is a good place to keep photographic records.

Figures 2800-1 through 2800-5 show hexmesh- and S-bar-anchored linings in various stages of deterioration. Figures 2800-6 through 2800-8 show problems with thick monolithic linings with metal fiber reinforcement and vee-type anchorage.

Fig. 2800-1 FCCU Reactor Feed Riser (coke service)—*Hexmesh has bulged. Replace both hexmesh and refractory.*

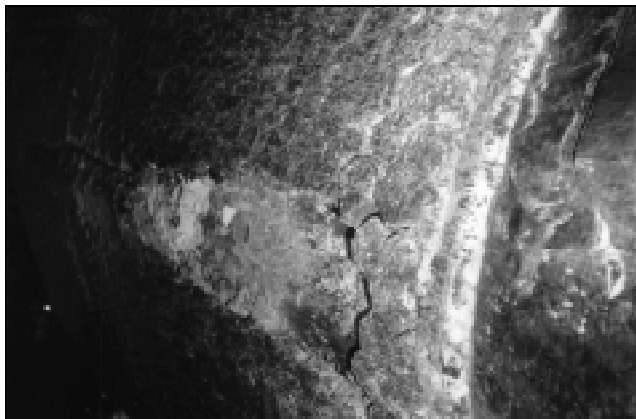


Fig. 2800-2 FCCU Cyclone—*Refractory and hexmesh have washed out. Metal has eroded down to the lances and clinches. Replace both hexmesh and refractory.*



Fig. 2800-3 FCCU Large Slide Valve—Approximately ½ of the hexmesh and S-bar anchorage is showing. Chop out and replace unsound refractory. Anchors do not need replacement.



Fig. 2800-4 Unidentified Area Showing Loose Refractory Biscuits—Hexmesh was incorrectly installed and formed narrow gaps which were impossible to pack properly. Replace both hexmesh and refractory.

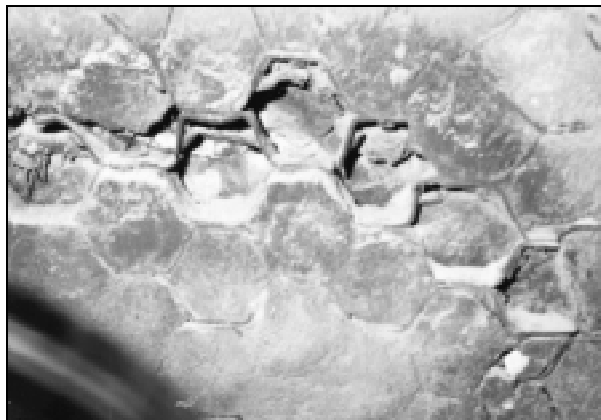


Fig. 2800-5 FCCU Regenerator U-bend—Erosion of Aeration Nozzle—Chop out and replace nozzle refractory. Metal of surrounding hexmesh shows, but this is acceptable. No anchorage repair needed.



Fig. 2800-6 FCCU Regenerator, Below Grid—*Laminated refractory and non-distributed metal fibers means poorly mixed material at installation time. Photo taken after 3 years of service. Replace both refractory and anchorage.*



Fig. 2800-7 Secondary Reformer Vessel—*Large void exposing back-up layer of two-component lining. Replace hot face and back-up layers and re-weld any anchors that come loose during refractory removal.*



Fig. 2800-8 Secondary Reformer Vessel—*Hot spot at anchor void just below vapor stop ring. Replace hot face and back-up layers and re-weld any anchors that come loose during refractory removal.*



2820 Analyzing Repair Needs

There are 12 pertinent questions to ask when considering a major refractory repair. Answers to these questions will greatly facilitate a successful repair.

1. Why did the lining fail? This question has been discussed in detail in Section 2100 and is covered briefly in Section 2830.
2. Was the failure premature? If the service life was quite good, repair/replace-ment with the “existing” lining may be the right answer. On the other hand, if failure was definitely premature, an entirely different improved lining system should be considered. As a general rule, linings should last at least 10 years or more.
3. Is time available to do a good-quality repair? If a quick repair is to be made, will it last until the next major shutdown?
4. Exactly how much of the existing lining must be removed? Visual observation of the deteriorated lining is the first step. Hammer testing is quite helpful with many lining systems. Taking core drill samples is sometimes warranted. Anal-yses (chemical, x-ray diffraction, etc.) are useful when chemical attack or slag-ging is involved, particularly when you are seeking a long-range solution.
5. What type of material (castable, RCF, plastic, etc.) should be used to repair the lining? In other words, is a better lining system available? RCF modules are generally replacing IFB and castables in fired heaters.
6. If the same type of material is to be used, is a better product available? Supe-rior products are being marketed as a result of new developments in ceramic technology. Have the new products been successfully service tested?
7. Does the Contractor have experience installing the intended refractory system?
8. If the repair involves replacement with monolithic refractory, will new or better anchors be used? In most cases, the answer is yes.
9. What should be done at the junctions of the old (existing) lining with the new?
10. If the repair involves castable refractory (or chemical setting plastic), should stainless steel fiber reinforcement be used? Fiber reinforced linings have many advantages when properly used.
11. If rapid start-ups are an operational necessity, will organic fiber additions be used to allow more rapid dryout?
12. Will third party inspectors be hired to ensure a good-quality refractory installation?

2830 Causes of Lining Failure

There are many causes and potential causes of refractory lining failures. These are discussed in detail in Section 2140, “Failure Mechanisms,” and briefly below. Causes may be divided into three categories.

Operation-related. This group of failures encompasses factors directly related to how the unit, furnace or other heated equipment is operated:

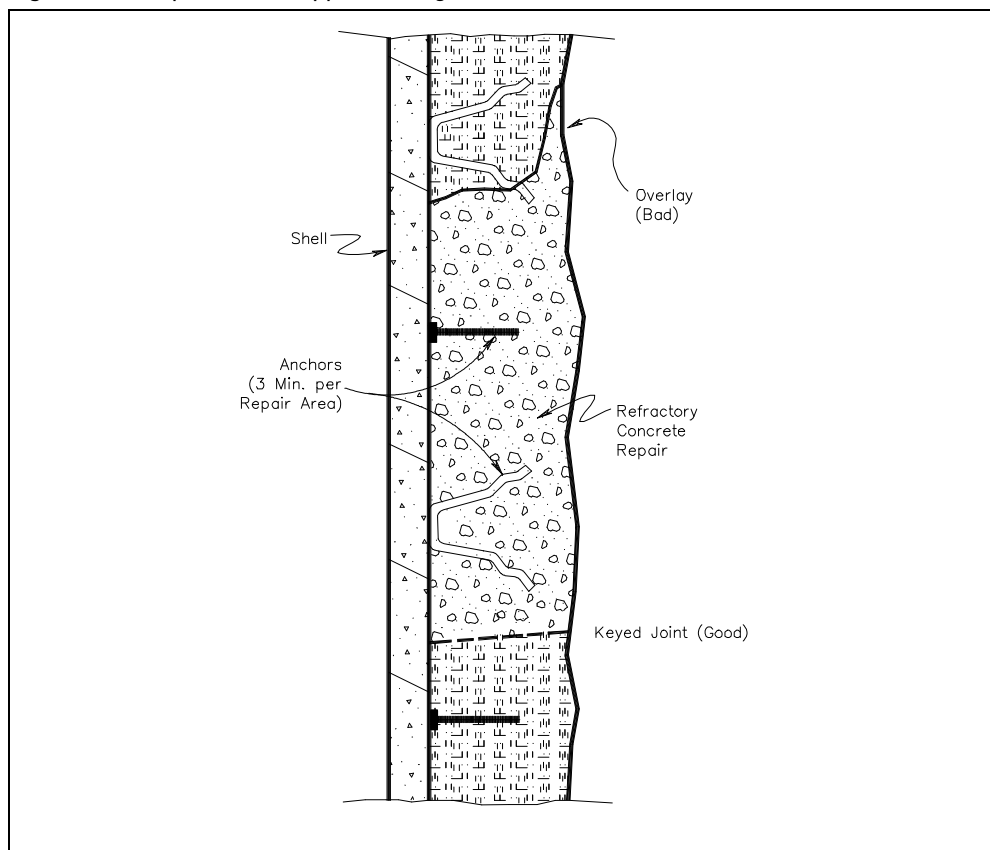
- Excessive temperatures
- Thermal stress and thermal shock
- Erosion
- Gas attack (H₂, high-pressure steam, CO, SO₃, etc.)
- Slag attack (a problem with some types of boilers and incinerators)
- Mechanical abuse
- Too rapid startup of the unit (very rare, but it has occurred—usually *with* extenuating circumstances)
- Startup of a unit whose refractory lining is wet or contains ice crystals (See Section 2700 for a modified dryout procedure)
- Old age

Design-related. This category of lining failures includes factors that were (or should have been) considered when the failed or deteriorated lining was designed. Included are:

- Refractory materials (including mortar used to lay brick)
- Anchors or anchorage materials and design
- Expansion allowances (important when brick, special shapes, or metal shrouds are involved)
- Mechanical considerations (e.g., excessive compressive stresses in a lining that is too thick)
- Auxiliary equipment (of particular importance are vapor stop rings, cones, shrouds, etc., to prevent by-passing of gases and hot spots)

Installation-related. This group of failures is perhaps the most obvious. Although inspection and testing are emphasized now, and should diminish the number of installation-related failures in the future, consider the following:

- Anchors or anchorage improperly installed
- Poor refractory workmanship
- Improper application of *gun-applied* castable linings (e.g., laminations and overlays. See Figure 2800-9.)
- Insufficient (ambient) curing
- Improper dryout (includes both too fast—which is rare—and too little)

Fig. 2800-9 Repair in Gun-Applied Lining

2840 Typical Repair Examples

In this section, typical examples of refractory repair are discussed, along with their solutions. Refractory types are defined on Standard Drawing GB-N1268.

2841 FCCU Regenerator Wall

Lining on the sidewall was deteriorating. Visual inspection and hammer testing defined areas to be replaced. This partial failure was the result of catalyst erosion, wear-and-tear, and not using a preferred castable during previous repair. The existing lining was cut back nearly perpendicular to the shell with a slight keyed taper where full 4-inch thickness of sound lining remained. A small jackhammer was used to remove the deteriorated refractory. The shell was abrasive blasted before the (new) 3-inch Type 304 wavy Vee anchors were welded in place. A 9-inch center-to-center, square pattern was used. The 83 pcf “one-shot” Type E castable was fiberized with 4% by weight of 1-inch long, Type 304 stainless steel (“melt-extraction”) metal fibers. After first wetting the entire repair area, the material was gun-applied. A colored membrane curing compound was sprayed on the repaired lining about one hour after installation. See Figure 2800-9 for details.

2842 Flue Gas Line, FCCU

The 5-inch thick, dual-component (hexmesh and 1-inch erosion-resistant castable at hot face) lining was failing from buckling and weld failures on the hexmesh-stud anchorage, and there was thermal shock damage around steam sprays. Erosion was not a significant factor in this straight run where the lining was replaced.

All of the old lining (and studs, etc.) was removed down to the shell. The shell was abrasive blasted and 4-inch long, 1/4-inch diameter footed wavy Vee anchors were welded in place on an 8-inch center-to-center, square pattern. L-studs, 3/8 inch in diameter, were installed around the removed hexmesh area to hold the adjacent hexmesh edge in place. A single layer of erosion-resistant castable (Type D2) was gun-applied to the shell to the same 5-inch thickness as the original lining. The castable was fiberized with 3% by weight of Type 304 stainless steel melt extraction-type fibers, 1 inch long. The castable contained fused silica aggregate (Type D2) for thermal shock resistance.

2843 Regenerator Cyclones, FCCU

Repair methods in regenerator cyclones are dependent on the type of anchorage and the amount of wear. Many of these cyclones have hexmesh anchorages filled with phosphate bonded castable or plastic. The usual guideline for inspection is full depth replacement if the clinch, located in the middle third of the hexmesh cross-section, is visible. If the clinch is not visible, at least two-thirds of the original thickness remains and the lining will probably last for another run. New offset hexmesh specified in Section 2200 has the lance/clinch located nearer to the shell, which provides 40% more erodible thickness before exposure of clinches. Replacement criteria are the same.

Full depth replacement calls for removal of the existing lining and worn hexmesh and installation of new anchorage—preferably S-bars. S-bars work well in cyclone repairs and are easier to install during shutdowns with limited time and unusual replacement configurations. If repair areas are large, hexmesh may be the least costly anchorage system to install. Plastic refractories (Type C) should be thoroughly rammed into the anchorage.

This system, which has been successfully used to patch 1-inch thick linings in regenerator cyclones, is not directly applicable to the erosion-resistant linings in reactor cyclones. The latter cyclones are subjected to steaming during FCCU startup operations. In addition, properly designed, installed, and “baked” linings in reactor cyclones very seldom need repairs. Erosion is less severe on the reactor side, and coke impregnated refractory appears to have superior erosion resistance.

Buttercoating. Buttercoating (the filling in of eroded areas less than 1/4-inch in depth) may be thought of as replacing the corrosion or wear allowance of the refractory. Buttercoating is practical where refractory surfaces have worn slightly (no greater than 1/4-inch) but hexmesh clinches are still not visible. If left unrepaired, major repair work, involving hexmesh replacement, etc., would likely be required at the next shutdown. Cyclone refractory repairs are expensive and difficult due to confined work areas. Buttercoating extends the life of cyclones before major

expenditures for hexmesh/S-bar repairs are required. The only brand of refractory for buttercoating is Kaophos Buttercoat manufactured by Thermal Ceramics. See Section 4100 for address. The success of buttercoating depends on:

1. Thorough cleaning of refractory surface by scraping *and* air blowing to remove all loose refractory and catalyst.
2. Prewetting of surfaces just prior to buttercoating.
3. Mixing of buttercoat to thick putty consistency. Too much water reduces erosion resistance.
4. Application by trowel, with buttercoat worked into all voids and depressions but screeded off level with hexmesh surface.

2844 Naptha Reformers

The usual problems involve hot spots on the shell caused by process gas flowing behind the lining. Any failure of the shroud welds will result in a hot spot at the shell. After repair of the shroud support, the refractory patch should be replaced in the same design as the surrounding lining, and the shrouds then replaced.

Erosion is usually not a problem in naptha reformers because the catalyst is in a fixed bed. However, the frequent regeneration produces thermal expansion and contraction stresses which can lead to excessive cracking of shrouds. Castable to be used should have a low iron content (Type H) and stainless steel fibers should be incorporated in the lining to help it resist excessive fracturing and loss of fragments.

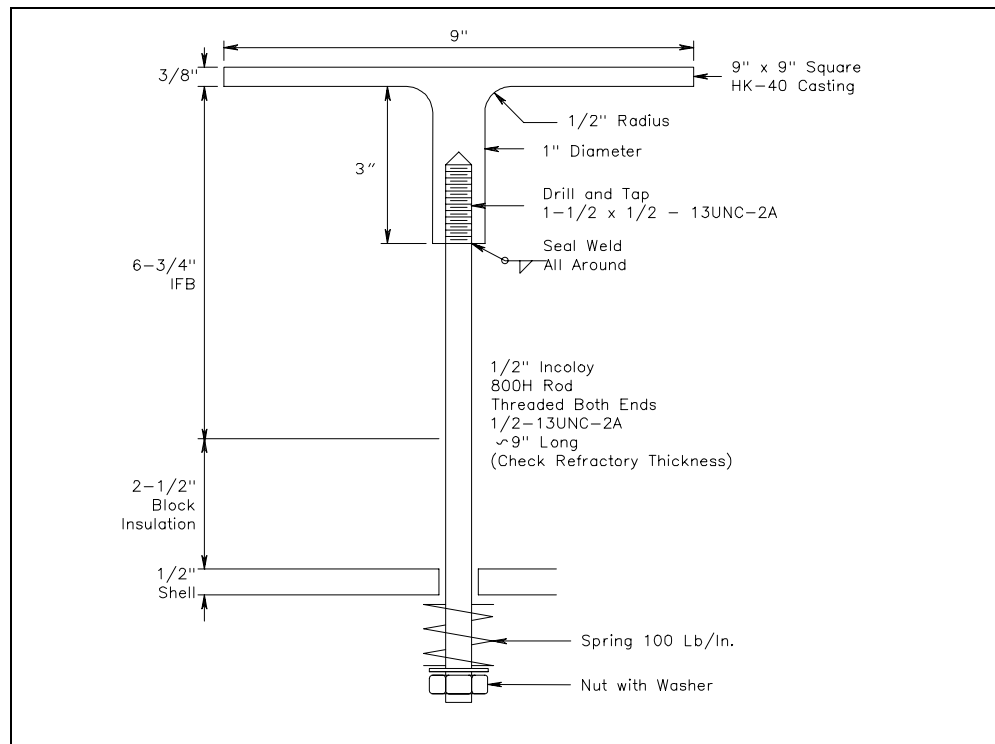
2845 Transfer Line in H₂ Plant

This is the transfer line between the primary reforming furnace and the waste heat boiler. Serious failure of the shroud/insulating castable system required complete lining replacement. The shroud and vapor stop cone system was redesigned for easier installation and improved thermal expansion. A 90 pcf fused silica refractory (Type D2 on Standard Drawing GB-N1268, specifically the brand HW Thermax ES-VC) was installed by vibration casting. Shrouds continue to be a problem. Future fixes may use single component linings without shrouds.

2846 Wall Lining, Primary Reforming Furnace

After many years of operation, the IFB and block insulation (back-up) walls in a primary reforming furnace were moving away from the shell—leaning inward. This was the result of ineffective anchors. The anchors were Type 304 stainless steel and suffered creep and oxidation. A through-bolt anchor system was fabricated to tie back the brick/block lining and prolong lining life an estimated 5 to 10 years. Figure 2800-10 shows this tie-back anchor system.

Several ½-inch diameter holes were drilled through the refractory and steel shell on appropriate spacings. The through-bolt anchor rods were inserted through these

Fig. 2800-10 Refractory Tie-back Anchor

holes and nuts were installed on the outside of the shell. Successive and systematic tightening of the nuts moved the sectionally supported wall back toward the shell.

2847 L-H-V Lining in Fired Heater

This lining had deteriorated in some areas from thermal and structural spalling after several years of operation. The failed L-H-V and some existing anchors were removed. The shell was cleaned, new anchors were added as required, and insulating castable (60 pcf dried density) was gun-applied as thick as the original lining. Type 304 stainless steel fibers (1 inch long) were added to the insulating castable for installation in areas where the castable would not be severely overheated. Repairs are considered highly satisfactory.

As an alternative, systematic replacement of deteriorated L-H-V linings with one-square-foot RCF modules has become common practice. The method involves complete removal of L-H-V and anchors plus light sandblasting of the shell. Stalastic vapor barrier is installed after anchors are welded in place and then the modules are installed in the soldier course pattern. The first installation is very successful and more areas including side walls and roofs are being relined with these modules. Casing temperatures are significantly lower and more economical operation is reported.

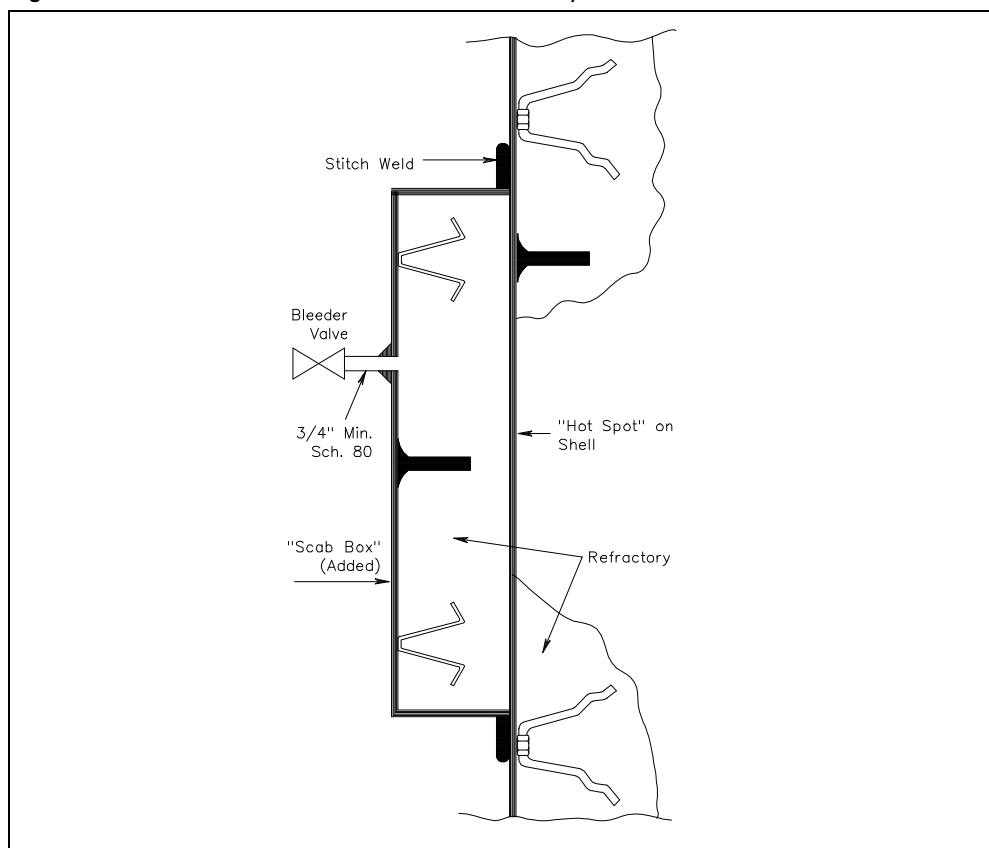
2848 "Hot Spot" Problems

Consider the use of color-indicating paint to identify hot spots in units that tend to give problems, such as transfer lines and rheniformer reactors. See the *Coatings Manual* for details.

Hot spot problems can be treated on-stream by a variety of methods. The easiest and most common involves directing steam lances on the hot shell where the refractory failure occurred. This is an effective temporary measure that has been used on hydrogen transfer lines and FCCU U-bends.

A second method involves fabrication of a refractory lined box (see Figure 2800-11) that is then welded to the shell over the hot spot area. The bleeder valve on the box provides pressure relief while the box is being welded in place and also provides a way to know the condition of the refractory by leak checking on the run. The box lining should be of the same material as the original lining, because once insulated by the box, the original shell will overheat and fail in a short time. This technique has been used on U-bends, feed risers, and standpipes.

Fig. 2800-11 Scab Box Added to Outside of Refractory Lined Section



A third method of repairing hot spots in furnace casings involves injecting a pumpable insulating material between the casing and the block/IFB lining that is sagging away from the wall. Deterioration of the block insulation also can create voids that can be repaired by using this method.

Thermal Ceramics' product Cease Fire 2000 is a two-component, inorganic refractory foam. One of the components is a dry powder that is mixed with water to form a semi-viscous slurry. The second component is mild phosphoric acid. When the two are mixed, a highly insulating, inorganic foam is formed. By means of special pumps (also available from Thermal Ceramics), the material can be placed inside the shell of the furnace. Generally, all that is required is to weld one or more bosses directly on the shell, drill holes through the shell, and pump the foam into place. It expands and sets quickly.

Pumping pressures should not be high enough to force the lining off the wall. If additional ports are available, this is generally not a problem. If the refractory failure has large gaps (greater than ½ inch) through which the slurry can escape into the firebox before the foam has a chance to set up, this method cannot be used.

Premier Refractories recently began marketing a pumpable ceramic fiber product that has improved thermal resistance over Cease Fire for higher temperature applications. See Figure 2800-12 for a listing of manufacturers of pumpable refractory.

Fig. 2800-12 Manufacturers of Pumpable Refractory

Manufacturer	Product Name	Maximum Temperature
Carborundum	Fiberfrax Pumpable LDS ⁽¹⁾	2300°F
Premier	Cer-Wool Hot Stop ⁽¹⁾	2400°F
Thermal Ceramics	Cease Fire 2400D	2400°F

(1) Contains Refractory Ceramic Fibers

2849 Repair of RCF Lining Systems

Ceramic Fiber Module Repair. Any missing or damaged modules can be replaced in kind. Be sure to check adjacent module anchors which may have become damaged during exposure. Any holes or cracks between modules should be stuffed tight with blanket or bulk RCF and then pounded out. When more than one module is involved, be sure to follow new installation guidelines, in Section 2610.

RCF Blanket and Blanket/Board Repair. Damaged blanket or board should also be replaced in kind.

The damaged area should be cut out so that the replacement material will have staggered seams. If studs need to be replaced, the blanket will have to be removed down to the furnace wall. Then follow the instructions for new installations, Section 2610.

Repairing with Sprayable RCF. Another way to repair minor damage to modules or blankets is with sprayable RCF. Sprayable RCF can not be used for very deep cracks or holes but could be used for surface damage. We do not have much information about how well sprayable RCF holds up and would not recommend its use unless it was much less expensive than other repair methods.