

2500 Refractory Installation in Vessels and Lines

Abstract

This section tells the engineer what to consider when planning the installation of refractory material in vessels and lines. Preparation before installation (storage and handling, surface preparation, and installation of anchorage) is discussed. The four main methods of installation are described (gunned, cast or handpacked, installation of chemically setting materials, and vibration cast). This section often refers to refractory material by type (e.g., Type A, Type C). The types are defined on Standard Drawing GB-N1268.

Curing and dryout, a critical part of installation, is discussed in Section 2700.

Refer to Section 2400 for the types of lining systems to use for various applications.

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2510 General Information

A refractory lining is no better than the quality of its installation. Maximum service life will not be obtained unless the lining (or other refractory component) is installed properly.

Many well-designed linings with high quality refractory materials have failed prematurely (sometimes within one year) because of poor installation procedures. Inferior workmanship is a potential problem with all types of lining materials used in refining/petrochemical operations. The major factors in obtaining satisfactory installations are:

- An honest and capable contractor with knowledgeable supervisors and conscientious, experienced workmen
- Well written refractory specifications
- Comprehensive and clearly defined quality control program
- Experienced inspectors

Accepting the lowest bid on a refractory installation job is often a mistake. Regardless of the size of the job or its complexity, a meeting prior to signing the contract is necessary. At this meeting, all details of the job should be discussed and agreements reached.

2511 Storage and Handling

After the refractory material has been prequalified and received at the job site, there is usually a time delay before it is installed. All refractory material must stay dry, and some materials have additional requirements. The most important factors in the handling and storage of these refractory products are:

1. Protect containers and factory shrink-wrap coverings from mechanical damage, tears, rips, etc.
2. Prevent water and moisture from reaching refractory. Inside storage is preferred in wet environments; however, tarps carefully secured can also be used to protect material that must be stored outside. Store material up off the ground to protect from standing water.
3. Do not allow plastic refractory to freeze.
4. Store phosphate bonded (Type B) castables at 40°F to 80°F. If this material is to be installed during hot, summer-like weather, an air-conditioned warehouse or refrigerated truck is usually needed (to improve pot life).
5. Consider warm storage for refractory material in cold climates. Cold dry material will be slow to set up and develop strength.

For additional information on allowable temperatures for refractory storage, see Purchase Specification IRM-MS-4785 and the manufacturer's recommendations.

Shop-lined Equipment

Equipment lined in a shop should be cured before it is transported to the field. Because large shop-fabricated equipment (e.g., heater stacks) can flex during shipment, it is better to have the fabricator ship it to a lining shop as close as possible to its destination.

2512 Surface Preparation

Although surface preparation (that is, creating a mechanical profile) is *not* a factor in “bonding” the refractory lining to the steel shell, the shell must be clean, dry and scale free to ensure sound anchor welds. If the steel is corroded badly or has been previously coated (e.g., with Stalastic), it should be brush-off blasted to SSPC SP-7 or NACE No. 4 standards or power tool cleaned to SSPC SP-3 standards before anchors (and/or vapor stop rings, etc.) are welded in place. Abrasive blasting is generally the more economical choice for cleaning large areas.

Adequate surface preparation also promotes adhesion of a vapor barrier coating (such as Stalastic). In most cases, however, vapor barrier coatings are *not* required for refractory installations in vessels and lines.

2513 Installation of Anchorage

Thick (usually 3-inch to 6-inch) castable refractory linings normally use independent anchors of the Wavy Vee or Double Hook types (shown in Figure 2200-1). Thin (1-inch) linings are anchored with either hexmesh or S-bars (Figures 2200-2 and 2200-3). Thin linings require more anchorage than thick linings. Because of this and other inherent differences, anchor placement and welding is discussed separately (below).

Welders must be qualified for all anchorage installations per ASME Section IX Paragraph QW-180. Stick electrode welding is used in both systems. Standard Drawings GD-N1269 and GD-N1270 list recommended welding consumables and preheat requirements for monolithic refractory linings.

Anchorage for Thick Linings (3 to 6 inches)

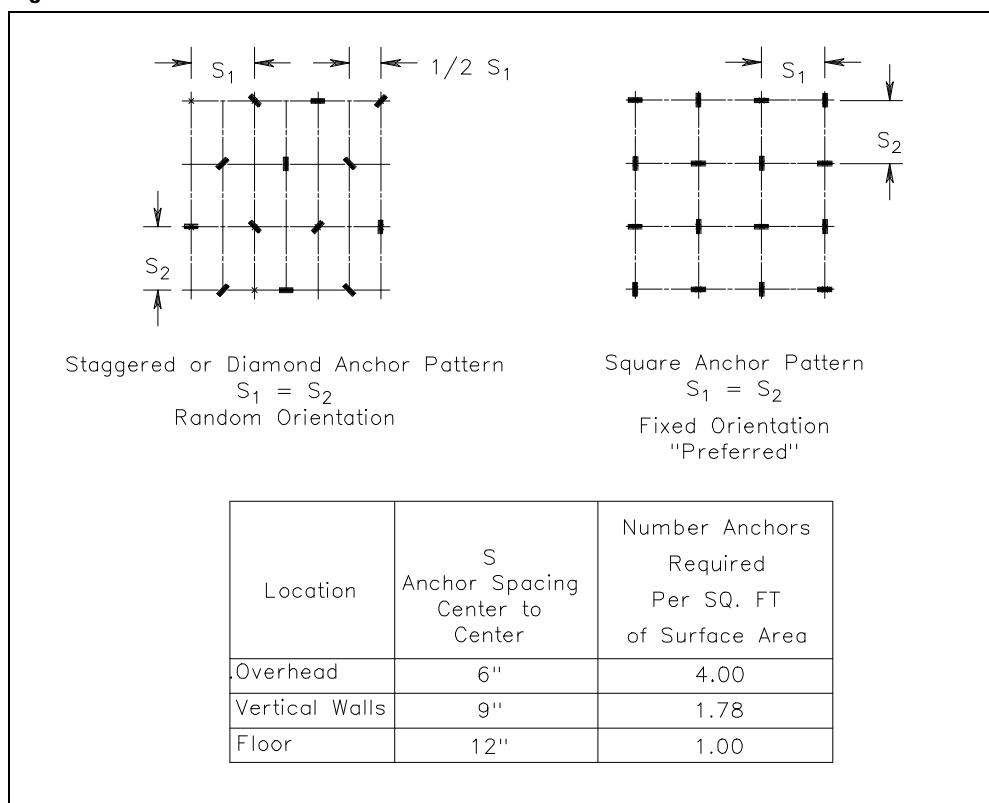
The layout pattern and spacing of individual anchors are inter-related. In general, anchor spacing is the more important consideration. Make sure that you have enough anchors for the lining system being designed and then worry about the anchor pattern.

A careful layout of anchor locations before welding begins prevents errors and rework. The project drawing(s) should show anchor type, anchor pattern, orientation and other necessary information. A welded wire or cardboard “template” is sometimes used to lay out the pattern on flat or cylindrical (barrel) surfaces. A template does not work well on conical surfaces or elliptical heads. When laying out anchor locations, encircling the center punch mark (beyond the area to be welded) with crayon makes the anchor welding site easier to see.

In addition to anchor spacing and layout pattern, the individual orientation of each anchor needs to be specified. Anchors must be oriented in a random or other-specified fixed orientation to prevent the alignment of anchors and the formation of a plane of weakness within the refractory lining.

A simple anchor pattern and orientation system is helpful to the welders. Figure 2500-1 shows two such systems for the hot face layer of one- and two-component linings. Anchors for the back-up layer of two-component systems should be placed in the middle of the squares formed by the hot face anchors.

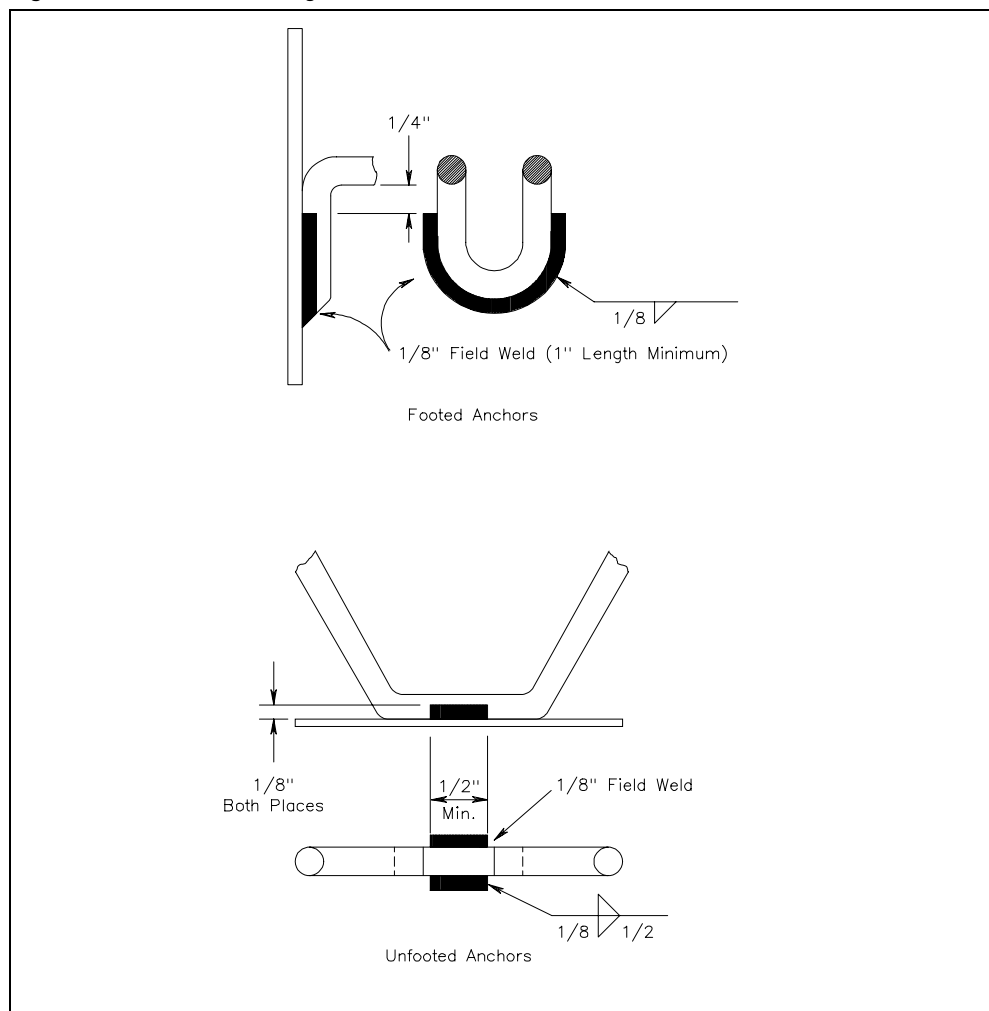
Fig. 2500-1 Anchor Patterns and Orientation



Anchors should be stick welded using 3/32 electrodes. Fillet welds should be 1/8 inch. Welds should be continuous and of the required length. Figure 2500-2 shows welding details for "footed" and "unfooted" anchors. Care should be taken to prevent undercutting or overheating the anchor being attached. Maximum anchor distance from a lining termination should be one-half the normal anchor spacing or 3 inches, whichever is less.

Figure 2500-3 shows a typical installation of anchors for two-component linings. Either style of anchor can be used for either layer of the lining, but hot face anchors need a nut welded to them for attachment to a stud welded to the shell. The threads at the end of the stud must be covered by a plastic or rubber cup during installation of the back-up layer. This layer should leave about 1/2 inch of stud showing.

Standard Drawing GD-N1269 gives anchor installation details for these thick linings.

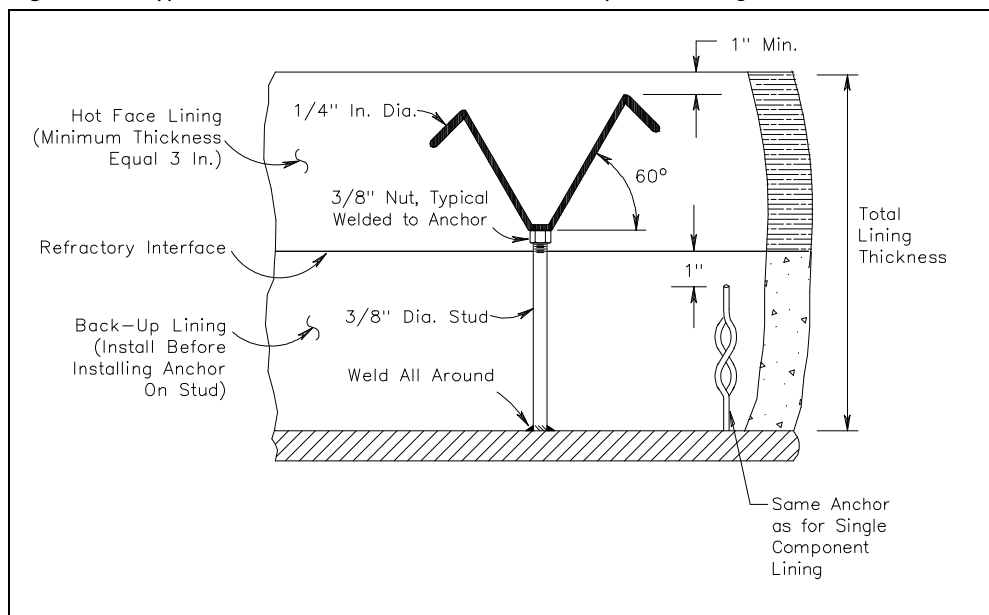
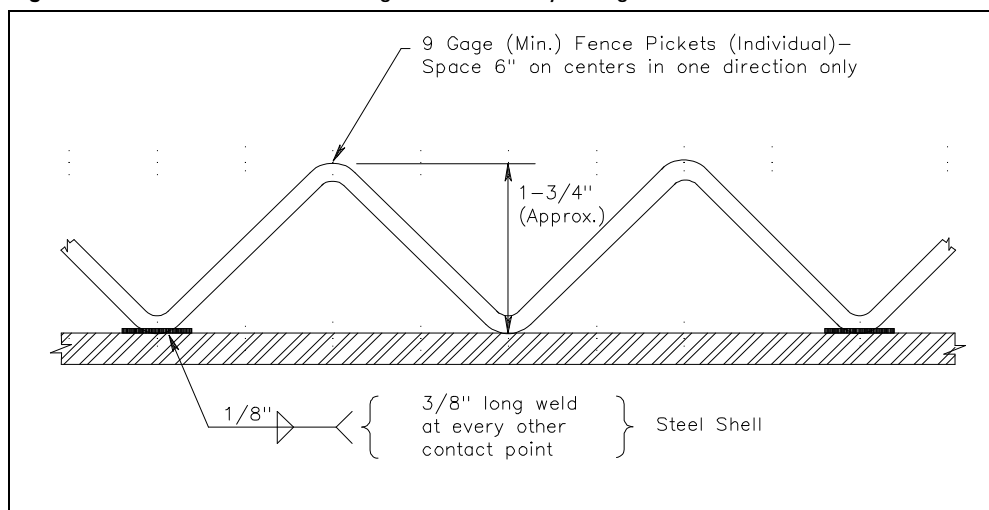
Fig. 2500-2 Anchor Welding Details

Anchorage for Relatively Thin Linings

Relatively thin (usually, 1½ inches to 2½ inches) linings in stacks and breechings are often anchored with individual strands of cyclone fence pickets. Although these low-temperature linings are most often encountered in fired heaters, they are sometimes used in FCC units. Figure 2500-4 shows this type of anchorage. Note particularly that orientation can be varied (from “flat” to “on-edge”) to suit the lining thickness. See Standard Drawing GD-N1269 for installation details.

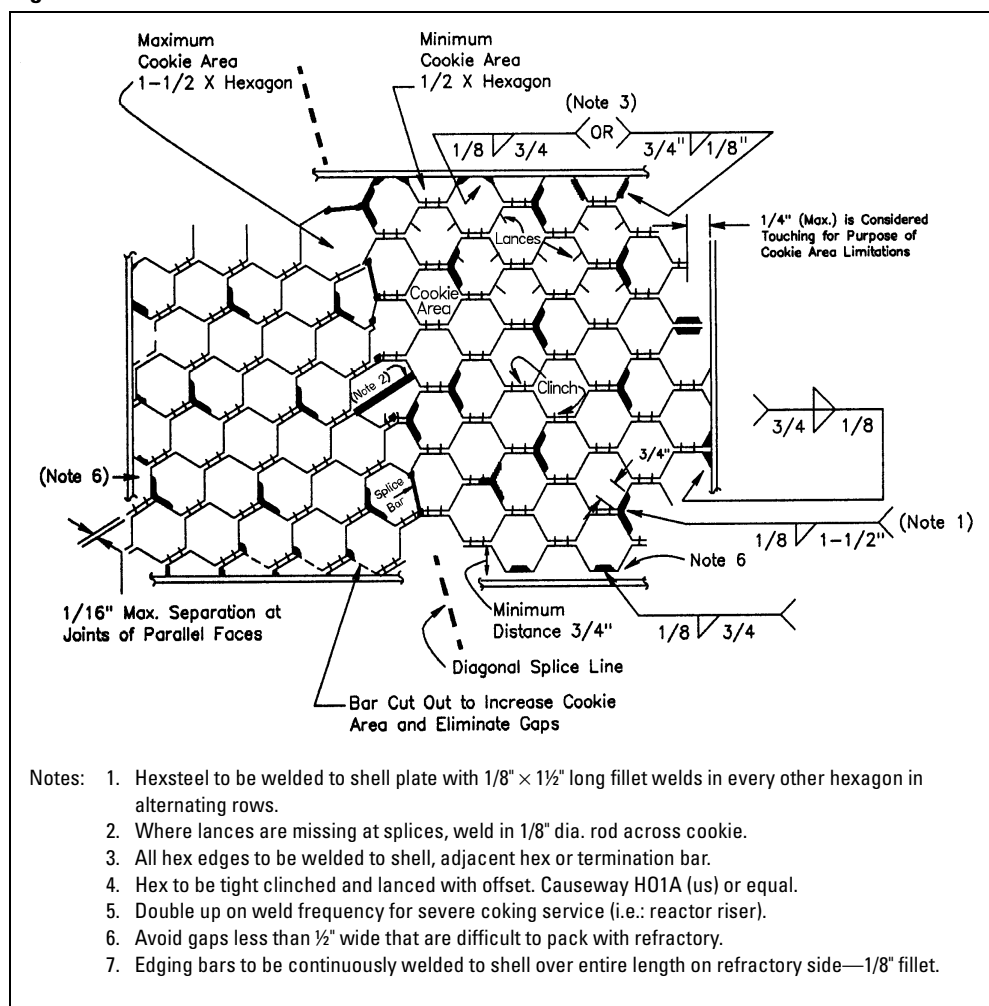
Anchorage for Thin Linings

These linings are used in cyclones, slide valves, plug valves, and hot wall riser lines. With new equipment, welding of anchorage (and installation of refractory) is normally done in a fabrication shop. Drawings and/or specifications should be provided to show type of anchorage, metallurgy, installation details, and welding information. Refer to Standard Drawing GD-N1270 for details of anchorage installation for these thin linings.

Fig. 2500-3 Typical Installation of Anchors for Two Component Linings**Fig. 2500-4** Fence Picket Anchorage for Refractory Linings that are 1½" to 2½" Thick

Hexmesh. Hexmesh should be rolled in the direction most resistant to bending (in the "hard direction") and concentric with the inside wall of the shell. It should be welded to the steel shell as shown in Figure 2500-5. Longitudinal joints of hexmesh must be offset to avoid continuous seams. Also, hexmesh should be installed in sections as large as practical to minimize seams. At joints between panels or between hexmesh and edging bars, individual openings should not be larger than 1½ times the hex area, and no smaller than ½ the area of a standard hex opening.

S-Bars. The recommended method for installing S-bars is shown in Figure 2500-6. The maximum distance from the last S-bar to a termination bar or the existing lining is 1½ inches.

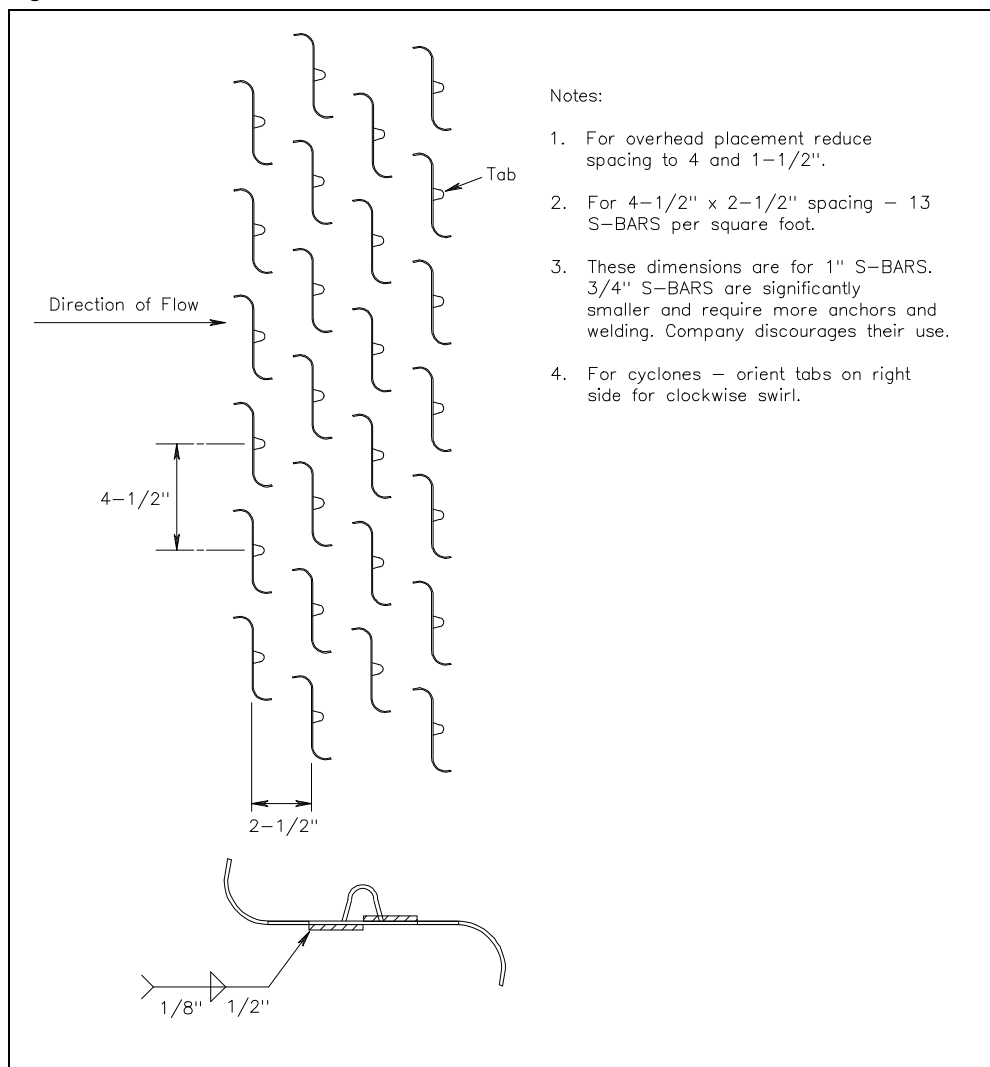
Fig. 2500-5 Hexmesh Installation Details

2514 Weather Protection

Hydraulically bonded castables should be installed at moderate ambient temperatures. The preferred temperature range is 60 to 80°F. For this reason, FCC unit turn-arounds in the Gulf Coast area are normally scheduled for the spring or fall seasons. Unfortunately, this is not always feasible. Also, during major refinery expansions (or construction) the refractory work will span many months. Hence, we must occasionally install castable refractories when ambient temperatures are not ideal. In these cases, ambient temperature limits are established as follows:

- 50°F minimum temperature
- 95°F maximum temperature

Installation methods during cold and hot weather are given below. Additional information on allowable temperature for refractory storage and installation appears in the Purchase (IRM-MS-4785) and Installation (IRM-MS-4786) Specifications.

Fig. 2500-6 S-Bar Installation Details

Cold Weather

Freezing weather complicates the installation and curing of hydraulically bonded castables. After they are installed, these materials must be kept above 50°F for at least one day in order to develop maximum strength. If fresh refractory concrete is frozen before it has a chance to hydrate, the result will be a weak material with little or no coherence (somewhat akin to mud). If the concrete is allowed to membrane cure at 50°F or higher for 24 hours, subsequent freezing cycles will not harm it.

When the shell temperature is below 50°F, the area to be lined should be heated or externally insulated prior to and while the refractory is being placed and should be maintained at 60°F (or above) for at least the first 48 hours after placement.

Castables should be stored at 50°F to 90°F for 48 hours prior to use. Warm water may be used to raise the temperature of the wet-mixed castable above 60°F, if

necessary. Refractory mixing, handling, and preparation areas should be enclosed, heated and weatherproofed.

Hot Weather

Hot weather causes problems too. Plugging of the hose on the guniting machine and too rapid setting of the material after installation are examples of problems due to hot weather. When ambient temperature is above 95°F, the following hot weather procedures should be followed:

1. Cold or iced water (do not use ice) may be used to reduce the temperature of the mix to between 60°F and 80°F.
2. When the shell temperature exceeds 95°F, its exterior (particularly the area to be lined) should be cooled by water spray and/or shading prior to and during placement of refractory.
3. The mix (castable plus water) temperature may also be reduced by storing the dry refractory castable in an air-conditioned area prior to use.
4. During hot weather application, the material mixing and handling areas must be shaded from the sun.

2515 Equipment Cleanliness

The rotating-blade paddle mixer should be cleaned as often as necessary—at least once every shift. Guniting equipment should also be cleaned every shift, particularly the “goose-neck” (tapered connection to material hose at bottom of machine). Buckets and other items used in handling and transporting wet-mixed materials should be kept free of hardened refractory buildup.

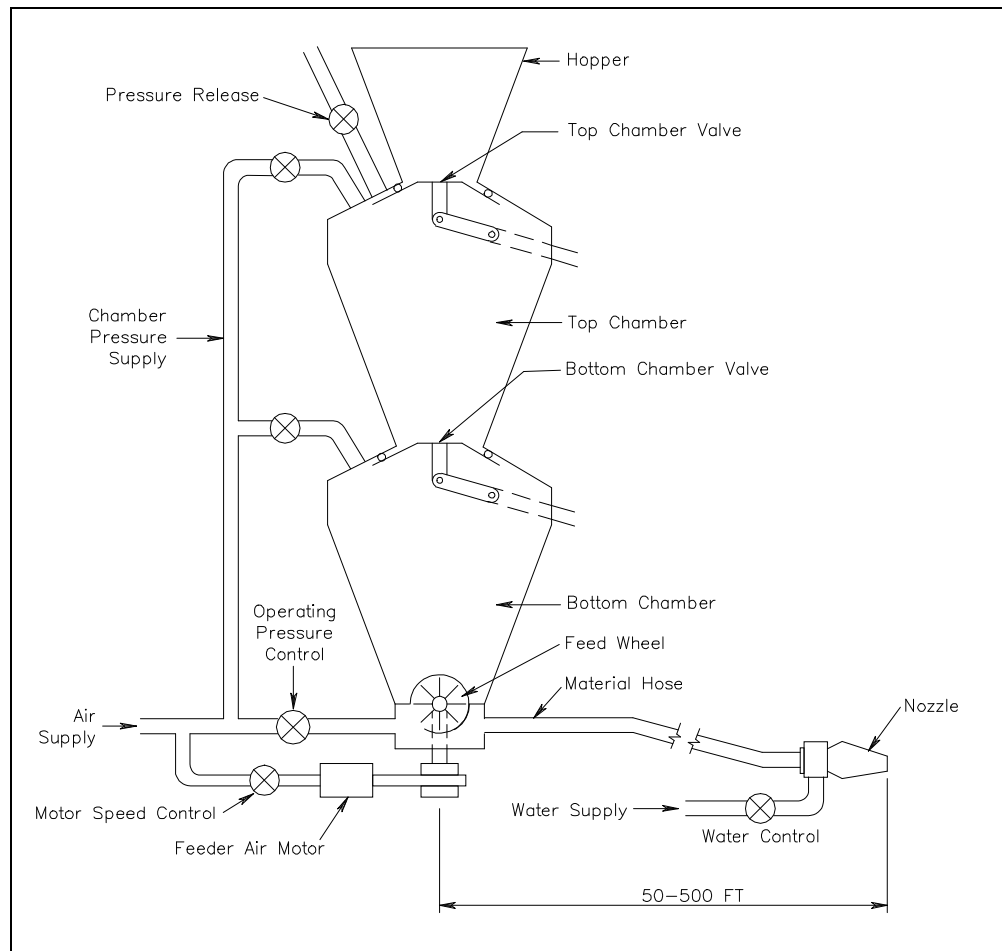
2520 Gunned Linings (More Than 3 Inches Thick)

The information below gives an overview of the gunned method of application. See also the installation specification, IRM-MS-4786.

2521 Equipment

Gun-applied refractory linings comprise the major tonnage of those used in our industry. Regenerator and reactor wall linings, flue gas lines, and secondary reformers and cat reformer wall linings are primary areas of use. The dry gun process (Figures 2500-7 and 2500-8) consists of 1) a pressure pot into which predampened refractory material is charged; 2) a 1½ to 2-inch delivery hose to pneumatically convey the damp mix to the work area; and 3) a water mixing nozzle that adds water to the damp mix just prior to its shooting from the nozzle onto the wall.

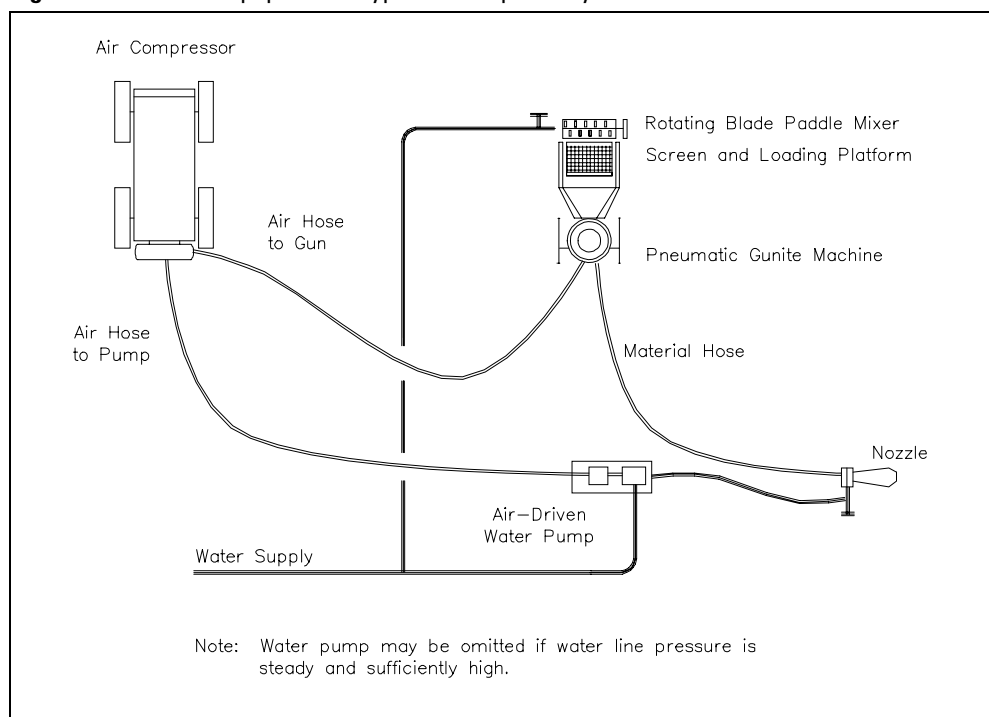
The type of nozzle-mix gun(s) brought to the job should be a function of what type(s) of castable will be installed and how high the predampened refractory material must be lifted (through the hose). Some small guns are not capable of lifting the

Fig. 2500-7 Typical Nozzle-Mix Pneumatic Machine

material vertically 70, 80, or more feet to reach the regenerator on the seventh floor of the FCCU structure. Quite often, it is impractical to mount the gunning equipment on the structure. For this reason it is important to qualify the nozzleman and equipment on the job at the highest elevation gunned linings will be applied. If the equipment is inadequate, it is better to discover this early in the job and not as the shutdown is approaching its conclusion. Prequalification of nozzlemen is covered in greater detail in Section 2900. The work area usually needs to be on the ground and it should be covered to protect materials and the operation from wet weather.

For several types of castables, a Micon rig (or similar equipment) that “connects” the mixing and predampening operation with the nozzle-mix gun by means of a bucket/belt conveyor has these advantages:

- Timing of mixing/predampening is better coordinated with the operation of the gun.
- Some labor is saved since the mixed/predampened material does not have to be dumped into a large holding “box” and then shoveled into the gun.

Fig. 2500-8 Gunite Equipment—Typical Set-Up for Dry Gun Process

The Micon rig is less attractive for those castables that require a hold or tempering period between predampening and gunning. Type A and D refractories often require tempering. Review manufacturers' installation procedures.

2522 Gunite Crew

The gunite crew consists of at least 5 men. The **gun operator** controls material flowing through the hose at the nozzleman's direction. **Two laborers** charge dry bags of refractory into the paddle mixer and add metal fibers and predamp water. The fourth and fifth men apply the lining: **the nozzleman**, the key man in the gunite operation, operates the nozzle and controls water addition. He also controls dry material feed rates via radio contact with the gun operator. The **second man** at the point of lining application is also important. His job is to cut back the finished lining, gage lining depth, clean rebound from trapped areas and apply curing compound.

If tempering of the predamp material is required, a second charging operation into the gun after the desired time has elapsed is also required.

2523 Limitations of Guniting

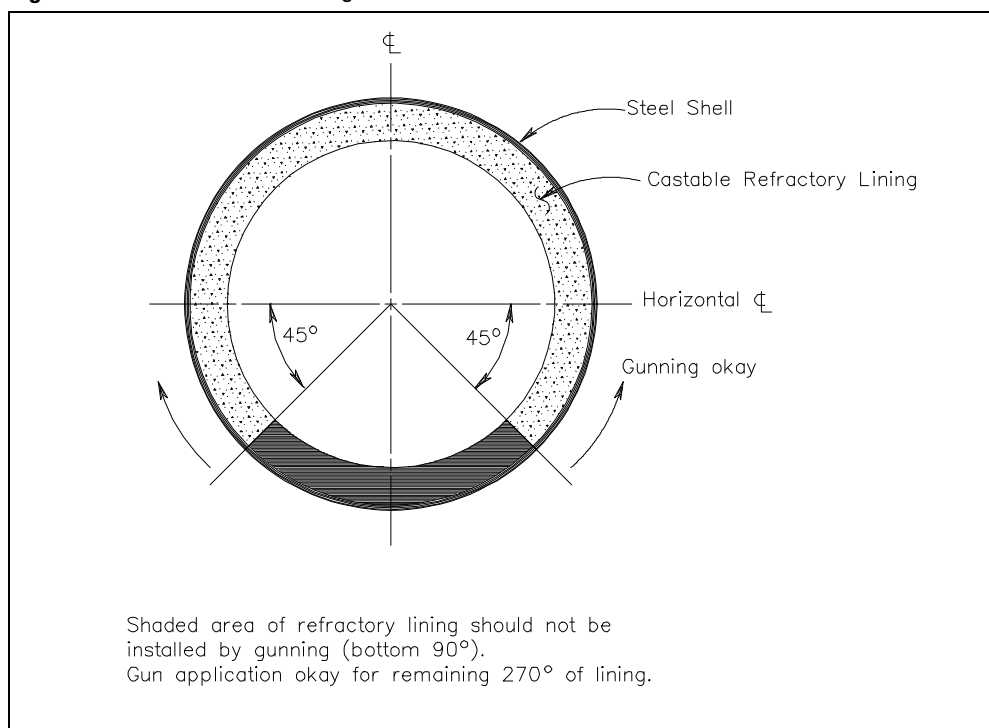
The use of gunite has the following limitations and restrictions.

1. As a general rule, wet mix gunning of refractory concretes is restricted in Company installations. (This method differs from the dry gun process described above. The difference is where you add the water. The wet gun

method mixes the water and the castable in a vessel and then pneumatically conveys the mix to the point of application.) Because control of water content is difficult with the wet-gun method, strength can be adversely affected. This method may be acceptable in non-critical applications, such as for fired heater floors.

2. Gunning should not be done in the downhand position below 45 degrees from the horizontal. See Figure 2500-9. Gunning downhand results in trapped rebound and laminations in the lining. Refractory concrete linings for the bottom sections of horizontal piping should be cast or the pipe should be rotated prior to gunning.
3. The minimum diameter of cylindrical sections for gun-applied linings is 40 inches (finished inside diameter of refractory lining). Small areas make it difficult to work the nozzle properly and achieve a sound lining. If gunning must be done in areas smaller than 40 inches in diameter (finished refractory dimension) a mock-up should be gunned and destructively analyzed to demonstrate quality.

Fig. 2500-9 Downhand Guniting—Area Where This Method is Disallowed



2524 Metal Fibers

Metal fiber reinforced castable, when required, should preferably have the stainless steel fibers mixed in at the manufacturer's plant. Unfortunately, there are times where this is impractical and the metal fibers must be added in the field. Metal fibers are added in proportion to the material density. An approximate 1 volume percentage of metal fibers is required. Figure 2500-10 gives recommended weights

of metal fibers per 100 pounds of dry refractory to achieve the desired amount. Specifying needle amounts by weight per hundred pounds of dry mix is the easiest method for contractors to use in the field.

Fig. 2500-10 Metal Fiber Reinforcement—Recommended Amount

Dried Density (without fibers) of Castables and Gun Mixes, lb/ft³	Approximate Volume Percentage	Pounds of Fiber Per 100 Pounds of Dry Mix
150–180	1	3.0
100–150	1	3.5
60–100	3/4	5.0

Great care must be used to ensure that the metal fibers are uniformly dispersed throughout the castable. Metal fibers should be added after the castable has been placed in the paddle-type mixer. While the mixer is running, metal fibers should be introduced through a vibrated screen box as a “rain” of individual fibers. Most contractors prefer ¾-inch maximum length metal fibers in gunned linings to minimize the risk of plugging the gun with clumped fibers. One inch melt extract metal fibers specified by Chevron have not given problems.

2525 Water

The water used should be clean and potable (less than 200 ppm chlorides). Water for pre-dampening the castables should be added immediately after the metal fibers are added. Add as much predampening water as recommended by the manufacturer (usually 1/4 to 1/3 of the total requirement) and premix for 2 minutes. Too much water will cause plugging of the equipment. Predampening water reduces dusting, reduces rebound, and begins the cement wetting reaction. Figure 2500-11 gives equivalent water requirements.

2526 Placement

Pneumatic gunning of castables should start at the lowest elevation and work up to minimize the inclusion of rebound material. Gunned linings must be installed full thickness in bands or individual sections (less than 35 square feet in area) to avoid laminations in the lining. Rebound material should be discarded and not reused. Adjacent anchors should be cleaned off frequently during gunning to avoid shadowing and creation of voids around the anchors.

Depth gages and shot boards are used to ensure that castable is applied to the correct thickness. Thickness tolerance for single component gunned linings should be the design thickness: –0 inch, + ¼ inch. This tolerance should also be maintained if a metal shroud is to be installed. When interruptions occur in gun application for more than 30 minutes, the installed castable should be cut perpendicular to the hot face where it has been applied full thickness and at a point about midway between anchors. The cut edge should be scored after cutting and thoroughly

Fig. 2500-11 Equivalent Water Requirement Chart (per 100 lbs of Dry Material)

% or lbs.	Gallons	Quarts	Pints	Ounces	Liters	Cu. Ft.
0.5	.06	.24	.48	7.7	.23	.008
1	.12	.48	.96	15.4	.45	.016
2	.24	.96	1.92	30.7	.91	.032
3	.36	1.44	2.88	46.1	1.36	.048
4	.48	1.92	3.84	61.4	1.82	.064
5	.60	2.40	4.80	76.8	2.27	.080
5.5	.66	2.64	5.28	84.4	2.50	.088
6	.72	2.88	5.76	92.1	2.72	.096
7	.84	3.36	6.72	107.5	3.18	.112
8	.96	3.84	7.68	122.8	3.63	.128
9	1.08	4.32	8.64	138.2	4.09	.144
10	1.20	4.80	9.60	153.6	4.54	.160
11	1.32	5.28	10.56	168.9	5.00	.176
12	1.44	5.76	11.50	184.2	5.45	.192
13	1.56	6.24	12.48	199.7	5.90	.208
14	1.68	6.72	13.44	215.0	6.36	.224
15	1.80	7.20	14.40	230.3	6.81	.240
16	1.92	7.68	15.36	245.0	7.27	.256
17	2.04	8.16	16.32	261.0	7.72	.272
18	2.16	8.64	17.28	276.4	8.17	.288
19	2.28	9.12	18.24	291.9	8.63	.304
20	2.40	9.60	19.20	307.1	9.08	.32
25	3.0	12.0	24.0	383.8	11.35	.40
30	3.6	14.4	28.8	460.6	13.62	.48
40	4.8	19.2	38.4	614.1	18.16	.64
50	6.0	24.0	48.0	767.6	22.70	.80
60	7.2	28.8	57.6	921.2	27.24	.96
70	8.4	33.6	67.2	1074.7	31.78	1.12
80	9.6	38.4	76.8	1228.2	36.32	1.28
90	10.8	43.2	86.4	1381.8	40.86	1.44
100	12.0	48.0	96.0	1535.0	45.40	1.6
150	18.0	72.0	144.0	2303.0	68.10	2.4
200	24.0	96.0	192.0	3070.0	90.80	3.2

wetted before application of adjacent lining begins. This procedure will minimize overlay problems (wherein fresh castable is gunned over “older” castable that has already taken its initial set) which create weak cold joints.

Ambient temperature curing of installed linings is covered in Section 2700.

Refractory concrete properties are generally enhanced by gunning. This method provides an economical method of installing large amounts of material in relatively short times. Where gunning is not practical or feasible, casting, hand packing or vibration cast techniques are used.

2530 Cast or Handpacked Linings

This section discusses the cast or handpacked method of installing refractory linings. See also the installation specification IRM-MS-4786.

2531 Equipment

In cast or handpacked applications the material is mixed in a paddle-type mortar mixer. Water is added to the mixer within the manufacturer's recommended water range.

The water content of castables installed by casting or handpacking is an important consideration. The ambient temperature and material temperature will affect the amount of water addition. ASTM C-860 Ball-in-Hand Test is used to determine the optimum water content for placement. A handsized ball of mixed castable is tossed about 1 foot into the air. Mix having the correct water for casting will form to the hand and into the voids between fingers. Too much water will ooze or run out between fingers. Too little water will not form and may crumble. The amount of water used should be kept at or near manufacturer's prequalification levels. For handpacking applications, the wet-mixed castable should be a little drier than the ball-in-hand water content for casting. Figure 2500-11 gives equivalent water requirements.

Metal fibers (when used) in handpacking applications should be selected and mixed as described in Section 2520.

2532 Forms

Forms are often used when refractory concrete is installed by the casting method. These forms must be sufficiently strong to support the wet castable while it hardens. They should be essentially water tight and securely anchored. Before use, all forms must be thoroughly cleaned and waterproofed. A form release agent should be applied to prevent sticking and to make form removal easier. After placement of the castable, forms must be left in place for an absolute minimum of 12, preferably 24, hours.

2533 Placement

Placement of material in forms is generally done by pouring from the buckets carried by bucket brigade from the mixer. For larger jobs out in the open, a crane with a larger bucket may be practical.

2534 Vibration

Vibration of cast material using internal vibrators is recommended to consolidate material, promote flow around anchors, and eliminate voids. This vibration is of the material itself and is not to be confused with the much more vigorous external vibration of equipment to enhance flow of vibration cast material. This topic is discussed in Section 2550.

2540 Thin Erosion-Resistant Linings (Types B and C)

The installation of phosphate bonded castables (Type B) and phosphate bonded plastics (Type C) is markedly different from that of most hydraulically bonded castable refractories. These differences include:

- Thickness of linings (phosphate bonded materials are usually only about 1 inch thick)
- Method of placement (phosphate bonded materials are normally installed by a combination of hand packing and pneumatic ramming)
- Anchorage (the thin phosphate bonded refractories require more and different types of anchorage)
- Methods of mixing (the mixing of phosphate bonded castables is more complicated and phosphate bonded plastics are supplied in “ready-to-use” form)

Successful installation of phosphate bonded castables and plastics is a function of following manufacturer's instructions and attention to detail. These products should be carefully rammed or hammered into hexmesh or S-bars (on close spacings). Thorough compaction is necessary to fill all holes and openings. The size of the batch is important with phosphate bonded castables.

The method of installing Types B and C linings is given below. See also the installation specification IRM-MS-4787. See Standard Drawing GD-N1270 for anchorage installation details.

2541 Type B, Phosphate-Bonded Castables

Phosphate-bonded castable is available as two-component or single-component. Whether one or two dry components is used, these castables require careful measurement and mixing with water. The mix must be installed quickly before phosphate bonding reactions begin. It is essential that these products be prequalified, mixed and installed by conscientious and experienced workers. The mixing

operation should be close to the work. In most cases, the installed product takes a cold “air” set and becomes quite hard after about one hour.

Equipment. Planetary-type mixers (Hobart or equal) should be used. If stainless steel fiber is to be added, suitable means must be provided for introducing and dispersing it into the mixer pan. Scales for weighing the dry components and graduated measuring vessels for water additions are necessary. Clean plastic buckets are used to transport the wet-mixed castable to the point of installation. Small pneumatic rammers and rubber (or wooden) mallets are used to install and consolidate the material.

Metal Fibers. Stainless steel fiber is *not* to be added if the anchorage system is hexmesh. Fiber may be added when S-bar anchorage is used and will improve holding power of the anchors. Metal Fibers used in Type B refractory should be $\frac{3}{4}$ -inch long, melt-extraction type. Type 304 stainless steel fibers are most often used and at the rate of 3 pounds per 100 pounds of dry material.

Mixing. Phosphate bonded castables must be mixed in accordance with manufacturer's recommended procedures. The least amount of water possible, within the range specified by the prequalification test data, should be used for mixing to maximize properties. When ambient temperature exceeds 70°F, the use of iced water may help installation by prolonging pot life. Typically, batch size will be 25 pounds, consisting of 12½ pounds of grey material and 12½ pounds of white material. Half or double batches may also be used. All components should be accurately weighed or measured volumetrically (water) and proportioned as per manufacturer's instructions. Mix only as much material as can be placed within 12 minutes. **Under no circumstances should more water be added (after initial prescribed mixing is completed).** Figure 2500-11 gives equivalent water requirements.

Placement. Type B refractory linings should be installed by hammering or ramming. Handpacking (without further compaction by ramming) is not acceptable. Apply material downhand as much as possible. It must be compacted thoroughly into the anchorage and worked sufficiently to eliminate air bubbles and pockets. All holes, gaps and openings in the lining must be filled. The material should be cut smoothly to the top surface of the anchorage. Avoid unnecessary movement of the lined equipment until phosphate bonding action has occurred. This reaction is exothermic, and heat generated within the refractory indicates that it is setting. The lining's finished thickness tolerance should be +1/16 inch and -1/32 inch relative to the top of the anchorage.

2542 Type C, Phosphate Bonded Plastics

General. Because Type C refractories come ready-to-use (mixed), the problems of mixing (inherent in Type B refractories) and short pot life are eliminated. This makes Type C linings particularly useful for repair of FCCU regenerator cyclone linings (in place) during a turnaround. Since phosphate bonded plastics require heat to set (chemical bonding takes place at about 700°F), they have two disadvantages relative to Type B refractories:

- Installed linings are semi-soft and must be treated carefully prior to dryout. Bloating is sometimes a problem with these plastic linings.
- Prior to dryout, Type C refractory linings are chemically unstable in atmospheres containing high concentrations of steam. Because of this, these products should not be used on the “reactor side” of FCC units *unless* they have been preheated to 700°F.

Type C refractories should be placed late in a shutdown, especially if used in a high-traffic area, since they are easily damaged until thermally cured. Also, dryout of shop-lined equipment should occur before the equipment is moved to the job site.

Metal Fibers. If metal fibers are desired, the manufacturer must add them before he ships the mixture. When the material arrives at the job site, it has the consistency of putty—sometimes stiff putty. It is absolutely impossible to add metal fibers to this stiff mix once it has been shipped to the customer. If metal fibers are desired (use only with S-bars, not hexmesh), they must be specified in the Purchase Order so that the manufacturer can add them during his mixing/blending operation. Metal Fibers used in Type C refractory should be 3/4-inch long, melt-extraction type and (usually) made of Type 304 stainless steel. They are added at the rate of 3 pounds per 100 pounds of material.

Installation. Type C refractory should be stored in a cool dry place at 40°F to 80°F until used. It is installed by ramming the material thoroughly into the anchorage system. Use a pneumatic rammer with a 2-inch to a 2½-inch diameter hard rubber head. Air pressure to the rammer should be 90 to 100 psi. Apply material down-hand as much as possible and compact it thoroughly into the anchorage. All holes, gaps and openings must be filled. Any broken bits or slabs of plastic should be used quickly before they become dry and crumbly. The installed refractory should be cut smoothly to the top surface of the anchorage and then scraped or screeded to give it a somewhat open and porous finish. Do not “slick” the surface. Installed plastic refractory may require a partial dryout to several hundred degrees to harden so that it can be moved. Do not allow water, water vapor or steam to contact Type C refractory prior to dryout.

2550 Vibration Cast Linings

Castables for placement by vibration casting are specifically designed for this technology. Their grain size distribution is critical. Very little water is used and additives are typically employed to promote flow of wet-mixed castable. Vibratory casting of these specially formulated materials produces a lining having better physical properties than normally obtainable by other methods of installation. Porosity is decreased and erosion resistance and strength values are significantly improved. Mock-up testing using prequalified material is a common practice to determine the contractor's capability to install a particular vibration cast system. Most vibration cast projects entail use of new piping sections and the linings are usually installed at either the contractor's shop or at a fabrication shop. Key elements in obtaining high quality vibration cast linings include:

1. Vibration casting forms
2. Vibrators
3. Metal Fibers
4. Mixing
5. Installing

These elements are inter-related but will be discussed separately. See also IRM-MS-4788, the vibration cast installation specification.

2551 Vibration Casting Forms

Forms are usually fabricated by a specialist working with the refractory contractor. Made of sheet steel, the forms must be rigidly constructed and sufficiently water-tight to prevent leakage. They must also be strong enough to resist both deformation and movement during the vibe-cast process. Also, they must be constructed and installed to resist floating due to the wet installed castable. Forms should be removable without having to be burned out. Arc gouging is typical in the industry and does not cause a problem.

Openings or pouring ports in the forms may be used for placement of the wet-mixed castable. The pouring ports must be large enough (and numerous enough) to allow observation of the free refractory surface at the top of the casting, if necessary. Pouring ports are often provided in pairs—180 degrees apart and at the same elevation.

Means must be provided to keep the form centered within the piping section. The installed lining must be concentric within the following tolerances:

Piping Component	Tolerance	
	in	mm
Straight section	±1/4	±6
Curved section	±1/2	±13
Maximum step at adjoining sections	±1/16	±1.6

2552 Vibrators

Vibrator capacity must be sufficient for the job. For example, larger vibrators would be needed to line an 8-foot diameter pipe section than for a 5-foot diameter pipe section of the same height. It is recommended that the total force provided by the vibrators be equal to or exceed the total weight of the pipe section being lined plus the weight of the castable being installed. Vibrators which operate in the frequency range of 5000 to 8000 cycles per minute are very effective in moving wet-mix castable.

At least four external, rotary mechanical vibrators are required for each vibration casting operation (unless a very short section is being lined). The vibrators should

be used in pairs at each elevation, located 180 degrees apart and approximately on 4-foot centers. Each pair of vibrators should be offset 90 degrees from the pair of vibrators above and below. The lowest pair of vibrators should be located from 18 inches to 24 inches from the bottom of the casting. The top pair should be placed as close to the top of the casting as reasonably possible.

Vibrators should be strapped to the outside of the piping section to be lined. Steel straps or chains are used for this purpose. Vibration should not be applied through any attachment which is welded to the pipe shell. Fatigue of attachment welds has damaged equipment.

If the castable is installed in piping (or vessel) sections prior to erection, a gap at the top of each section should be left unlined (until the erected sections have been welded). A reactor riser line will not require the same concentration of vibrational energy as a wye-section or slide valve due to its smaller mass. Trial runs can help determine if the vibration is sufficient for the pour. Over-vibrating can be a problem—causing excessive movement of the castable, entrapment of air in the lining, damage to the anchors (fatigue), or cracking of structural welds.

2553 Metal Fibers

Stainless steel fibers are always incorporated in vibration cast linings, to improve thermal shock resistance and overall durability. Metal fibers should be 0.020-inch diameter by 1-inch long, made from melt extracted material. The project drawing should state metallurgy required, but Type 304 is most commonly used. Metal fibers are added to the castable at the rate shown in Figure 2500-10 depending on refractory density. This addition may be made by the refractory manufacturer during the final mixing operation at his plant *or* in the field. When metal fibers are added in the field, it is essential that they be thoroughly dispersed throughout the material (see Mixing below).

2554 Mixing

All mixing must be performed in horizontal-shaft, rotating-blade paddle mixers. The first time that one sees a batch being mixed, he or she would conclude that the wet-mixed castable was too dry. Quite often the castable will compact into lumps (during mixing or transportation to the section being lined). Such lumps are not detrimental. The water content is very probably correct. Water content must be very carefully controlled and maintained within the limits developed during prequalification testing of the material. If prequalification testing was done without metal fibers, a *small* (2 to 3%) increase in water is made to compensate for the metal fibers. Figure 2500-11 gives equivalent water requirements.

It is necessary to weigh the refractory and measure or weigh the water being added (since all bags do not contain exactly the specified amount of dry material). The water must be potable (less than 200 ppm chlorides) and clean. Stainless steel fibers should be uniformly dispersed throughout the refractory. To accomplish this, pre-weighed lots of stainless steel fibers are introduced into *dry* refractory (inside the

operating mixer) through a shaking screen box. The metal fibers must fall as a rain to prevent fiber agglomeration.

The quantity of castable mixed at one time must be no greater than that which can be placed before initial set begins, typically 200 to 400 pounds per batch. Mixing time should be per manufacturer's recommendation, generally 5 to 10 minutes, and time from water addition (in mixer) to placement should be less than 20 minutes. Other details covering mixing of castables for vibration-cast installation are given in Specification IRM-MS-4788.

2555 Installing

Before mixing any refractory material, the entire vibration system for the casting (pipe section) should be checked to assure:

1. The forms are clean and have been waterproofed.
2. Each vibrator is fully operational.
3. The frequency of each vibrator is reasonable and appropriate.
4. All anchors are secure with no evidence of anchor failure under vibrational stress.

Only clean equipment should be used in transporting the wet-mixed castable from the mixer to the point of installation. The mixer should be as close to the piping section being lined as reasonably possible—to reduce time required for transporting.

Vibration cast refractory material should be deposited vertically whenever possible. The material must be deposited as closely as feasible to its final position with free fall limited to eight (8) feet. Vibration cast linings should be compacted by vibrating the piping shell (or other equipment). Forms should be vibrated only with the approval of Chevron's engineer. Immersion vibrators are prohibited with this installation method.

Work should be continued until an entire piping section has been completed. Vibrators should be stopped about 5 minutes after the free surface of the refractory has passed the vibrator level. Also, vibrators should be stopped 5 minutes after a section is completely lined.

Work stoppages may occur due to loss of air to the vibrators or malfunction in the vibrators or their attachment method. Work stoppages over 30 minutes may require abandoning the pour for 16 to 24 hours. After a stoppage, when the vibrators are started again, check to see if the lining will “melt” (become soft as it was before the work stoppage). If the lining does not melt, the stoppage was too long and the pour should be abandoned until the following day. Linings that do not move may be subject to damage with further vibration. After the lining “sets,” the vibrators do not affect the refractory, and the pour may resume.

The thickness tolerance for vibration cast linings is a function of form diameter tolerances (see Specification IRM-MS-4788) and diameter tolerances of the piping being lined. The forms should stay in place for at least 24 hours after installation of the lining.