

2200 Lining Systems for Vessels and Lines

Abstract

Refractory lining systems for vessels and lines consist of a castable concrete material anchored to the inside wall. The systems differ from each other in anchoring method, in type of refractory material used and/or in how the material is applied. This section discusses types of anchorage and lining systems used for vessels and lines: their properties, advantages and limitations, and their recommended applications.

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2210 Anchor Systems

Good anchorage systems are required to hold the refractory lining tightly against the vessel wall. Important areas to consider are: metallurgy, the selection of the correct anchor, anchor height and layout, and the welding of the anchor to the vessel shell.

Anchor Material. Carbon steel anchors are not recommended for any service. Even in very mild service (e.g., gas treater linings), carbon steel anchors may rust. The cost of upgraded metallurgy for most common anchors to 12 chrome or 304 stainless steel is generally a very small percentage of the total refractory job cost.

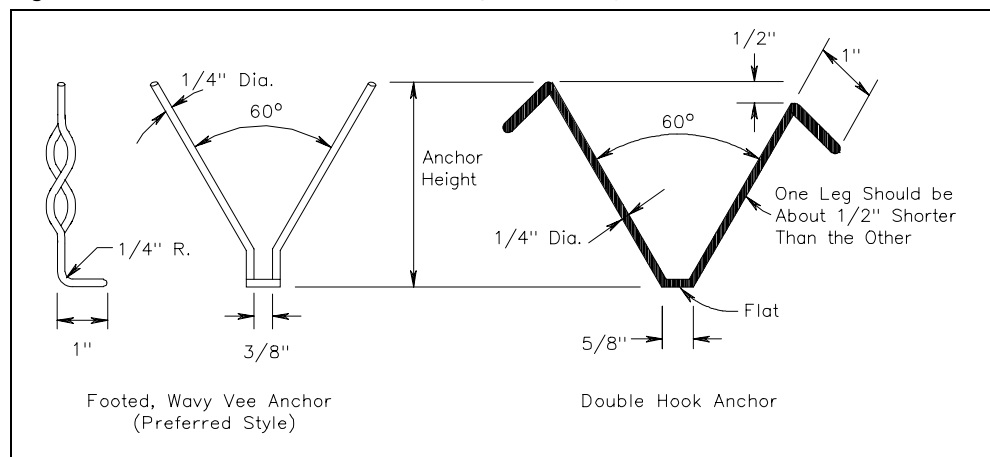
Anchor metallurgy is selected on the basis of hot face temperature, because cracks or spalls in the lining may expose anchors to process gas temperatures. The Company's recommendations are given in Table 1 of Standard Drawing GD-N1269. These recommendations are for clean (non-sour) service. For severe process conditions (i.e., high H_2S levels) call the refractory specialist in CRTC's Materials Engineering for help.

In FCC units, the reactor side typically uses 410S anchors (S denotes the low carbon version of 410, which is more readily weldable) and the hotter (1250° to 1300°F) regenerator side uses 304 metallurgy.

Type of Anchor or Anchorage System. Types that the Company uses are: various vee anchors, hexmesh and S-bars, and other unitized anchors.

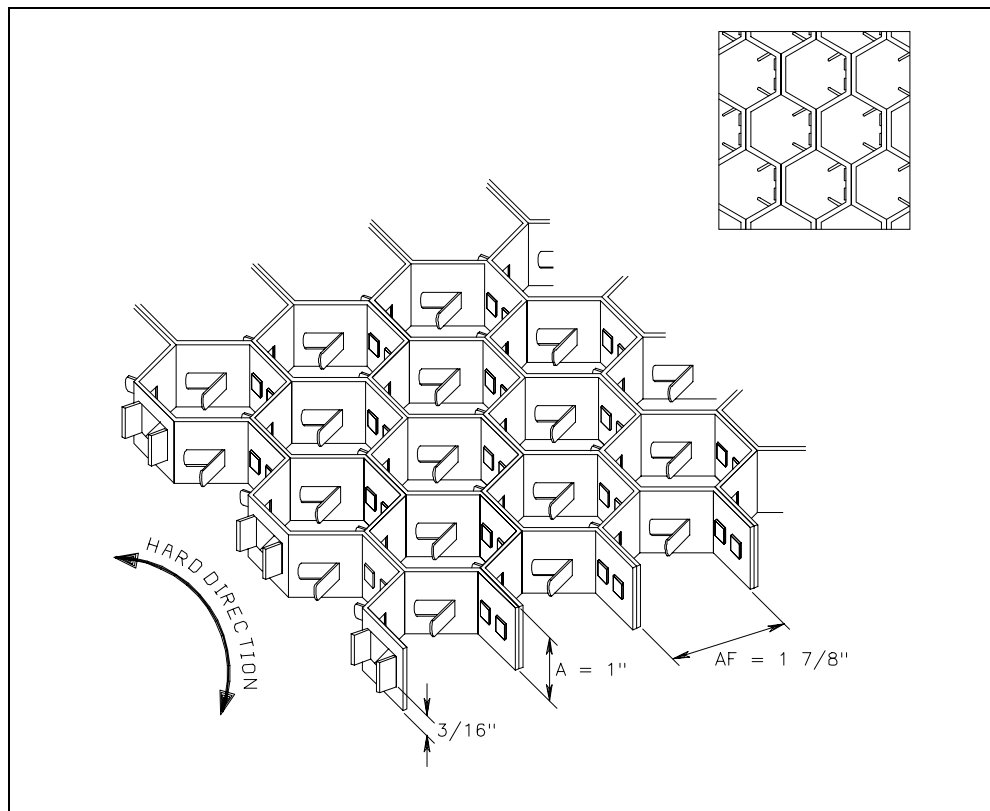
- For one- and two-component linings (3-inch to 6-inch) use the types of vee anchors shown in Figure 2200-1.
- For relatively thin (1½ to 2½-inch) linings (in stacks, breachings) individual strands of cyclone fence picket are used. These anchors are illustrated in Section 2500.
- For thin (one-inch) linings in cyclones, use hexmesh or S-bar anchors.

Fig. 2200-1 Anchors for One- and Two-component Linings



Hexmesh. Figure 2200-2 shows a new preferred hexmetal type with offset clinch/lance. Hexmesh is used in new installations and large repairs. This hexmesh has 40% more erodible depth than hex with centered clinch/lance. Hexmesh and refractory need to be replaced when the refractory hexmesh has eroded and reveals the clinches which hold the hex together. It is important to specify tight clinched hexmesh, because forming operations tend to pull clinches apart. Always bend hexmesh the “hard way” to minimize the chance of creating gaps between strips. Hexmesh is welded to the shell.

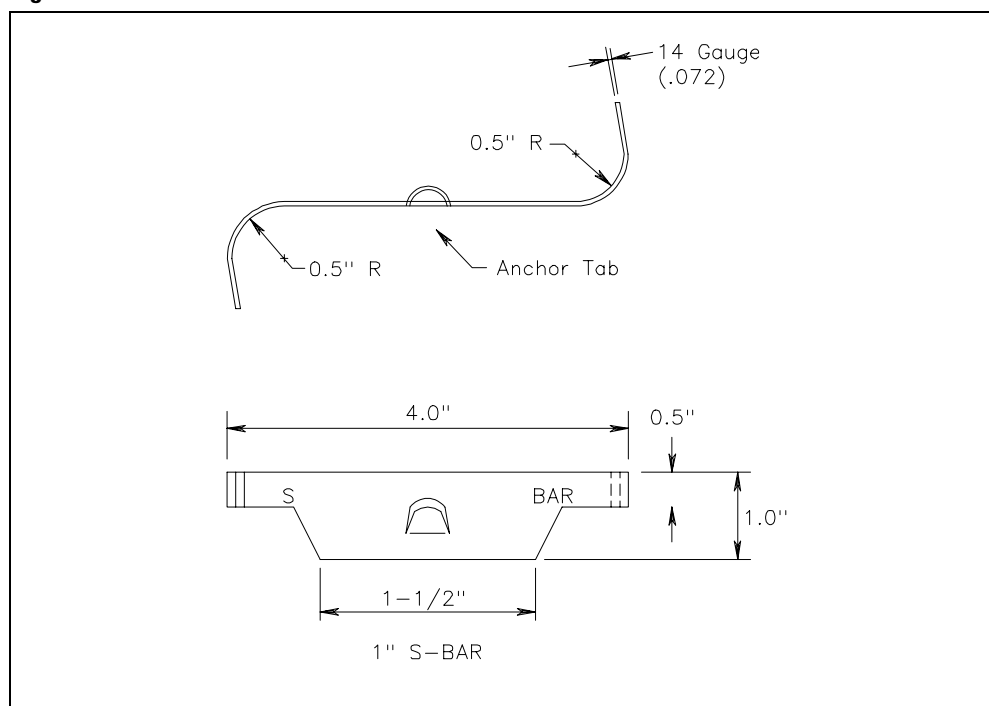
Fig. 2200-2 Hexmesh with Offset Lance Tight Clinched



S-bars. Figure 2200-3 shows an S-bar anchor. The primary advantage of S-bars is that each anchor is individually welded to the shell. Lining systems anchored with S-bars do not fail by means of entire sheets lifting off the shell the way hexmesh is prone to do. S-bars are used for small (less than 2 sq. ft.) repairs.

Anchor Height. In most cases, individual anchors should extend approximately three-quarters of the way through the lining thickness. For anchors with unequal length legs, the longest leg should be so covered. (This rule does not apply to S-bar anchors or hexmesh, which should be flush with the hot surface.)

Anchor spacing, pattern and orientation are discussed in Section 2500, Installation.

Fig. 2200-3 S-Bar Anchor

2211 Vapor Stop Rings

Vapor stop rings are used in services where there is a pressure drop across a catalyst bed and wherever two-component linings are to be installed. The rings, installed on 3- to 4-foot centers, stop process gas from burrowing between the lining and the shell. Each ring (3/16 to 1/4-inch plate) is welded to the shell and is wide enough to extend approximately 40% of the way (usually 2 to 3 inches) into the refractory lining.

2220 Refractory Concrete Lining Systems

The lining systems discussed in this section are also called “monolithic refractories” because they have no joints. They may differ from each other in anchorage systems, refractory materials, and/or installation method. Refractory types A through I are defined on Standard Drawing GB-N1268.

2221 Gunned Linings

This term refers to linings that are normally applied with a nozzle-mix gun and are usually one layer. These linings are also called “one-shot” linings. Thicknesses for this type of lining are usually in the 3- to 6-inch range, although linings in breechings and stacks are sometimes only 2 inches thick.

Anchorage. Individual anchors such as the wavy Vee or double hook are used in the thicker linings. Cyclone fence pickets (Type 304 stainless steel) on 6-inch spacings are useful with the thinner (stack and breeching) linings. Metal fiber

reinforcement is advantageous in most “one-shot” linings. See Section 2500 for an illustration of fence picket anchorage.

Advantages of “one-shot” linings include their simplicity, ease of installation, cost competitiveness, elimination of hot spot problems and general durability.

Disadvantages are:

- Less thermal efficiency than a two-component lining. However, two-component linings can be difficult to install and expensive to maintain.
- Less erosion resistance than a vibration cast lining

Where Used. A major use of “one-shot” linings is on the walls of FCCU regenerators and reactors. They are also used in flue gas lines and some large diameter catalyst transfer lines. Different types of castables are used depending on how much erosion protection (if any) is needed. Some “one-shot” linings serve largely as internal insulation, reducing heat loss and shell temperatures.

Lining Design Calculation. Reference [46] gives a method for calculating mechanical and thermal stresses in “one-shot” vessel linings at operating temperature. This system is useful in determining the best lining design and preventing lining over-thickness.

The calculation comprises 3 steps: 1) calculation of lining and shell temperatures, 2) calculation of the strains in the lining and shell, and 3) calculation of the stresses in the lining. In cylindrical vessels, circumferential stresses are larger than the axial stresses and, therefore, are critical from a design standpoint. It is very desirable to have the hot face in a state of moderate compression. This keeps the lining tight against the steel shell and eliminates bypassing problems. This hot face compression also closes most cracks in the refractory surface at operating temperature (cracks equal to or less than 1/16 inch wide).

2222 Thin (1-inch) Erosion-resistant Linings

The major application for thin erosion-resistant linings is in cyclones. High quality erosion-resistant cyclone linings are *critical* to the operation of the FCC unit. Material selection and installation need to be closely monitored. Similar linings may also be used in slide valves, plug valves, and hot shell linings. The refractory material may be either phosphate bonded castable or phosphate bonded plastic.

These phosphate bonded materials are installed by handpacking followed by hammering or pneumatic ramming to consolidate material, eliminate voids and force material into and around lances and clinches. Gunning of these materials is prohibited.

Not all cyclone linings have the same requirements. Reactor cyclones have the advantage of operating at a lower temperature than regenerator cyclones (approximately 960°F versus approximately 1350°F). In addition, the coke buildup in the reactor cyclone lining improves its erosion resistance. These linings must also be resistant to the steaming that occurs in the reactor at startup.

New cyclones are normally lined and baked before shipment to the refinery.

Anchorage. Either S-bar or hexmesh anchorage will work well in these one-inch linings. Hexmesh is preferred for new construction where time constraints are not critical because it is more durable and gives better anchorage. The unitized S-bars have advantages that suit them for maintenance work, especially for small irregular areas.

Metal Fiber Additives. It is often advantageous to add metal fiber to phosphate-bonded refractory in cyclone linings having S-bar anchors.

There are significant differences between phosphate-bonded castables and plastics:

Phosphate Bonded Castable

This Type B material is available as single-component or two-component. The single-component is Resco AA-22S; the two-component is Resco AA-22. In AA-22S the components are pre-mixed at the factory to make field mixing less complicated

This castable material requires careful weighing of ingredients (dry ingredients plus water) and mixing. Once mixed, it has a relatively short working time (12 to 15 minutes), after which it takes an air set. Stainless steel fibers can be added to this material in the field, if desired.

Where Used. As a general rule, the phosphate bonded castables (Type B) are the better choice for reactor and regenerator cyclones and third-stage cyclones where the material can be installed and baked under ideal (shop) conditions. The lining should be shop inspected and tested to achieve optimum results. Because these castables are less susceptible to steaming damage than the Type C products on startup of the FCC unit, they are a better choice for reactor cyclone linings. The castables are also recommended for slide valves, plug valves, and miscellaneous applications.

Phosphate Bonded Plastic

This material (Type C, Standard Drawing GB-N1268) is usually an 85 to 90% Al_2O_3 composition that requires heating to 700°F to harden and develop strength. Workers must take care not to damage this material before it is fired.

(This Type C material should not be confused with what the industry calls “heat setting plastics”, which require high temperatures (1900 to 2100°F) to sinter the bond.)

The phosphate-bonded plastics are ready-to-use as received. A five-gallon pail of plastic can be worked for several hours. This feature eliminates the problems with mixing and short working time of phosphate bonded castables. It is not possible to add stainless steel fiber to pre-mixed plastic in the field, but it can be added at the factory. This requires more pre-planning and estimating of materials requirements. Material is available in different consistencies (such as “Putty” or stiffer “Ram” varieties). There is sometimes a problem with slumping of installed “biscuits”

especially overhead. This can be avoided by experienced installers using stiffer ramming mixes.

Where Used. The phosphate bonded plastics are best suited for new regenerator cyclones and regenerator cyclone repairs where their easier workability is an advantage and for linings that will be preheated (or baked) before installation. We do not encourage the use of plastics on the reactor-side of the FCC unit because of the aforementioned steaming problem.

Inspection and Testing

Considerable inspection and testing are essential during the installation of both erosion-resistant castables and plastics. Shop inspection and testing of anchorage, welding, and refractory are necessary. Section 2900 covers Inspection and Testing requirements.

2223 Two-component Linings

Two-component linings are really one castable lining laid on top of another (two distinct layers). The outer layer is called the hot face or working lining and the inner layer is called the back-up or insulating lining. These linings are used with vapor stop rings, discussed in Section 2211.

Anchorage. Individual anchors are used to hold each layer in place. Although it would seem that the hot face layer would, of necessity, keep the back-up layer in place, the Company prefers to use a second set of shorter anchors to hold the back-up layer tightly against the shell. The shorter anchors help hold the back-up lining in place until the hot face anchors are installed on their studs and the hot face is installed. Anchorage installation for two-component linings is illustrated in Section 2500.

The Company no longer recommends the use of hexmesh in two-component linings for FCC units. See Section 2227.

Metal Fiber Additives. Metal fiber reinforcement is usually desirable for the hot face layer, but not for the back-up layer.

Advantages. A two-component lining offers the advantage of a stronger, higher temperature, erosion-resistant castable for the hot face and a less costly, insulating castable for the back-up layer.

Disadvantages. Problems developed in some applications when bypassing occurred (behind the hot face layer). Because of these problems, we conclude that one-shot linings are less apt to experience bypassing than two-layer linings.

Where Used. These linings have been successful in secondary reformers, waste heat boiler channel sections, and some fired heater applications.

Installation Method. These types of linings are normally installed with a nozzle-mix gun (see Section 2221), with some time delay between application of the two layers. During this interval, the hot face anchors are added. Two-component linings can also be installed by other methods, such as vibratory casting (see Section 2224).

2224 Vibration Cast Linings

This installation method has been developed and popularized within the past few years (starting approximately 1980). In some respects it is the most complicated and scientific method for installing castables. The castables specifically designed for vibration-cast linings are critically gap-sized. Water content is quite low and carefully controlled, giving the lining the advantages listed below.

Advantages. Superior strength and erosion resistance combined with reasonable thermal conductivity make these linings very attractive. Because of their reduced porosity, they also resist coke impregnation. Vibration cast U-bends at Richmond and El Segundo are giving exceptional service compared to the previously used high-maintenance two-component lining with hexmesh.

Disadvantages. The major disadvantages of the vibration cast lining system are:

- Rather difficult to do in the field, particularly in the time allowed for most shut-downs. Prior planning is essential to get forms made, mock-ups tested, etc.
- Field erection of the lined pipe sections is a major undertaking, particularly on the large FCC units.
- Vibration casting into lines during a shutdown is also difficult because of the dampening effect on vibration of connected large vessels.

Where Used. This system has been used to line reactor riser lines, U-bends, stand-pipes, J-bends, Tee-sections and parts of flue gas lines on FCC units. It has also been used to install both layers of a two-component transfer line in a hydrogen producing unit. Vibration cast linings are best installed in new lines or vessels in the shop. This minimizes the problems of time constraints and vibration dampening by attached equipment.

Application Method. The lining is generally applied to a new pipe section (having a diameter less than or equal to 10 feet and a length of approximately 20 feet). Once started, the casting operation must be continuous. A typical procedure is given next, as an illustration.

1. Double hook anchors are welded to the inside surface of the pipe.
2. The pipe section is set vertically on a concrete surface and a large metal form (in sections) is carefully positioned within the pipe shell. Powerful external vibrators are mounted on the outside of the shell at several elevations and used in sequence, as required.
3. The fiberized, low moisture castable is mixed.
4. The mixture is quickly moved into the annular space between the form and the pipe shell. High-frequency vibration causes the shell to vibrate, and the stiff, wet-mixed thixotropic castable flows into place and densifies. Usually two or more mixers are used, to keep the material coming at a rapid rate and to provide spare equipment in case of failure.

2225 Cast and Hand-packed Linings

Regular casting (as opposed to vibration casting) and hand packing are the least preferred ways to install castable linings in refineries and petrochemical plants. As a general rule, materials installed by these methods do not have the strength and other physical properties inherent in gun-applied linings. This difference is largely a function of water content.

Regular Casting Method. Quite often the floors of fired heaters, process furnaces, and large rectangular ducts are installed by ordinary casting methods. Either semi-insulating or insulating-type castables are used. Sometimes, metal fiber is added to increase the lining's durability. Use of this method is largely confined to non-critical applications where other installation techniques are impractical. For example, gunned material is difficult to apply downhand.

Installation Concerns. The main concern in most casting jobs is that the installer not use too much water at the mixer. Like ordinary construction concrete, refractory concrete requires specific water additions to obtain the optimum strength. Too much water causes a drastic decrease in strength and increased shrinkage.

Hand Packing Method. Hand packing is sometimes used to patch small spalled areas in castable linings. A limited quantity of air-set mortar is mixed with insulating castable (perhaps 1 to 3 by volume), water added to give a workable consistency, and the mix packed into the voids. Hand packing is also used to fill the field joints (usually a band about ½ inch wide) in vibration-cast lined sections. The refractory material is usually a phosphate-bonded, high Al_2O_3 plastic. Hand packing of these field joints is much easier to accomplish than in situ vibration casting.

Hand packing is also used in filling nozzle necks on vessels and piping, particularly those less than 4 inches in diameter. Hand packing is generally an inferior installation method because the dry mix allows voids to occur. Close inspection is required.

2226 Shroud with Refractory Material

The refractory material is either an insulating or semi-insulating castable covered by a protective stainless steel shroud. The shroud prevents erosion of the refractory, allowing the use of refractory that is less expensive and more insulating.

Where Used. This type of system is used in transfer lines in ammonia and hydrogen plants and some waste heat boilers. A similar shrouded design is used in catalytic reformer shell linings. Thermal expansion of the shrouds during regeneration often causes buckling, which leads to gas bypassing behind the lining and hot spots.

If a shrouded line is necessary, allow a small gap between shroud and lining to compensate for thermal expansion of the shroud and to minimize buckling of the shroud. The gap may be formed by gluing corrugated waterproof cardboard to the inner surface of the shroud.

Replacement of shrouded lines with two-component refractory lines should be considered wherever feasible, since two-component refractory lines should require less maintenance. A Materials Engineering report on transfer line design and materials selection contains suggestions for line upgrades. See Reference [68].

2227 Two-component Linings with Hexmesh

This type of lining system is no longer recommended for applications in FCC units. It consisted of a 3-inch insulating lining covered by 1 inch of abrasion-resistant refractory material in hexmesh. Failures occurred and were especially difficult to repair. The hexmesh broke away in large sheets due to thermal expansion between the hot face and the back-up lining. Fifteen or twenty years ago, it was still being used in catalyst transfer lines—particularly U-bends, risers, standpipes, Tee-sections, and even reactor and regenerator wall linings. Now, we have better systems for lining these components, such as vibratory cast linings and gun-applied, one-shot linings of semi-insulating, erosion-resistant castable.