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2. GENERAL

2.1 Scope

a. This specification describes the refractory and anchorage materials to be used, and the methods of application, for internally lining vessels, equipment, piping, and duct work with a ¾ inch (19 mm) or 1 inch (25 mm) thick, abrasion resistant monolithic refractory lining. Refractory lining in fired process heaters, stacks, and related equipment is not included.

b. The refractory and all required hydrating water are blended in the mixer. The resulting mixture is transported to the installation site and placed where required. Consolidation and removal of air pockets is accomplished by ramming of the in place refractory.

c. The refractory materials and systems described in this specification provide a dense, abrasion resistant lining. They are not suitable for corrosion protection or insulating purposes.

d. This specification is not applicable to plastic refractories.

e. This specification is not applicable to materials that are conveyed or pumped to the installation site, nor is it applicable to self-leveling, pumpcast, or similar materials.

f. Exceptions or variations shown in the UOP Project Specifications take precedence over requirements shown herein.

g. When the refractory anchor manufacturer's installation pattern and welding requirements are more stringent than those shown herein, or are not addressed by the requirements of this specification, the manufacturer's requirements shall govern.

h. When the Manufacturer's requirements for refractory storage, mixing, placement, curing and heat drying, etc. are more stringent than those herein, the Manufacturer's requirements shall govern.

2.2 References

The edition in effect on the date of contract award for the equipment shall be used, except as otherwise noted. When a referenced document incorporates another document, use the edition of that document required by the referenced document.

a. ASTM International (ASTM):

(1) A240 "Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications"

(2) A820 "Standard Specification for Steel Fibers for Fiber-Reinforced Concrete"

(3) C71 "Standard Terminology Relating to Refractories"

(4) C113 "Standard Test Method for Reheat Change of Refractory Brick"

(5) C133 "Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories"

(6) C134 "Standard Test Methods for Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick"

(7) C309 "Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete"

(8) C704 "Standard Test Method for Abrasion Resistance of Refractory Materials at Room Temperature"

(9) C865 "Standard Practice for Firing Refractory Concrete Specimens"

(10) D4285 "Standard Test Method for Indicating Oil or Water in Compressed Air"

(11) E220 "Standard Test Method for Calibration of Thermocouples by Comparison Techniques"

b. American Welding Society (AWS) A 5.4 / ASME SFA-5.4/SFA-5.4M, "Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding".

c. AWS A 5.9 / ASME SFA-5.9/SFA-5.9M, "Specification for Bare Stainless Steel Welding Electrodes and Rods".

d. American Petroleum Institute (API) Standard 936, "Refractory Installation Quality Control – Inspection and Testing Monolithic Refractory Linings and Materials".

e. The Society for Protective Coatings (SSPC), Specification SP-7, "Brush-Off Blast Cleaning".

f. National, state, and local governmental regulations and laws.

2.3 Governing Documents

a. Refractory lining materials, testing, installation, and inspection shall comply with the requirements of API Standard 936, except where modified by either the UOP Standard Specifications or UOP Project Specifications and Drawings.

b. The refractory anchorage installer shall prepare a list of deviations (including sketches) from this UOP Standard Specification and the UOP Project Specifications and Drawings. The deviation list shall be submitted to the Owner and approved before the start of the refractory anchoring system installation.

c. The refractory lining applicator shall prepare a detailed, written, procedure covering the entire lining process including materials, storage, qualification, installation, curing, heat drying, inspection and testing. The applicator shall prepare a list of deviations from this UOP Standard Specification and the UOP Project Specifications and Drawings. The procedure and deviation list shall be submitted to the Owner and approved before to the start of refractory installation.

d. A pre-installation meeting between the Owner, Contractor, Anchor and Refractory Installers, and Heat Drying Contractor is recommended. The primary purpose is to ensure that the specification and job requirements are clear and understood by all parties. Additionally, any requested deviations may be discussed and resolved. Matters of responsibility and timing, as well as inspection issues, including hold points and notification requirements, may also be resolved.

2.4 Definitions

Terms related to refractory materials, installation, testing, inspection, etc., are defined in API Standard 936 and ASTM C71. For convenience, several of those definitions are repeated and expanded upon in the following list.

a. Biscuit or Cookie:
The refractory contained within a closed cell anchoring shape such as an individual hexagon of hexagonal mesh or rectangle of flexible mesh.

b. Closed Cell Anchors:
An anchoring system made up of a series of small enclosed volumes into which the refractory is rammed. Hexagonal and flexible mesh are examples. Other than through openings in the metal strips forming the mesh, the refractory is not continuous.

c. Flexible Mesh:
A continuous, metallic, anchoring system constructed of metal strips bent in a repeating, slightly greater than 90 degree contained angle, pattern. The flats are slightly smaller than the adjacent opening so that neighboring strips may be slightly nested, forming approximately square or rectangular enclosures. Strips are joined by a continuous rod or other hinge system to allow rotation about the longitudinal axis at the joint (see Figures 16 and 18). The assembly may be rolled to pass through equipment openings. The ability to flex, or bend, permits ready fit to singly curved surfaces. The mesh is first welded to the equipment shell and the rectangular enclosures later packed with erosion resistant refractory.

d. Hexagonal Mesh:
A continuous, metallic, anchoring system constructed of metal strips bent in a repeating 120 degree contained angle pattern. When the flats of adjacent strips are joined (usually by clinching) a hexagonal shaped enclosure is formed (see Figures 1 and 3). The completed system is rigid and must be bent to conform to the backing surface. It does not contain hinges or other flexible components. The mesh is first welded to the equipment shell and the hexagonal enclosures are later packed with erosion resistant refractory.

e. Hexalt Anchors:
Individual, non-continuous, normally proprietary metallic anchors used as an alternative to a hexagonal or flexible mesh system. The anchors are individual components that may or may not include an enclosure to be filled with refractory. The refractory between anchors is continuous. The anchors are first welded to the equipment shell. Abrasion resistant refractory is later packed between the anchors and, where applicable, into the enclosures within the anchor.

f. Non-closed Cell Anchors:
An anchoring system that does not create a series of individual cells of refractory (biscuits); hexalts (e.g., S-bars) are examples. The refractory is a continuous system; the anchors are embedded in the refractory. Some hexalt systems (e.g., individual hex cells) have characteristics of both closed and non-closed anchors.

2.5 Extent of Refractory Lining

a. Areas in which refractory lining is to be installed are identified in the UOP Project Specifications and UOP Project Drawings.

b. The lining thickness shall be either ¾ inch (19 mm) or 1 inch (25 mm) as specified on the UOP Project Specifications or UOP Project Drawings. If a lining thickness is not specified, ¾ inch (19 mm) shall be used.

c. Refractory lining is not required in non-flowing (e.g., dead end) nozzles NPS 6 (DN 150) and smaller.

2.6 Default Lining Specification

Unless otherwise specified on the UOP Project Specifications or UOP Project Drawings the refractory anchoring system and refractory shall

a. be hexagonal mesh
b. be ¾ inch (19mm) thick
c. not include lances
d. be fabricated from Type 304 or 304H strips
e. be welded every hex of every other row
f. not include reinforcing fibers in the refractory

3. ANCHORS, EDGING BARS, COLLARS, AND WELDING

3.1 Anchoring System

The refractory anchoring system for the installation of abrasion resistant lining shall be limited to hexagonal mesh in accordance with Paragraph 3.2a. or S-bar hexalts in accordance with Paragraph 3.2c.(3)(d) as specified in the UOP Project Specifications and UOP Project Drawings. Fabricator shall consult UOP for prior approval before using alternate anchoring systems such as flexible mesh in accordance with Paragraph 3.2b. or other hexalt anchors in accordance with Paragraph 3.2c. other than S-bars. If an anchoring system is not specified hexagonal mesh shall be used.

3.2 Materials

a. Hexagonal Mesh

(1) Hexagonal mesh shall be fabricated from 14 gauge (2 mm) strips of the material specified in Table 1. The strips shall be bent into a series of parallel and angled sections so that when two strips are joined back to back a series of hexagons, each approximately 1-7/8 inches (48 mm) across the flats are formed (see Figure 1).

(2) The hexagonal mesh depth shall equal the full specified depth of the lining (i.e., ¾ or 1 inch (19 or 25 mm)).

(3) The top and bottom surfaces of the hexagonal mesh shall be flat and parallel prior to forming of the hexagonal mesh. Infrequent offset strips may be permissible; however no strip shall extend more than 1/32 inch (0.8 mm) above or below the plane surface and the total offset between the highest and lowest strip shall not exceed 1/32 inch (0.8 mm). The maximum offset between neighboring strips shall be 1/32 inch (0.8 mm).

(4) The parallel sides of the formed strips shall contain either perforations or prongs on alternating sides. The prongs from one strip fit into the perforation of the neighboring strip. The prongs are then bent to clamp neighboring strips together to form the continuous mesh (see Figures 1 and 3).

(5) The angled or sloped portions of each strip shall contain perforations. Refractory filling these perforations will join neighboring biscuits together.

(6) The prongs and perforations shall be centered at mid-depth of ¾ inch (19 mm) hexagonal mesh. For 1 inch (25 mm) hexagonal mesh, the perforations shall be located the same distance from the surface of the mesh to be attached to the shell as they are for ¾ inch (19 mm) hexagonal mesh (i.e., centered 3/8 inch (10 mm) from the shell surface and 5/8 inch (15 mm) from the process exposed surface. Refractory filling the perforations will join neighboring biscuits together.

(7) Hexagonal mesh shall not include lances, or prongs, extending into the refractory biscuit unless specified in the UOP Project Specifications or UOP Project Drawings. When lances are specified:

(a) Lances shall be located at the same elevation as the prongs and perforations.

(b) Two lances shall be provided in each biscuit.

(c) Lances shall be located approximately in the center of two sides of each hex, separated by a clinched side.

(d) Lances shall not point towards each other. The included angle between the lance and hexagonal mesh strip shall be between 60 and 90 degrees (see Figure 2).

(8) Tightly rolled hexagonal mesh shall be welded as shown in Figure 13. The welds shall be completed before the hexagonal mesh is formed/rolled. Tightly rolled is defined in Figure 13.

b. Flexible Mesh

(1) Flexible mesh shall be fabricated from 14 gauge (2 mm) strips of the material specified in Table 1. The strips shall be bent at a series of near 90º angles to form three sides of a trapezoid. The parallel sides of the trapezoid shall be approximately 1½ inches (38 mm) and $1^{7}/_{16}$ inches (36 mm) long. The trapezoid depth shall be approximately $1^{13}/_{16}$ inches (46 mm) (see Figures 16 and 18).

(2) The strips shall be nested as shown in Figure 16 and 18. The strips shall be joined by a means that permits free rotation of each strip relative to the neighboring strips; for example, a rod passing through holes near the bottom of the flexible mesh.

(3) The flexible mesh depth shall equal the full specified depth of the lining (i.e., ¾ or 1 inch (19 or 25 mm)).

(4) The top and bottom surfaces of the flexible mesh shall be flat and parallel prior to forming of the flexible mesh. Infrequent offset strips may be permissible, however no strip shall extend more than 1/32” (0.8 mm) above or below the plane surface and the total offset between the highest and lowest strip shall not exceed 1/32” (0.8 mm). The maximum offset between neighboring strips shall be 1/32” (0.8 mm).

(5) Each side of each trapezoid shall contain perforations. The perforations shall be centered at mid-depth of ¾ inch (19 mm) flexible mesh. For 1 inch (25 mm) flexible mesh, the perforations shall be located the same distance from the surface of the mesh to be attached to the shell as they are for ¾ inch (19 mm) flexible mesh (i.e., centered 3/8 inch (10 mm) from the shell surface and 5/8 inch (15 mm) from the process exposed surface. Refractory filling these perforations will join neighboring biscuits together.

(6) Flexible mesh shall not include lances, or prongs, extending into the refractory biscuit unless specified in the UOP Project Specifications or UOP Project Drawings. When lances are specified:

(a) Lances shall be located at the same elevation as the perforations.

(b) Two lances shall be provided in each biscuit, one in approximately the center of each opposing sloped side.

(c) Lances shall not point towards each other. The included angle between lances shall not exceed 120º (see Figure 17).

c. Hexalts

(1) Hexalt anchors are generally proprietary products. A few, such as S-bars, may not be proprietary.

(2) Hexalts shall be fabricated from the materials specified in Table 1.

(3) Any hexalt system may be used if it has a record of proven performance in an application similar to the intended use and surface geometry, and its use is approved by the owner.

(a) Hexalts with three, non-linear points of attachment (i.e., forming a tripod) are preferred.

(b) Hexalt thickness shall be a minimum of 14 gauge (2mm).

(c) Hexalts shall include an overhang, an area through which the refractory may pass at the shell, and/or perforations centered near mid-depth of the lining.

(d) S-bars shall conform to the dimensions of Figure 21.

d. Auxiliary Components

(1) Auxiliary components include corner tabs, radius tabs, U-tabs edging bars, taper bars, filler strips, anchor bars, binding bars, etc.

(a) Corner tabs are used to anchor the refractory at base metal intersections. Fixed, 90 degree tabs are used at right angle intersections and variable tabs are used at non-right angle joints. Corner tabs are used for both inside and outside corners with all anchorage systems. See Figure 33 for details.

(b) U-tabs are used at the edges of plates that are lined on both sides. See Figure 34 for details.

(c) Radius tabs are used to anchor the refractory onto small diameter pipes. See Figure 32 for details.

(d) Edging bars are used at abrasion resistant lining terminations. See Figure 30 for details. Edging bars are used with all anchorage systems.

(e) Taper bars are used at abrasion resistant lining terminations that form a step change in the flowing stream and elsewhere that a gradual transition is desirable. Use of a taper bar results in a much smoother transition. See Figure 29 for details. Taper bars are used with all anchorage systems.

(f) Filler strips are used to join sections of hexagonal, or flexible, mesh at side offsets. See Figures 8 and 10 for details. Filler strips are used only with hexagonal or flexible mesh anchorage systems.

(g) Binding strips are used to link previously and newly installed refractory field joints using hexalts (see Figures 23, 25, and 26).

(h) Anchor bars are used to attach hexagonal, or flexible, mesh at transitions between abrasion resistant and thicker insulating or dual purpose refractories. See Figures 14 and 15 for details.

(2) Auxiliary components shall be fabricated from the same material as the primary anchoring system (hexagonal mesh, flexible mesh, or hexalt). See Table 1.

(3) Perforations and prongs shall be provided in corner tabs, U-tabs, radius tabs, and binding strips. Where space permits, perforations shall be provided in filler strips. Perforations and prongs are not applicable to other auxiliary components (e.g., edging, taper, and anchor bars). Perforations and prongs shall be centered at mid-depth of ¾ inch (19 mm) linings. For 1 inch (25 mm) linings they shall be centered the same distance (3/8 inch (10 mm) from the base metal surface as for a ¾ inch (19 mm) lining.

(4) Auxiliary components shall be of the following dimensions:

(a) Corner tabs, U-tabs and radius tabs shall be fabricated from 14 gauge (2 mm) strip of a depth equal to the full specified depth of the lining (i.e., ¾ inch (19 mm) or 1 inch (25 mm)). See Figure 33 and Figure 34 for other dimensions.

(b) Filler and binding strips shall be fabricated from 14 gauge (2 mm) strip of a depth equal to the full specified depth of the lining (i.e., ¾ inch (19 mm) or 1 inch (25 mm)). Other dimensions shall be as required for the use.

(c) Edging bars shall be fabricated from ¼ inch (6 mm) plate of a depth equal to the full specified depth of the lining (i.e., ¾ inch (19 mm) or 1 inch (25 mm). See Figure 30 for additional details.

(d) Taper bars shall be fabricated from 3/8 inch (10 mm) plate. Other dimensions shall be as required to comply with Figure 29.

(e) Anchor bars shall be fabricated from 14 gauge (2 mm) strip, 1/2 inch (13 mm) wide. Other dimensions shall be as required to comply with Figure 14 or Figure 15.

3.3 Welding Electrodes

a. Welding shall utilize a metal arc process using covered or bare electrodes in accordance with Table 1.

Table 1 - Anchorage System Materials and Welding Electrodes

Base Metal (see Note)	Anchoring System Material	Welding Electrodes
Carbon and low alloy steel through 5Cr-1Mo	ASTM A240 Type 405 or 410S	ASME SFA-5.4/SFA-5.4M / AWS A-5.4 Class E309 - 15 or 16 or E310 - 15 or 16 or ASME SFA-5.9/SFA-5.9M / AWS A-5.9 Class ER 309 or ER 310
Type 405 or 410S	ASTM A240 Type 405 or 410S	ASME SFA-5.4/SFA-5.4M / AWS A-5.4 Class E309 - 15 or 16 or E310 - 15 or 16 or ASME SFA-5.9/SFA-5.9M / AWS A-5.9 Class ER 309 or ER 310
Type 304 or 304H	ASTM A240 Type 304	ASME SFA-5.4/SFA-5.4M / AWS A-5.4 Class E 308 - 15 or 16 or ASME SFA-5.9/SFA-5.9M / AWS A-5.9 Class ER 308
Type 309S or 310S	ASTM A240 Type 304, 309, or 310	ASME SFA-5.4/SFA-5.4M / AWS A-5.4 Class E309 - 15 or 16 or E310 - 15 or 16 or ASME SFA-5.9/SFA-5.9M / AWS A-5.9 Class ER 309 or ER 310
Type 316 or 316H	ASTM A 240 Type 316	ASME SFA-5.4/SFA-5.4M / AWS A-5.4 Class E-316 - 15 or 16 or ASME SFA-5.9/SFA-5.9M / AWS A-5.9 Class ER 316
Type 321, 321H, 347, or 347H	ASTM A240 Type 321 or 347	ASME SFA-5.4/SFA-5.4M / AWS A-5.4 Class E347 - 15 or 16 or ASME SFA-5.9/SFA-5.9M / AWS A-5.9 Class ER 347

Note: Where the base metal is lined with a metallic cladding or weld overlay the anchorage material and welding electrode shall be based upon the lining metallurgy.

b. Anchors shall not be studwelded.

3.4 Installation of the Anchoring System

a. Preparation

(1) Grind all welds and slag flush with the shell before installation of the refractory anchoring system. The anchoring system may straddle misaligned equipment surfaces at joints up to a maximum of the allowable misalignment or 1/16 inch (1.5 mm), whichever is less.

(2) Immediately prior to anchor installation, prepare the interior plate surface by grit blast cleaning to remove rust, loose mill scale, oil, dirt, or other foreign materials. The grit shall be compatible with the base metal (e.g. steel grit shall not be used on stainless steel base metal) and shall not damage or leave residue on the base metal. The grit and the blasting air supply shall be dry and clean. Testing of the air stream discharged from the hose shall be in accordance with ASTM D4285. Cleaning shall be brush-off blast clean in accordance with SSPC-SP-7.

(3). After grit blast cleaning, the surfaces to be lined shall be vacuum cleaned to remove all debris. Do NOT wash with water. Inspect the surfaces for cleanliness and repeat the above blast cleaning as necessary.

(4). Wax crayons, grease markers or other substances that will interfere with the quality of the attachment weld shall not be used to locate anchor, bar, tab, etc., positions.

b. Welding

(1) Welding to equipment covered by a design or fabrication Code shall be performed by Code qualified welders.

(2) Welding shall be done after any radiography or other nondestructive examination requirements are completed, but before postweld heat treatment (PWHT).

(3) Hexagonal Mesh

(a) Hexagonal mesh and auxiliary components shall be rolled to conform to the base metal and shall be welded to the base metal as illustrated in Figures 3 through 10, 29, and 31 through 35. Roll hexagonal mesh the hard way (parallel to the strips) as shown on Figure 1. Note the orientation of the mesh relative to the direction of flow. Also, note the requirements for additional welding in coking, thermal cycling, or vibration services when specified on the UOP Project Specifications or UOP Project Drawings.

(b) Install 1 inch (25 mm) hexagonal mesh so that the perforations and clinches are closer to the base metal than to the process surface. The perforations and clinches are in the center of ¾ inch (19 mm) hexagonal mesh, therefore it may be installed either side up.

(c) Hexagonal mesh shall be welded to the base metal as described in Figure 3. Welds within a hexagon shall be on each side of the joint between the bent strips that form the hexagonal mesh.

(d) When specified in the UOP Project Specifications or UOP Project Drawings, each hex shall be welded to the base metal. This will most commonly occur in severe coking, vibratory, or thermal cycling services (see Figure 3, Notes 2 and 3).

(e) Auxiliary components shall be perpendicular to the base metal. They shall fit tightly against, and be firmly welded to the base metal and, where indicated, the hexagonal mesh. The welding method shall not result in distortion of the auxiliary component or cause it to be other than perpendicular to the base metal.

(f) The extent of welding specified is minimum. Tightly clinch the closure prongs and provided additional welds to ensure that no portion of the hexagonal mesh is loose and all edges are firmly welded to the base metal and edging bars.

(g) Installation of hexagonal mesh at field seams or other areas where the mesh must be installed later than the surrounding mesh shall comply with the requirements of Figure 11. Sections less than 24 inches (600 mm) inside diameter of refractory where radiography and PWHT will not be performed and where the joint is inaccessible from the inside may conform to the requirements of Figure 12.

(h) Transitions between abrasion resistant lined sections and insulating lining lined sections shall comply with the requirements of Figures 14 and 15.

(i) Place each section of the hexagonal mesh so that it conforms with the shell surface.

  (i) Fit the hex mesh tightly against the shell by bending in the direction of the exposed closure prongs, in other words, in the strong direction of the mesh.

  (ii) Tightly rolled sections shall include vertical welds where the strips of the hexagonal mesh meet. The welds shall be inside of each hex and entirely below the exposed surface of the mesh. Grind off any weld above the mesh surface. See Figure 13 for details and definitions of tightly rolled.

(iii) After installation abutting strips of hexagonal mesh shall remain tightly joined. When hexagonal mesh is rolled to a small diameter (less than 36 inches (915 mm) for ¾ inch (19 mm) mesh and 48 inches (1220 mm) for 1 inch (25 mm) mesh) a separation between abutting strips of the hexagonal mesh assembly not exceeding 1/32 inch (0.8 mm) may be permitted.

(j) Clinch each section of hexagonal mesh to the adjoining sections. When adjoining sections cannot be clinched together they shall be tightly abutted together and firmly welded to the base metal.

(k) Surface protrusions of the hexagonal mesh shall be ground flush.

(4) Flexible Mesh

(a) Flexible mesh shall be welded to the base metal as indicated in Figures 19 and 20. Special details and auxiliary component attachment shall be similar to Figures 4 through 10, 29, and 31 through 35.

(b) Install 1 inch (25 mm) flexible mesh so that the perforations and hinges are closer to the base metal than to the process surface. Install ¾ inch (19 mm) flexible mesh so the hinge is closer to the base metal than the process surface. If the hinge is centered, ¾ inch (19 mm) flexible mesh may be installed either side up.

(c) When specified in the UOP Project Specifications or UOP Project Drawings, weld each cell of the flexible mesh to the base metal. This will most commonly occur in severe coking, thermal cycling, or vibratory environments or where the mesh is sharply curved. (see Figure 20).

(d) Auxiliary components shall be perpendicular to the base metal. They shall fit tightly against and be firmly welded to the base metal and, where indicated, the flexible mesh. The welding method shall not result in distortion of the auxiliary component or cause it to be other than perpendicular to the base metal.

(e) The extent of welding specified is minimum. Provide additional welds to ensure that no portion of the flexible mesh is loose and all edges are firmly welded to the base metal and edging bars.

(f) Installation of flexible mesh at field seams or to the areas where the mesh must be installed later than the surrounding mesh shall be similar to the requirements of Figure 11. Sections less than 24 inches (600 mm) inside diameter of refractory where radiography and PWHT will not be performed and where the joint is inaccessible from the inside, may conform to the requirements of Figure 12.

(g) Transitions between abrasion resistant lined sections and insulating lining lined sections shall comply with the requirements of Figures 14 and 15.

(h) Surface protrusions of the flexible mesh shall be ground flush.

(5) Hexalts

(a) S-bars and auxiliary components shall be welded to the base metal as indicated in Figures 21, 22, and 28. Note the relation of the installation to the direction of flow. The spacing between S-bars and auxiliary components shall not be less than one-half nor more than one and one-half the S-bar spacing shown in Figure 22.

(b) Other styles of hexalts shall be installed in an overlapping pattern perpendicular to the direction of flow, similar to the pattern illustrated for S-bars, adjusted to account for differing hexalt sizes and shapes. Details of the pattern (e.g., hexalt spacing) shall be in accordance with the manufacturer's recommendations.

(c) Hexalts shall be located so that hexalts are encountered frequently regardless of the direction of flow over the refractory surface.

(d) Auxiliary components shall be perpendicular to the base metal. They shall fit tightly against and be firmly welded to the base metal and, where indicated, the hexalts. The welding method shall not result in distortion of the auxiliary component or cause it to be other than perpendicular to the base metal.

(e) Weld locations, sizes, and procedures shall be in accordance with the hexalt manufacturer's recommendations. Welding shall not "burn through" the anchor, shall not result in distortion of the hexalt, and shall result in the hexalt being firmly welded and perpendicular to the base metal.

(f) The installation of S-bars at field seams or other areas where the S-bars must be installed later than the surrounding anchors shall comply with the requirements of Figure 23. Sections less than 24 inches (600 mm) inside diameter of refractory where radiography and PWHT will not be performed and where the joint is inaccessible from the inside may conform to the requirements of Figure 24. Similar details shall be used with other types of hexalts.

(g) Transitions between abrasion resistant lined sections and insulating lining lined sections shall comply with the requirements of Figure 26. S-bars shall be used for the transition regardless of the hexalt system used elsewhere.

(h) Surface protrusions of the hexalts shall be ground flush.

c. Inspection and Testing

Installed anchors (hexagonal mesh, flexible mesh, or hexalts) and auxiliary components, shall be inspected by the Owner or Owner's authorized representative. Hexagonal and flexible mesh shall be hammer tested by striking at one foot (300 mm) centers from several directions with an 8 to 16 ounce (225-455 gram) hammer. Each hexalt and auxiliary component shall be tested by striking from several directions with an 8 to 16 ounce (225 – 455 gram) hammer. Loose or broken anchors or cracked welds shall be removed and replaced. Hammer test the replaced anchors or components.

4. LINING MATERIALS

4.1 Refractory

a. Refractory materials shall be of a grade suitable for rammed installation.

b. Selection of the refractory product(s) to be installed shall be based upon positive experience with the product in the same or similar service to the anticipated service. Recommended suppliers and products are listed in Paragraph 4.1l.(2).

c. Refractory shall be new. Reclaimed, recycled, reconditioned, rejected, or material beyond its shelf life shall not be used or blended into the new material at production or at installation.

d. The as supplied refractory materials shall NOT include metal reinforcing fibers. Organic fibers, as recommended by the refractory manufacturer, are acceptable.

e. Refractory material shall be provided in polyethylene lined bags, shipped on plastic shrink-wrapped pallets. Each pallet shall contain material from only one manufactured batch (i.e., lot or production/blending run). The polyethylene shrink-wrapping shall cover all sides of the shipment, including the underside, not including the pallet. The shrink-wrap shall not be removed until the refractory is to be used. If a bag is removed for testing, the shrink wrap shall be resealed immediately.

f. Pallets shall be identified by order number and shall be numbered consecutively, beginning with one. The total number of pallets in the lot shall be included, i.e. 2 of 10. Material identification signs shall be prominently displayed on all sides of each pallet.

g. Each bag and/or pallet of material shall include, as a minimum, the following information: manufacturers name; plant of manufacture; product brand name; batch identification; date of manufacture; an accurate bag weight; mixing instructions (included hydrating water requirements); special cautions and/or requirements. If organic fibers are included, their presence shall be clearly indicated on each bag.

h. Refractory material shall be kept at a temperature between 35°F (2°C) and 50°F (10°C) for 24 hours prior to use. Higher temperatures may be used if approved by the refractory manufacturer. At all times the material shall be stored on an elevated ventilated platform, protected by a weatherproof covering above and on all sides, and so arranged that no water can come into contact with any of the material or bags. The platform shall be supported by a concrete slab or dry, durable surface, sloped to drain moisture away from the storage area. Care shall also be taken to avoid high humidity under the covering.

i. Previously opened bags of refractory, materials that are older than the lesser of nine months or the manufacturer's shelf life from their date of manufacture, materials exhibiting agglomeration or lumps that are not easily broken by hand, and material that has gotten wet or is otherwise damaged shall not be used.

j. The properties listed in Paragraph 4.1l.(3) are the range of values from the product catalog data sheets for the recommended products. These values are often averages rather than minimums. Guaranteed (or compliance) values shall be agreed upon with the chosen refractory vendor. The guaranteed values shall be the reference(s) used for all testing and material evaluations (see Section 8.1). Testing shall be in accordance with the listed specification(s).

k. The compliance value for abrasion loss of the refractory material when tested in accordance with ASTM C704 shall not exceed 4cc.

l. Abrasion Resistant Refractory

(1) These materials are used when excellent abrasion resistance is required but insulating properties are not necessary.

(2) The following ramming grade refractory products are recommended:

(a) For installations where the following two conditions apply:

(1) Application into FCC/RFCC Regenerators, Regenerated Catalyst Standpipes, Recirculation/Circulation Catalyst Standpipes, Cooled Catalyst Standpipes and downstream Regenerator Flue Gas Line components operating at similar temperatures under similar atmospheres.

(2) Sulfur content of the feed oil injected into the FCC/RFCC unit is greater than 0.40 wt %.

The following refractory materials are recommended.

Manufacturer	Product Name	Contact Information
Resco Products, Inc.	RESCOBOND AA-22S	www.rescoproducts.com
Stellar Materials	THERMBOND FORMULA 12-L	www.thermbond.com

(b) For installations other than those described in Paragraph 4.11.(2)(a) including FCC/RFCC Reactor, Spent Catalyst Standpipes and Reactor Riser and entire FCC/RFCC units where the sulfur content of the feed oil injected into the unit is less than or equal to 0.40 wt %, or in UOP/Hydro MTO Process Units (MTO) or Rapid Thermal Process Units (RTP™ Pyrolysis), there are no restrictions on the recommended abrasion lining materials.

Manufacturer	Product Name	Contact Information
Artech Technologies	ACTCHEM 85	www.actchem-usa,com
Calderys	CALDE™ STIX PB 85 C/G	www.calderys.com
Morgan Thermal Ceramics	KAOCRETE HPM 90-TR	www.morganthermalceramics.com
NV Gouda Vuurvast	CURAS 90 PF	www.goudarefractories.com
AGC Plibrico Co., Ltd.	THERVEK RM-3-25	www.plibrico.co.jp
Resco Products, Inc.	RESCOBOND AA-22S	www.rescoproducts.com
Resco Products, Inc.	R-MAX MP	www.rescoproducts.com
Stellar Materials	THERMBOND FORMULA 12-L	www.thermbond.com
Vesuvius Refractories International, Inc.	Petrogard XMA Plus	www.vesuvius.com

(3) Following is the range of product catalog data sheet values for the recommended materials. The properties are based upon samples prepared by ramming and without metal reinforcing fibers. The listed ranges are for informational purposes and are not to be used for quality control or decision making regarding individual products.

(a) Setting time does not exceed 24 hours.

(b) Service temperature is at least 2300 °F (1260 °C).

(c) Density after heating to 1500°F (815°C) and cooling to ambient temperature is at least 155 lb/ft^3 (2480 kg/m^3) per ASTM C134.

(d) Cold crushing strength after heating to 1500°F (815°C) and cooling to ambient temperature is at least 12,000 psi (845 kg/cm^2) per ASTM C133.

(e) Modulus of rupture after heating to 1500°F (815°C) and cooling to ambient temperature is at least 2,000 psi (140 kg/cm^2) per ASTM C133.

(f) Permanent linear change after heating to 1500°F (815°C) and cooling to ambient temperature is between 0.00 and -0.30% per ASTM C113.

(g) Erosion loss – See Paragraph 4.1k.

(h) Iron oxides are less than 1.0 weight percent.

(i) Aluminum oxides are greater than 80 weight percent.

4.2 Water

Mixing water shall be potable (suitable for drinking) with a pH between 6 and 8. Water from the firefighting system shall not be used. Water shall contain less than 50 ppm chlorides, and be free from deleterious impurities. Equipment used for storing and handling of the water shall be clean, so that no contaminating material is introduced. Water temperature shall be between 35°F (2°C) and 60°F (16°C) unless higher temperatures are approved by the refractory manufacturer {also see Paragraphs 5.3a.(1) and 5.3b.(9)}.

4.3 Metal Reinforcing Fibers

Reinforcing fibers shall comply with ASTM A820. Fibers shall be 20 mil (0.5 mm) Type 304 austenitic stainless steel, with a length of ¾ inch (19 mm). The material tensile strength shall comply with the requirements of the specified metallurgy. Fibers shall be of a uniform size and shape and shall not clump together. Fibers that become magnetic shall not be used. Fibers shall be manufactured by the melt extract process (ASTM A820 Type III), which is preferred, or, alternatively, corrugated fibers manufactured from slit sheets (ASTM A820 Type II). Corrugated fibers shall be twisted about their longitudinal axis. The corrugations shall be a smooth and gentle curvature, without any sharp bends. The corrugation range shall not exceed 1/16 inch (1.5 mm).

5. REFRACTORY INSTALLATION

5.1 Equipment and Tools

a. Equipment and tools used for refractory mixing, handling, and installation shall be clean and in good operating condition.

b. Backup or spare equipment and tools shall be provided at the jobsite for all items that would halt refractory placement in the event of their failure.

c. The capacity and number of pieces of equipment and tools in use during refractory installation shall be sufficient to ensure that application will proceed uninterrupted.

5.2 Preparation

a. Refractory installation shall not begin until after completion of welding, PWHT, and pressure testing. If the refractory installation must take place prior to pressure testing, all pressure retaining weld seams shall be left unlined, i.e., exposed to the testing medium, and the testing medium shall not damage or degrade the refractory. Installation of abrasion resistant lining over pressure retaining weld seams prior to pressure testing shall be limited to areas where access to properly install abrasion lining after pressure testing is limited. Fabricator shall confirm UOP does not object to proposed areas where abrasion resistant lining will be installed prior to pressure testing.

b. The mixing area and the installation site shall be kept clean, dry, and isolated from the surrounding area by use of heavy plastic or other means. The protective means shall prevent the entry of dust, rain or other deleterious material and shall protect against excessive wind, heat, and exposure to the sun (i.e., shaded).

c. The area to be lined shall be well lit and ventilated to provide good visibility and a cool breathable atmosphere during refractory installation.

d. Provide a reliable means of communication between the mixing and installation sites that is effective while both sites are in operation. Test the system under actual conditions and locations.

e. The surface to which the refractory lining is to be installed shall be dry and clean. Grit blast cleaning immediately prior to installation of the refractory is required if:

(1) Anchors have been installed over 30 days.

(2) Rust, weld slag or spatter, oil or grease, dirt, loose scale, debris, or other foreign materials are present on the surface to be lined.

(3) The surface does not comply with the requirements of SSPC SP-7.

(4) Hydrotest was performed after the grit blast cleaning for anchor installation.

f. The grit used for grit blast cleaning shall be compatible with the base metal (e.g. steel grit shall not be used on stainless steel base metal) and shall not damage or leave residue on the base metal. The grit blasting air supply shall be clean and dry. Testing for contamination of the air stream discharged from the hose shall be in accordance with ASTM D4285. Grit blast cleaning shall be brush-off blast clean in accordance with SSPC-SP-7.

g. After grit blast cleaning, the surfaces to be lined shall be vacuum cleaned to remove all debris. Do NOT wash with water. Inspect the surfaces for cleanliness and repeat the above grit blast cleaning as necessary.

h. Nozzle and other openings that will not be lined shall be closed by means of sealed wood or metal jacketed plugs of such dimensions that they fit snugly into the openings. The plugs shall be designed for easy removal after completion of the lining installation.

i. Obstructions that will interfere with the satisfactory and continuous application of the refractory lining (e.g., ladders, scaffolding, etc.) shall be avoided.

j. When welded joints or seams in the backing material will be completed after the refractory has been installed, the refractory shall be installed as shown in Figure 11 or for hexalts, Figure 23. After welding (including welding of additional anchors (e.g., hexagonal mesh)), examination, and heat treatment have been completed, the remaining lining shall be installed. This interruption of application shall follow the procedures described in Section 5.4d. When the seam is located in an inaccessible location of a small (less than or equal to 24 inch (600 mm) inside diameter of refractory lining) item, and neither PWHT or radiography is performed, the detail shown in Figure 12, or for hexalts, Figure 24 may be used.

5.3 Application

a. Precautions

(1) When mixing and handling refractory, personnel shall wear appropriate personnel protective equipment (PPE), shall comply with all appropriate safety measures as defined by the refractory manufacturer's Material Safety Data Sheet (MSDS) for the subject material, and shall comply with other measures required at the site and by the applicable licensing and governing bodies.

(2) During cold weather, the refractory lining and the surface to which it is applied shall be continuously kept at a temperature above 50°F (10°C) during application, curing, and before heat drying. If required, suitable means for heating and/or exterior insulation shall be provided; however, live steam shall not be used for this purpose.

(3) During hot weather, the refractory lining and the surface to which it is applied shall not exceed a temperature of 95°F (35°C) during application. If required, the exterior surface of the vessel shall be cooled by shading, spraying with cold water, air conditioning, or other means before and while the refractory lining is being applied. Installation at night, when it is cooler and there is no radiant heat from the sun, may be considered. After refractory application, cooling of shell is no longer required.

(4) The interior shell temperature shall be registered by temperature recorders with a minimum of 3 thermocouples around the shell for each recorder. The thermocouples shall be calibrated in accordance with ASTM E220. The number of recorders and thermocouples and their location shall be approved by the Owner or the Owner's authorized representative. The shell temperature where refractory is being applied shall be monitored. Certified copies of the shell temperature control log shall be provided to the Owner or the Owner's authorized representative.

b. Mixing and Quality Control

(1) Mixing shall be performed in a stainless steel planetary style mixer (e.g., Hobart Mixer). Concrete mixers shall not be used. The mixing bowl, paddles, and all tools shall be stainless steel.

(2) The mixer shall be stabilized, grounded and fixed into place on level ground or a solid platform near the installation site. Provide large, clear, access areas at the mixer. Provide a cover or other system to prevent entry of foreign material or objects into the mixer.

(3) Mix only as much refractory as will be placed within 20 minutes or the working time of the refractory, whichever is less. This time may be extended if a longer working time is approved by the refractory manufacturer and is demonstrated by mixing in accordance with the manufacturer's instructions and procedures (see Section 8.3), waiting the proposed time, ramming and testing samples for the required properties (see Paragraphs 8.4a, and 8.4c.(3)). Test results shall meet the guaranteed values.

(4) The full contents of each bag of premixed refractory material shall be used in the same mixer batch. Do not use bags that have been wet or that have been previously opened.

(5) No cement, lime, or other admixtures of any kind shall be added to the premixed refractory materials as received from the manufacturer. The only permitted addition is metal reinforcing fibers when they are specified in the UOP Project Specifications or UOP Project Drawings.

(6) Refractory lining materials from one manufacturer shall not be mixed with those from other manufacturers.

(7) Use of Metal Reinforcing Fibers

(a) Metal reinforcing fibers SHALL NOT be used with hexagonal mesh, flexible mesh, or closed cell hexalt anchoring systems.

(b) Metal reinforcing fibers SHALL be used with non-closed hexalt systems.

(8) When metal reinforcing fibers are required, they shall be screened into the dry refractory lining material in the mixer at the job site. Fibers shall be added at a rate of 2% by weight (i.e., weight of fibers divided by weight of refractory) for each batch of refractory material.

(9) The mix temperature shall be maintained between 45˚F (7˚C) and 65˚F (18˚C).

(10) Prior to mixing the first batch of the day, or after a lengthy pause, moisten all interior surfaces of the mixer, including the blades.

(11) Weigh 10 bags randomly selected from throughout the pallet of refractory (e.g., not all from the top). If each bag is within ± 2 percent of the weight marked on the bag, the water to be added to the mixer for bags from that pallet may be based upon the average weight of the sampled bags. If any bags are outside of ± 2 percent of the weight marked, each bag from that pallet must be weighed before it is discharged into the mixer. The mixer water addition is then based upon the actual weight of the refractory in the mixer. Each pallet of material shall be evaluated separately.

(12) The refractory material shall be thoroughly dry mixed (with the reinforcing fibers, when required), before the addition of water. When the use of metal reinforcing fibers is specified, the refractory shall be introduced into the mixer first and dry mixing begun. The reinforcing fibers shall then be introduced into the refractory materials in the operating mixer as a rain of individual fibers through a shaken or vibrating screen to prevent clumping of the fibers.

(13) The amount of water (or manufacturer supplied mixing fluid) required for proper hydration, the mixing procedure and time, and the mix consistency shall be in accordance with manufacturer's recommendation and the results of the prequalification testing (see Section 8.4).

(a) Ninety to ninety-five percent of this water is initially added to the mixer and blended. If necessary, additional water is then added and blended until a mix of the proper consistency is obtained. When mixing fluid is provided the entire, premeasured amount is used. It is not adjusted or supplemented.

(b) The final water addition shall be within the water range provided by the refractory manufacturer.

(c) The water (or mixing fluid) shall be added to the refractory/fiber mixture as a rain while the refractory dry mixes.

(14) The mixer contents shall be discharged into a clean, dry stainless steel container. Material that misses the container, is discharged onto the ground, etc., shall not be used. Discharged refractory shall not be placed back into the mixer or remixed.

(15) The refractory shall be transported to the installation site in clean, dry, impervious stainless steel or plastic containers. The means of transportation shall prevent the separation of the refractory components or the entry of foreign material.

(16) All equipment (mixer, discharge and transport containers, etc.) shall be thoroughly washed and dried before use, at the end of each workday, and at the end of the refractory installation. The mixer bowl and blades shall be thoroughly cleaned after each batch (i.e., mixer charge) to prevent build-up of refractory lining materials. The discharge and transport containers and all tools used in mixing and applying the refractory lining shall be cleaned after each batch and kept free of all deleterious materials.

(17) The supply of refractory to the installation site shall be continuous, uninterrupted, and provided to the site at approximately the rate of refractory placement throughout the refractory installation.

(18) For each batch of refractory mix, the total weight of water (or mixing fluid), refractory, and reinforcing fibers added to the mixer, and the resulting weight percent of water (or mixing fluid), shall be reported and recorded. The refractory manufacturer and product name, mixing fluid description if other than water, type of reinforcing fibers, installation location, atmospheric conditions, mixing temperatures, installation procedures, and job site conditions shall also be recorded. Provide the Owner or the Owner's authorized representative with certified copies of the quality control log.

c. Placement

(1) The full thickness of the lining shall be installed in a single application.

(2) Application shall be made by ramming using reciprocating pneumatic rammers (i.e., the "Pneumatic Method"). The size and style of the equipment, and the installation procedure, shall be as required for the specific refractory lining application.

(3) The head of the rammer shall be smaller than the cells of closed cell systems (e.g., hexagonal and flexible mesh, some hexalts) and the space between anchors of hexalt systems. The rammer shall compact the refractory without contacting the anchor metal.

(4) Refractory shall be placed at its final location. Movement of the refractory shall be minimized.

(5) Only qualified personnel thoroughly familiar and experienced with rammed installation of refractory lining shall be employed for this work.

(6) The shell and anchors shall be inspected to confirm that they are clean before the lining is installed. Refractory that adhered to the shell or anchors during earlier refractory installation shall be removed before refractory is installed around the anchor.

(7) Do not use refractory that has begun to setup or has exceeded the manufacturer's recommended working time (whichever is less). If a recommended working time is unknown, use 20 minutes. Refractory shall not be re-tempered.

(8) Refractory installation shall be downhand to the greatest extent possible. Where necessary, overhead and vertical surface placement is acceptable if steps are taken to prevent sagging of the installed refractory.

(9) During refractory installation the item to be lined shall be placed in a position that provides good access for refractory placement, permits downhand refractory installation and eliminates all enclosed or unvented areas. If necessary, the refractory maybe installed in two (or more) placements with the lined item orientation optimized for each placement. Reorientation shall not occur until the refractory has attained sufficient stiffness and reorientation shall not detrimentally affect the previously placed refractory.

(10) The installation method shall conform to the manufacturer's recommendations and the procedures developed during installer prequalification (see Section 8.4).

(a) Press sufficient refractory material into place to overfill the closed anchor (e.g., hexagon) or area to be filled when using hexalts.

(b) Do not press more material into place than can be compacted before the working period of the refractory expires or set-up begins.

(c) Thoroughly, and uniformly, distribute and compact the refractory to eliminate voids, laminations, pockets, etc., and fill under and around all overhangs, through all openings, and around all lances to form a uniform, homogeneous lining. Move the rammer forward and back and vary the angle of impact to aid in accomplishing uniform compaction. When using hexalt systems, ensure that new refractory is compacted into neighboring, previously placed, material.

(d) Refractory installation in hexalt systems shall be continuous and uninterrupted to avoid the creation of joints in the refractory system.

(e) The method of placement and compaction shall not distort the anchors or damage the anchor welds.

(11) Immediately after completion of placement and compaction, and before the refractory begins to set-up, strike off the lining flush with the surface of the anchors using a trowel or curry comb, discarding any surplus. Take care to avoid removing too much material, resulting in an under cut, or pulling refractory from the shell. Trimming shall continue as installation work progresses. A trowel finish is adequate; do not float finish, water slick, screen, etc.

(12) The abrasion resistant lining thickness tolerance shall be -0 to +1/16 inch (-0 to + 1.5 mm).

(13) Lined items shall remain in the same position throughout the lining installation unless this results in an area of inferior refractory placement. In that case the refractory may be placed in two (or more) placements with the lined item orientation optimized for each placement. Comply with all requirements of Paragraph 5.4d. Reorientation shall not detrimentally affect the previously placed refractory.

d. Interruption of Application

(1) When refractory application in hexagonal or flexible mesh anchoring systems is interrupted, the cells in the anchoring system before the termination shall be completely filled with refractory and the cells beyond the termination shall be completely free of refractory. Partially filled cells shall be cleaned of all refractory and the removed material discarded.

(2) When refractory application in hexalt anchoring systems is interrupted, the refractory lining shall be cut back to the shell with a steel trowel. The cutback shall be perpendicular to the shell and at a location where the full refractory thickness has been applied. The refractory cutback or termination shall not be parallel or near parallel to the direction of process flow. All material beyond the termination shall be discarded.

(3) All material left in the placement equipment, mixer, etc., over 15 minutes shall be discarded.

(4) Anchors and plate surfaces shall be completely cleaned of all refractory lining materials.

(5) During the period of interruption in application, curing of the refractory lining already applied shall be in accordance with Section 6.1.

(6) Immediately prior to resuming refractory application, the exposed surface of the refractory lining to which a bond must be made shall be cleaned of all loose refractory material and debris, roughened, and thoroughly wetted with lining mixing water.

(7) The lining shall not be permitted to stand before heat drying when the ambient temperature is expected to fall below 50°F (10°C), unless provisions are taken to keep the lining above 50°F (10°C).

(8) When installation is halted for the day, all openings in the item being lined shall be covered, closed, and/or sealed.

6. CURING AND HEAT DRYING

6.1 Curing

a. The curing period shall begin immediately after installation of each section of lining and shall last until a minimum of 24 hours after curing of the last segment of the lining has begun. Refractory shall be cured for at least 24 hours. Use a longer curing period if required by the refractory manufacturer.

(1) Except as noted in Paragraph 5.4c.(13), the lined item shall not be moved until the curing period is complete (e.g., at least 24 hours after the completion of the refractory lining installation).

(2) During the curing period, the temperature of the vessel shell and refractory lining shall be kept above 50°F (10°C). Use a higher temperature if required by the refractory manufacturer.

(3) Provide adequate ventilation during the curing period.

b. During the curing period the refractory surface shall remain exposed and uncovered. Do not use sealing compounds, water sprays, etc., unless required by the refractory manufacturer. If sealing is required it shall conform to the following.

(1) During the curing period, exposed refractory lining shall be protected from moisture loss by a spray applied owner and refractory manufacturer approved membrane curing compound. The curing compound shall be a non-flammable, non-reactive, non-toxic, membrane forming solution of resin and hydrocarbon base in conformance with ASTM C309, with a low permeability, compatibility with aluminous cements, ease of application, short drying time, and long storage life. It shall contain a factory added contrasting color to allow identification of the areas to which the compound has been applied and shall burn off of the surface to which it has been applied at a temperature between 150°F (65°C) and 200°F (95°C).

(2) Spray application of the membrane curing compound shall begin immediately after application of the lining, as soon as the surface is dry to the touch. A one coat application of membrane curing compound of sufficient thickness to completely cover the exposed surfaces of the lining shall be used. The membrane curing compound shall be allowed to dry tack free before lining is installed in an adjoining area. Adequate ventilation shall be provided during the membrane curing compound application and curing period.

c. After curing, the refractory lining shall be tested by striking the refractory with the ball of a 16 ounce (455 gram) ball peen hammer at about one foot (300 mm) intervals over the entire surface. Any voids or dry filled spaces will emit a dull sound; the full lining depth in these areas shall be removed and replaced. Any soft, spalling, or otherwise damaged areas shall also be removed and replaced. See Section 9.

d. Provide the Owner or the Owner's authorized representative with certified copies of records indicating the location, size, damage discovered, and the extent and means of repair at each repair site.

e. Refractory shall not be exposed to steam until heat drying has been completed.

6.2 Heat Drying

a. All refractory lining shall be heat dried prior to being placed into service. If the lining is to be subjected to hydrostatic testing, it shall be cured and fully heat dried before and fully heat dried again after testing.

b. Heat drying shall be performed by personnel experienced in, and with the equipment required for, heat drying of refractory lined equipment.

c. The heat drying contractor shall prepare a detailed plan for review and approval prior to the start of heat drying (see Paragraph 2.3c.). The plan shall include the heating and cooling rates, hold points and durations, heat source(s) and location(s), the means of monitoring refractory and shell temperatures, and the means of ensuring all of the refractory is exposed to the dryout medium and adequately dried.

d. Heat drying of the refractory shall begin as soon after completion of the refractory installation and the curing period as is practical. Items that were lined in the shop shall be heat dried in the shop. If heat drying does not occur within 30 days of completion of the refractory curing period, the equipment shall be sealed and kept above 50°F (10°C) until heat drying is performed. During the time between curing and heat drying, the entry of moisture (e.g., rain and steam) or contaminants shall be prevented.

e. Lining shall be completely heat dried and inspected prior to (and independent of) startup of the equipment, vessels, piping, and duct work.

f. Sections that are not adequate for the maximum heat drying temperature (e.g., inadequate metallurgy or thickness, or cannot accommodate the thermal expansion) shall be sealed or otherwise protected from the drying temperatures. Temperature of these areas shall be monitored to ensure that they do not exceed their allowable temperature values.

g. Provide the heat necessary for dryout by use of gas fired heaters only. The gas supply shall be clean, reliable, and adequate to reach and maintain the required temperatures.

h. Heat may be applied only to the exposed surface of the refractory lining or heat drying may be performed in a furnace but shall not take place as a part of PWHT. Heaters shall not be located inside of equipment being dried nor shall the lining be exposed to the flame. Do not insulate the metal surface.

i. Multiple heaters may be used to maintain the required temperatures over the entire lining surface. If multiple heaters are used, their operation shall be coordinated so that all hold periods and temperature changes occur at the same time and rate.

j. The flow of heated air shall be controlled so that the entire surface of the refractory is subjected to the movement of air and the full heat drying cycle. Dead or low flow areas are not permitted. Back pressure, throttling of the air flow, or other means may be necessary. During heat drying the lined equipment shall be oriented to allow even heating of the refractory (i.e., a more uniform temperature profile), permit the escape of moisture (steam), and eliminate trapped or enclosed areas. Vertical positioning of the item to be dried is generally preferred. During the drying period, adequate ventilation shall be provided for the escape of moisture. Special consideration shall be given to areas that are difficult to dry or vent. If heat drying takes place in a furnace, ensure an adequate cirulation of air through all interior portions of the lined item.

k. Refractory surface temperatures during heat drying shall be monitored and controlled with thermocouples placed a maximum of 1/2 inch (13mm) from the lining surface.

(1) The thermocouples shall be arranged to measure the air, not the refractory, temperature.

(2) Calibrate the thermocouples in accordance with ASTM E220.

(3) Thermocouples shall be placed in circumferential rings around the refractory surface, with at least 4 thermocouples equally spaced in each ring. In small diameter items, the number of thermocouples may be reduced to maintain a minimum of approximately 5 feet (1500 mm) between thermocouples in a ring. Rings shall be placed to fully monitor the heating profile of the refractory surface, including the bottom, top, and

midpoint of cylindrical sections, to ensure that all of the refractory is properly heated and dried. Stagger the thermocouples in adjacent rings so they are not above or below each other.

(4) Thermocouples shall also be placed near the hot air inlets, the exhaust air vents, and in the rear of any enclosed areas.

(5) Include thermowells where the refractory surface temperature is expected to be the greatest and least.

(6) The thermocouple's output shall be continuously monitored throughout heat drying, and all of the thermocouples shall be connected to recorders to provide a record of the heat dryout.

(7) The final arrangement of thermocouples and recorders shall be approved by the Owner or their authorized representative before the start of heat drying.

l. Heating rates shall be controlled by the refractory thermocouple exposed to the greatest temperature and rate of temperature change, typically the thermocouple nearest the heat source.

m. Hold temperatures and durations shall be achieved by the coolest thermocouple, typically the one nearest the exit.

n. Provide exterior skin thermocouples to monitor the exterior metal temperature during dryout. Frequent infrared scans may be substituted for external skin thermocouples. At a minimum, monitor the temperature in areas expected to see the greatest metal temperature (e.g., at the hot air inlet or where the exterior of the metal is in an enclosed or heated area). Monitor and record these temperatures in the same manner as used for the interior temperatures.

o. Heat drying shall proceed as follows (except where the refractory manufacturer's recommended heat drying procedure is more stringent):

(1) Raise the temperature of the air in contact with the refractory lining at a continuous rate not to exceed 50°F (28°C)/hour to approximately 300°F (150°C).

(2) Hold for a minimum of 2 hours. All thermocouples shall reach and maintain a steady temperature for a minimum of 30 minutes prior to completing the hold and proceeding with the dryout.

(3) Raise the internal temperature of the air in contact with the refractory at a continuous rate not to exceed 50°F (28°C)/hour to approximately 700°F (370°C).

(4) Hold for a minimum of 2 hours. All thermocouples shall reach and maintain a steady temperature for a minimum of 30 minutes prior to completing the hold and proceeding with the dryout.

(5) Cool down may begin after completion of the hold period at 750° F (400° C). If desired, although not required, heat drying may proceed to the operating temperature as follows:

(a) Raise the internal temperature of the air in contact with the refractory at a continuous rate not to exceed 50°F (28°C)/hour to the internal process operating temperature.

(b) Hold for a minimum of 2 hours. All thermocouples shall reach and maintain a steady temperature for a minimum of 30 minutes prior to completing the hold and proceeding with the dryout.

(6) After the final hold period, cool down shall be at a continuous rate not to exceed 100°F (56°C)/hour with no holds to approximately 300°F (150°C). After reaching approximately 300°F (150°C) the remaining cool down may be without heating.

(7) If steaming is observed during any hold period, the hold period shall be maintained until steaming ceases.

(8) Additional hold points are permissible.

(9) The shell temperature shall not exceed the design temperature of the shell.

(10) The air temperature differential between any two thermocouples within the item being heat dried shall not exceed 100°F (56°C).

(11) If heat is lost, resume the dryout procedure using the heating rate specified at the temperature at which the ability to heat is regained.

p. As an alternative to the method described in Paragraph 6.2o.(2) through (5), the refractory temperature may be raised without any holds at a continuous rate not to exceed 25°F (14°C) per hour between the hold at 300°F (150°C) and the final hold temperature.

q. When heat drying is completed the lining shall be inspected and any area with cracks 1/16 inch (1.6 mm) wide and larger and with spalling or unbonded material shall be removed and replaced in accordance with Section 9. If any anchor welds are broken or if the anchors are buckled, bent, or otherwise damaged, the affected welds, anchors, or mesh shall be repaired or replaced.

r. When lining that has been in hydrocarbon operation is exposed to the heat drying of new lining, precautions shall be taken to prevent ignition of the coke.

s. Field seams and repairs shall receive the same curing and heat drying as the remainder of the lining.

t. Provide the Owner or the Owner's authorized representative with certified copies of the heat drying procedure, internal heater, recorder, and thermocouple locations, and temperature control log.

7. INSPECTION

The Owner or the Owner's authorized representative reserves the right to inspect the refractory lining during all phases of preparation, application, repair, curing, heat dry, and clean-up. The following operations shall be included in those witnessed:

a. Pre-installation meeting with the refractory installer to discuss the installation procedure and any deviations from this Standard Specification or the UOP Project Specifications and UOP Project Drawings.

b. Preparation of the vessel by grit blast cleaning; welding of anchors, tabs, and bars.

c. Pre-installation testing of the refractory materials (if required) and pre-qualification of the installation crew.

d. Mixing of refractory materials with water (or mixing fluid) and reinforcing fibers (if required) to ensure that correct materials and procedures are used, that containers and water are clean, and that the entire contents of each bag is poured into the mixing machine.

e. Ramming of refractory materials to ensure that proper placement technique is used, the full lining thickness is obtained in one placement, all areas (e.g., hexagons) are completely filled and the refractory is properly compacted together around, under, and through all anchors; no previously opened or wet bags of refractory are used and that specified procedures are followed when the application is interrupted.

f. Curing and heat drying of the refractory lining to ensure that the proper curing technique and heat drying temperatures, ramps, and holds are used.

g. Inspection of lining after curing and after heat drying to ensure no unacceptable voids, cracks, spalling, or unbonded material is present.

h. Removal and replacement of unacceptable refractory lining to ensure that the rework is compatible with the original lining application.

i. Copies of all logs, record(s) of areas of refractory repair, and test reports.

j. Removal from plant site of refractory lining applicator's equipment, materials, and debris. Job site to be left broom clean.

The approval or acceptance of the above operations by the Owner or the Owner's authorized representative does not relieve the refractory manufacturer and/or refractory lining applicator of any responsibility, warranty, or guarantee.

8. TESTING

8.1 Compliance Values for Physical Property Testing

a. The Owner, refractory manufacturer, and contractor (as applicable) shall agree upon rammed installation based guaranteed or compliance values for all physical properties to be tested. If guaranteed or compliance values are not specified, then the manufacturer's data sheet values shall be used. The results of physical property testing shall be compared against the guaranteed or compliance values.

b. The refractory manufacturer shall provide a recommended weight percent of mixing or hydration water (or mixing fluid) to be added at the mixer. The refractory manufacturer shall also provide water curves indicating the effect upon refractory properties (e.g., cold crushing strength, permanent linear change, abrasion resistance, etc.) of a ± 10 percent variation (or alternate range as specified by the manufacturer) in the amount of mixing water.

8.2 Testing at the Manufacturer's Plant

a. The manufacturer of the refractory materials shall provide material data sheets and test certificates of rammed samples of the supplied refractory (i.e., the material to be shipped). Tests may be performed by the manufacturer or a mutually agreed upon independent laboratory. Specimen requirements (e.g., preparation, number, and shape) and testing shall be in accordance with the ASTM Standards and modifications listed below. Each lot or batch and each pallet within each lot or batch shall be tested. Samples shall be prepared from a bag of refractory randomly selected from the pallet. The entire bag shall be used to prepare the refractory from which the samples are prepared. Testing shall be without metal reinforcing fibers. The test certificates shall include the following information:

(1) Name of manufacturer

(2) Name of refractory material

(3) Dates of manufacture and testing

(4) Batch and serial number

(5) Order number

(6) Bulk density (minimum of 3 specimens per sample, tested per ASTM C134 as modified per API Standard 936), undried (green) and fired.

(7) Cold crushing strength (minimum of 3 specimens per sample, tested per ASTM C133 as modified per API Standard 936) using 2 inch cubes.

(8) Permanent linear change (minimum of 2 specimens per sample, tested per ASTM C113 as modified per API Standard 936).

(9) Abrasion Resistance (minimum of 2 specimens per sample, tested per ASTM C704 as modified per API Standard 936).

b. Tests shall be performed on samples that have been heated to 1500°F (815°C) and cooled to ambient temperature. Heating shall be in accordance with ASTM C865.

c. Refractory properties shall meet or exceed the guaranteed or compliance values. If guaranteed values have not been specified, the manufacturer's data sheet values shall be met.

d. No specimen result shall be more than 5 percent of the limiting value beyond the minimum or maximum limiting value. All of the specimen results shall be within ± 20 percent of the average value of the sample. No more than one specimen of the sample shall be beyond the limiting value(s).

8.3 Pre-installation Testing at the Job Site

a. Material that is more than three months old, shows evidence of minor damage or moisture exposure (including any pallet from which a wet bag has been discarded, and any other pallets stored with it), or has been exposed to temperatures beyond the storage limits of this specification, shall be retested approximately two weeks before the start of the refractory installation. Material that is nine or more months old (or beyond the shelf life if it is less than 9 months) shall not be used. Each lot or batch and each pallet within each lot or batch shall be tested. Rammed samples shall be prepared from a bag of refractory randomly selected from the pallet. The entire bag shall be used to prepare the refractory from which the samples are made. Samples shall not include metal reinforcing fibers.

b. The samples shall be tested for bulk density (per ASTM C134), cold crushing strength (per ASTM C133), abrasion resistance (per ASTM C704) and permanent linear change (per ASTM C113) after heating to 1500°F (815°C) in accordance with ASTM C865, and cooling to ambient temperature. All tests shall be modified as noted in Paragraph 8.2a.

c. Tests shall be conducted by a qualified independent laboratory before installation of the refractory material. Test results shall meet or exceed the guaranteed or compliance values. If guaranteed values have not been specified then the manufacturer's data sheet values shall be met. Specimen results shall comply with the limits specified in Paragraph 8.2d. In addition, the test results shall not differ from the results reported by the manufacturer (see Section 8.2a.) by more than 20 percent. If the tests do not meet these criteria, the refractory material shall not be used.

d. Provide the Owner or the Owner's authorized representative with certified copies of the test results.

8.4 Pre-qualification of the Installation Crew

a. Each refractory installer and other members of the installation crew shall be pre-qualified before refractory installation to ensure that proper procedures are used.

Prequalification shall be with each abrasion resistant refractory material for the most difficult installation orientation (downhand, sidewall, overhead in increasing order of difficulty), and for each anchoring style to be used. Pre-qualification shall be performed at the job site using the same equipment, materials (including metal reinforcing fibers when they are specified), anchoring system, utilities, crew members, mixing methods (e.g., mixer, quantitites mixed at one time, water (and metal fiber) addition, mixing time, etc.) and installation procedures (including ramming method (e.g., pneumatic rammer size, type and force)) that will be used for the refractory lining application. A minimum of one test panel shall be prepared by each installation crew, for each material to be installed, for each installation orientation, and for each anchoring style. Certification from a previous job or site is not acceptable.

b. Installer prequalification shall consist of ramming refractory into an 18 inch x 18 inch (450 mm x 450 mm) test panel, followed by inspection of the installation.

(1) The test panel shall be bounded by edging bars and shall replicate the smaller gaps found between the anchors and edging bars (e.g., partial hexagons).

(2) The refractory thickness shall equal the lining thickness to be installed and shall utilize the same tolerances.

(3) The backing plate and anchors shall be steel. The backing plate shall be designed for removal without damaging the contained refractory and shall be coated with a refractory vendor approved parting agent to prevent adherence to the refractory.

(4) Provide anchors of the same style and spacing as will be used for the refractory lining installation. Anchors shall be attached to the backing plate in a manner that permits removal of the backing plate.

(5) The refractory shall be rammed (with steel fibers if steel fibers will be used for the installed lining) using the same installation and ramming procedures to be used for the installed lining.

c. During crew prequalification:

(1) Determine the optimum weight percentage of mixing water.

(2) Determine the optimum mixing time.

(3) Determine the refractory working time.

(4) Determine the amount of refractory that can be pressed into place, completely rammed, and trimmed before it begins to set-up. Account for the time that will be required to transport the refractory from the mixing site to the installation site.

(5) Determine the optimum pneumatic ramming force, air pressure and technique.

d. After curing (see Section 6.1), remove the backing plate to observe the installation. The intact test panel shall be inspected. Voids, spalling, laminations incomplete filling, honeycombing, over or under compaction, uneven fiber distribution, shadowing at anchors, or other indications of poor installation are not acceptable. Only if inspection of the pre-qualification mock-up and the results of any testing are acceptable will the crew be allowed to install the refractory lining.

8.5 Sampling During Installation

a. The refractory lining installer shall prepare as-installed rammed refractory samples on the job site as a part of the installation process. Samples shall be prepared once per crew per shift, for each lined item, for each refractory material, and for each mixing station. The number of test samples required on the job site shall be agreed upon with the Owner or the Owner's authorized representative.

b. The sample preparation shall be representative of the installed refractory, including installation procedures and curing in the same manner (but not heat drying). The specimens for testing shall be formed by ramming the refractory into suitably sized molds. Ram sufficient specimens for all potentially required tests (see Paragraph 8.5.e.)

c. Molds shall be coated with a refractory manufacturer approved parting agent to prevent adherence of the refractory. The samples shall be cured in accordance with Section 6.1. The samples may be placed on the scaffolding after ramming but otherwise shall remain undisturbed and protected at the installation site until curing has been completed.

d. Marking of the refractory samples shall make it possible to identify each sample by number; date, time, and method of application; product name and batch number of the refractory material; location of application (e.g., sample map); steel fiber percentage (if any); weight percent of water (or mixing fluid) added; mixing fluid if other than water; weather; shell surface, water, material, and mix temperatures; and name of the installer.

e. The lining installer shall keep the cured samples on site available to the Owner or the Owner's authorized representative, who will indicate the extent of testing to be performed in accordance with ASTM Standards. Testing shall be in accordance with the procedures and requirements of Section 8.3.

f. In case of failure to comply with the acceptance criteria, any remedial measures shall be agreed upon with the Owner or the Owner's authorized representative.

9. SEAMS AND REPAIRS

9.1 Preparation

a. Unaceptable refractory biscuits in hexagonal mesh, flexible mesh and other closed cell systems shall be removed in their entirety. Unacceptable refractory lining in hexalt anchored systems shall be saw cut at a right angle to the shell the full depth of the lining, laterally to acceptable lining, and removed. The shell and anchors shall not be damaged. Unacceptable lining includes thin areas, spalled, fractured, poor quality (e.g., soft, porous), eroded and missing lining, and refractory not performing its intended function. The minimum area removed in non-closed hexalt systems shall be sufficient to expose at least three noncontinuous hexalt anchors as indicated on Figure 27. Cuts shall be made midway between anchors. Corners shall be rounded to a smooth, generous contour throughout the depth of the refractory.

b. Small (e.g., hairline), random, cracks are not a concern nor a cause for repair. Cracks larger than the limits given in Paragraph 6.2q., or cracks exhibiting signs of coking, catalyst entry or other indications that they are open and allowing flow during operation require repair.

c. The anchors and shell shall be cleaned of refractory, debris, loose material, or contaminants. If the anchors or their attachment weld are damaged, the anchor shall be replaced.

9.2 Lining Installation

a. Immediately before placement of the new refractory in hexalt systems, the joining surface of the sound lining adjacent to the seam or repair area shall be cleaned of debris, roughened, and completely wetted with a weak phosphoric acid solution prior to application of the replacement lining. Hexagonal and flexible mesh cells shall be cleaned of debris immediately prior to placement of new refractory.

b. Refractory lining at seams and repairs shall be performed in the same manner as the original lining application, including curing and heat drying. Proposed methods of repair shall be approved by the Owner or the Owner's authorized representative before repairs are started.

c. The location of all repairs shall be documented and provided to the Owner or Owner's authorized representative. The documentation shall include the material used, the means of anchorage and refractory installation, curing and dryout procedures, conditions during the repair, etc.

10. SHIPPING

10.1 Preparation

Shop installed refractory lining shall be prepared for shipment in a manner that ensures delivery to the destination in the original rammed, cured, and heat dried condition.

10.2 Bracing and Support

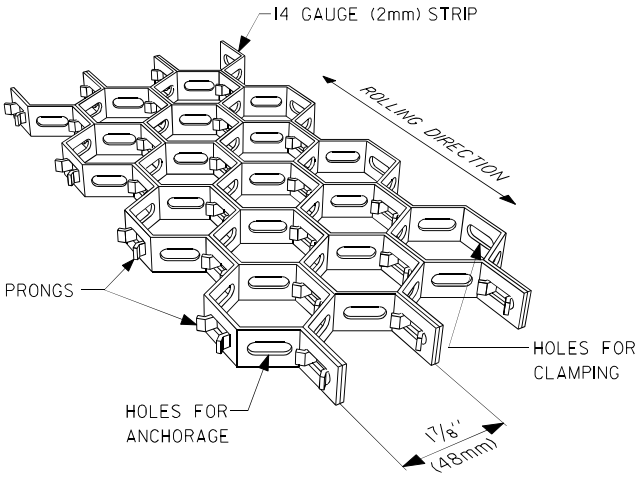
Distortion or deflection of the lined item may damage the refractory lining. Prevent distortion or deflection by means of braces, truing rings, support location, proper lifting and rigging techniques, and /or other means.

10.3 Sealing

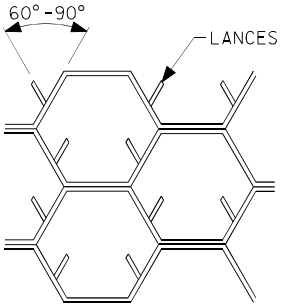
Seal the equipment from atmospheric conditions (e.g., close and seal all openings) during shipment and storage.

ABRASION RESISTANT REFRACTORY LINING

DATE	STATUS	SPNSR	APVD
27MAY19	Revised	MJK	MAS

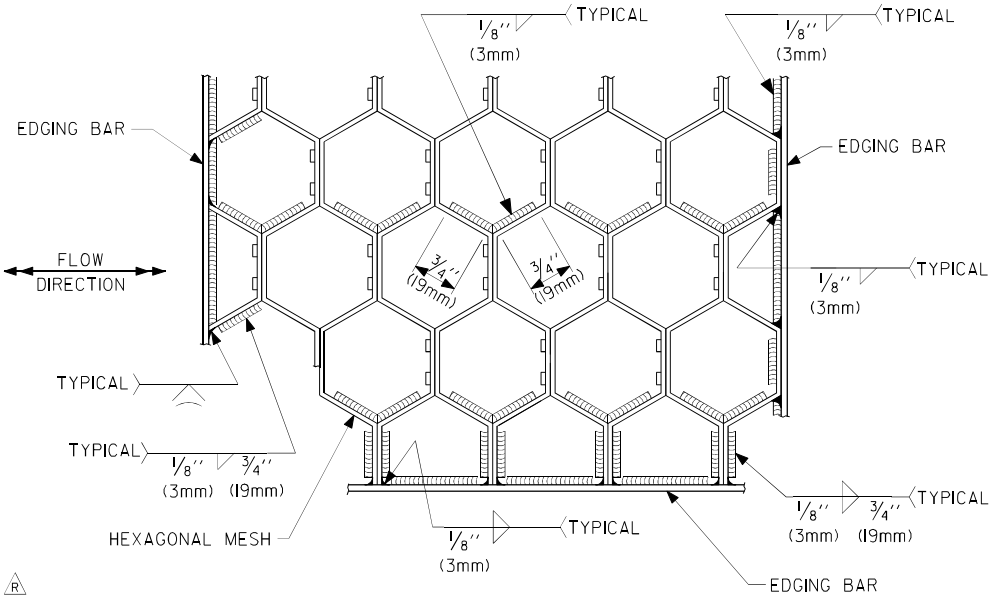


HEXAGONAL MESH
FIGURE – 1



NOTE:
LANCES ARE PERMITTED ONLY WHERE SPECIFIED ON THE UOP PROJECT SPECIFICATIONS OR UOP PROJECT DRAWINGS

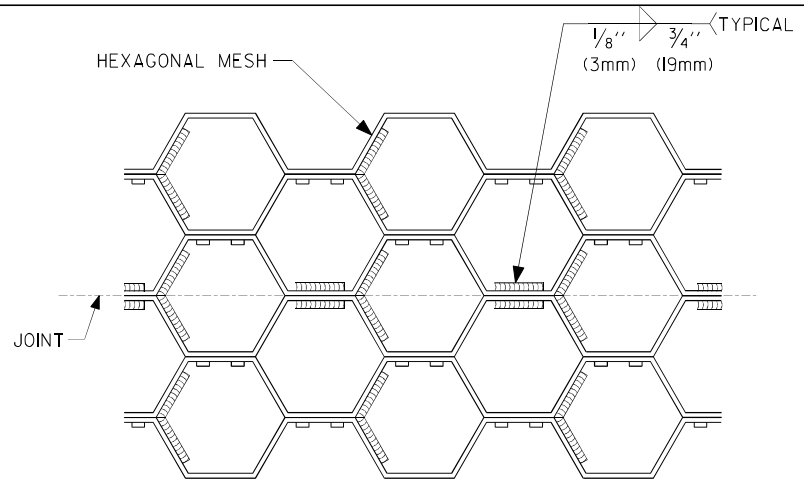
ALTERNATE HEXAGONAL MESH WITH LANCES (SEE NOTE)
FIGURE – 2



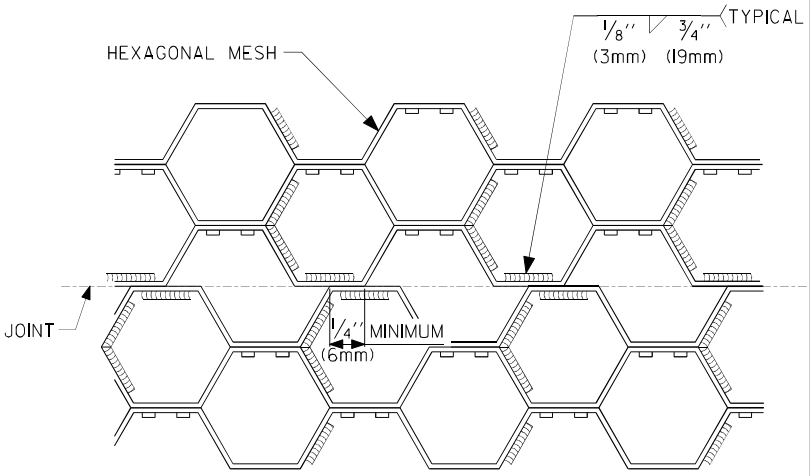
NOTES: (R)

1. WELD SHALL BE ON EACH SIDE OF THE JOINT BETWEEN THE BENT STRIPS THAT FORM THE HEXAGONAL MESH
2. IN THERMAL CYCLING SERVICES OR WHERE SEVERE VIBRATION IS PRESENT, WELD EACH HEXAGON TO THE BACKING MATERIAL
3. IN COKING SERVICES WELD THE FULL LENGTH OF THREE ADJACENT SIDES OF EACH HEXAGON TO THE BASE MATERIAL. WELD THE SAME THREE SIDES IN EACH HEXAGON. EACH SIDE OF A JOINT BETWEEN THE BENT STRIPS THAT FORM THE HEXAGONAL MESH SHALL BE WELDED

HEXAGONAL MESH
TYPICAL WELDING PATTERN (SEE NOTE)
FIGURE – 3



HEXAGONAL MESH
EQUAL BUTT JOINT PARALLEL TO SIDES
FIGURE – 4

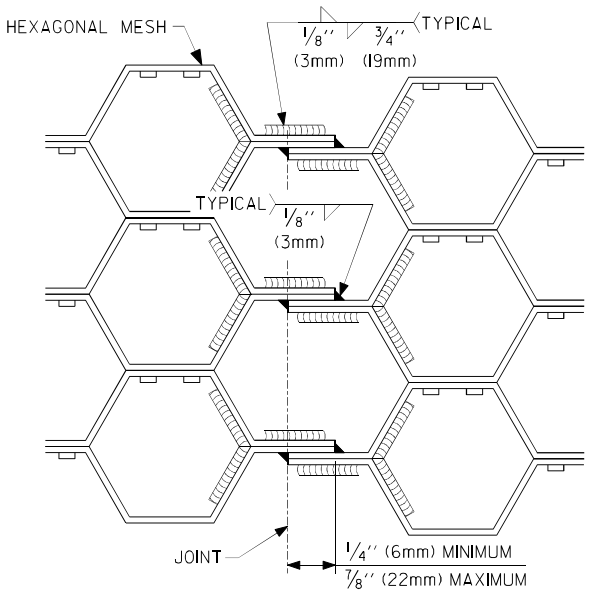


NOTES:

1. THE AREA OF THE IRREGULAR, ENCLOSED, SHAPES SHALL BE BETWEEN ONE-HALF (0.5) AND ONE AND ONE-HALF (1.5) THE AREA OF A REGULAR HEXAGON.

2. THE MINIMUM DIMENSION OF THE IRREGULAR, ENCLOSED SHAPES SHALL BE 3/4'' (19mm).

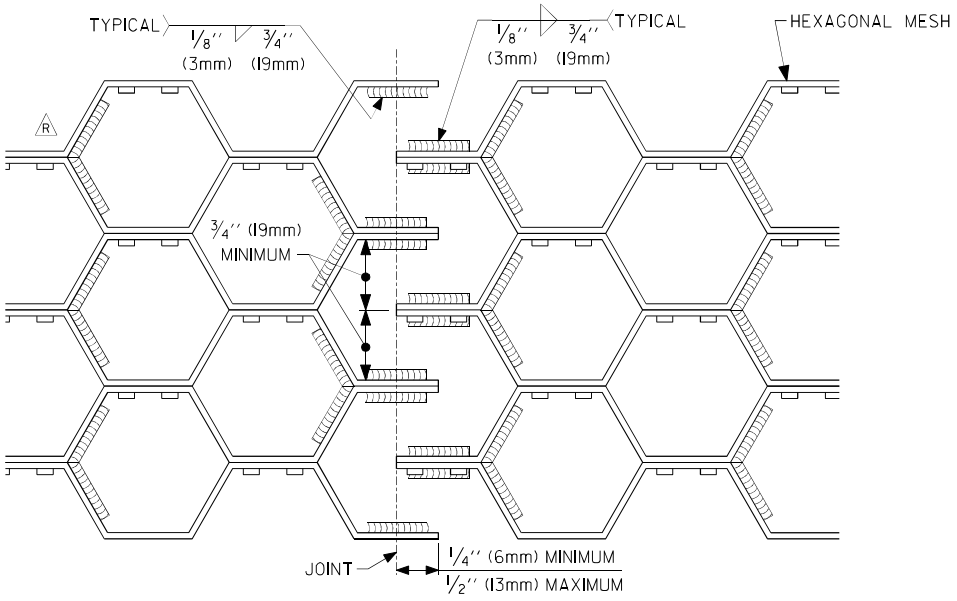
HEXAGONAL MESH
OFFSET BUTT JOINT PARALLEL TO SIDES
FIGURE – 5



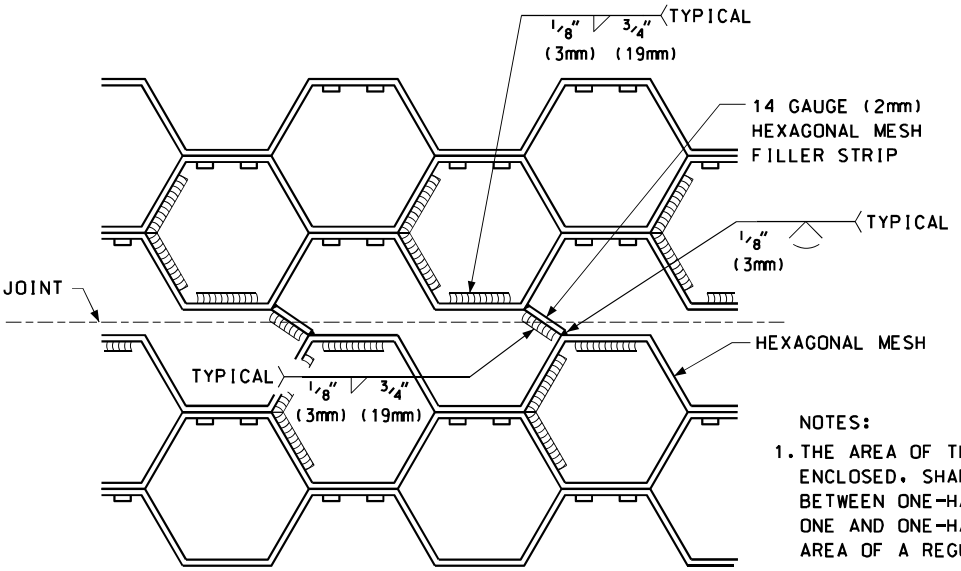
NOTES: (FIGURES 6 AND 7)

1. THE AREA OF THE IRREGULAR, ENCLOSED, SHAPES SHALL BE BETWEEN ONE-HALF (0.5) AND ONE AND ONE-HALF (1.5) THE AREA OF A REGULAR HEXAGON.
2. THE MINIMUM DIMENSION OF THE IRREGULAR, ENCLOSED SHAPES SHALL BE 3/4'' (19mm).

HEXAGONAL MESH
EQUAL BUTT JOINT PARALLEL TO SIDES
FIGURE – 6



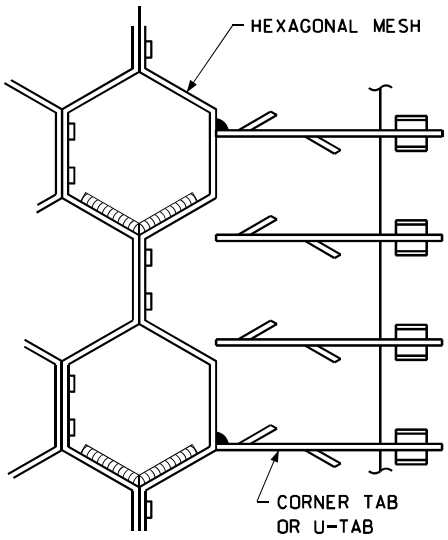
HEXAGONAL MESH
OFFSET BUTT JOINT PARALLEL TO SIDES
FIGURE – 7



NOTES:

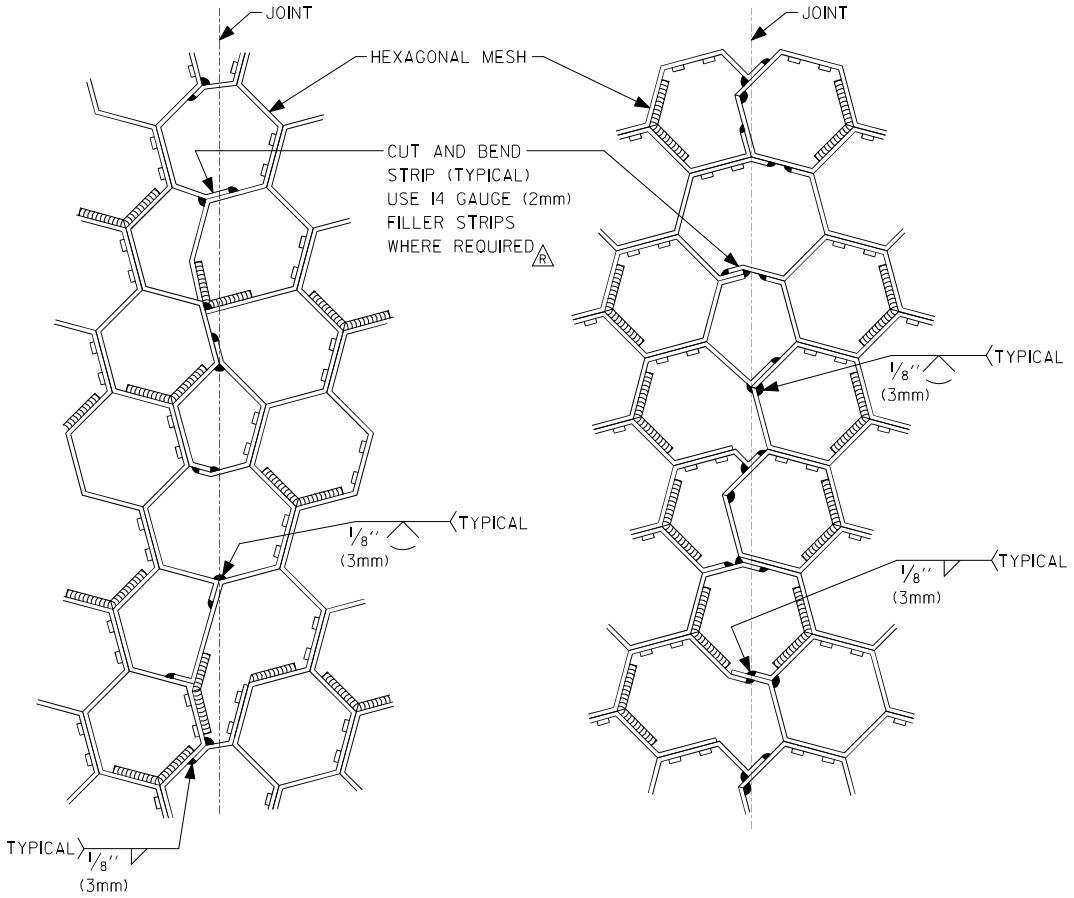
1. THE AREA OF THE IRREGULAR, ENCLOSED, SHAPES SHALL BE BETWEEN ONE-HALF (0.5) AND ONE AND ONE-HALF (1.5) THE AREA OF A REGULAR HEXAGON.
2. THE MINIMUM DIMENSION OF THE IRREGULAR, ENCLOSED SHAPES SHALL BE 3/4" (19mm).

HEXAGONAL MESH SIDE OFFSETS
FIGURE - 8



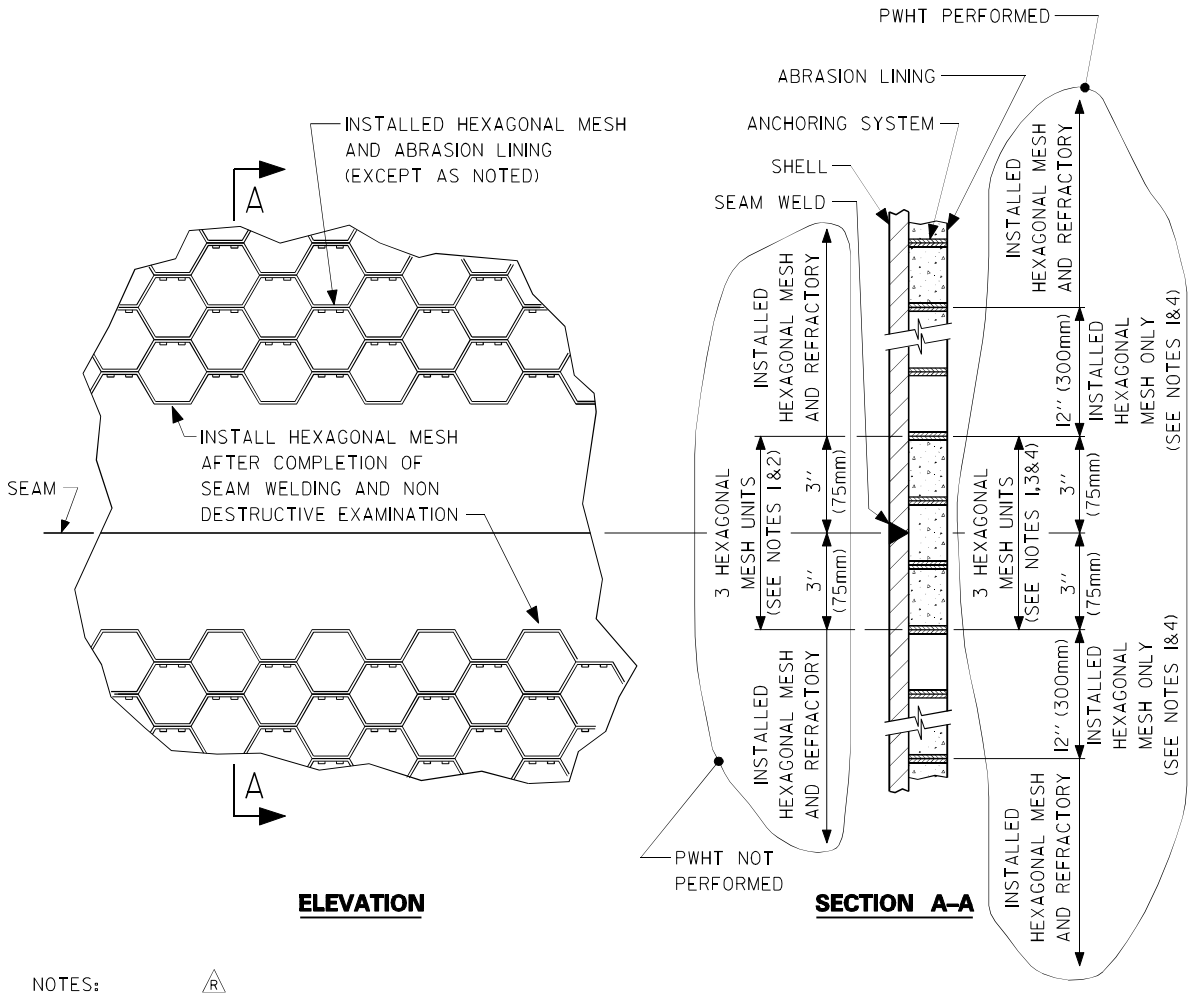
PLAN OF U AND CORNER TABS
FIGURE - 9

Figure 10 Hexagonal Mesh Transverse Joint Details



HEXAGONAL MESH TRANSVERSE JOINT DETAILS
FIGURE – 10

Figure 11 Hexagonal Mesh Seam Details

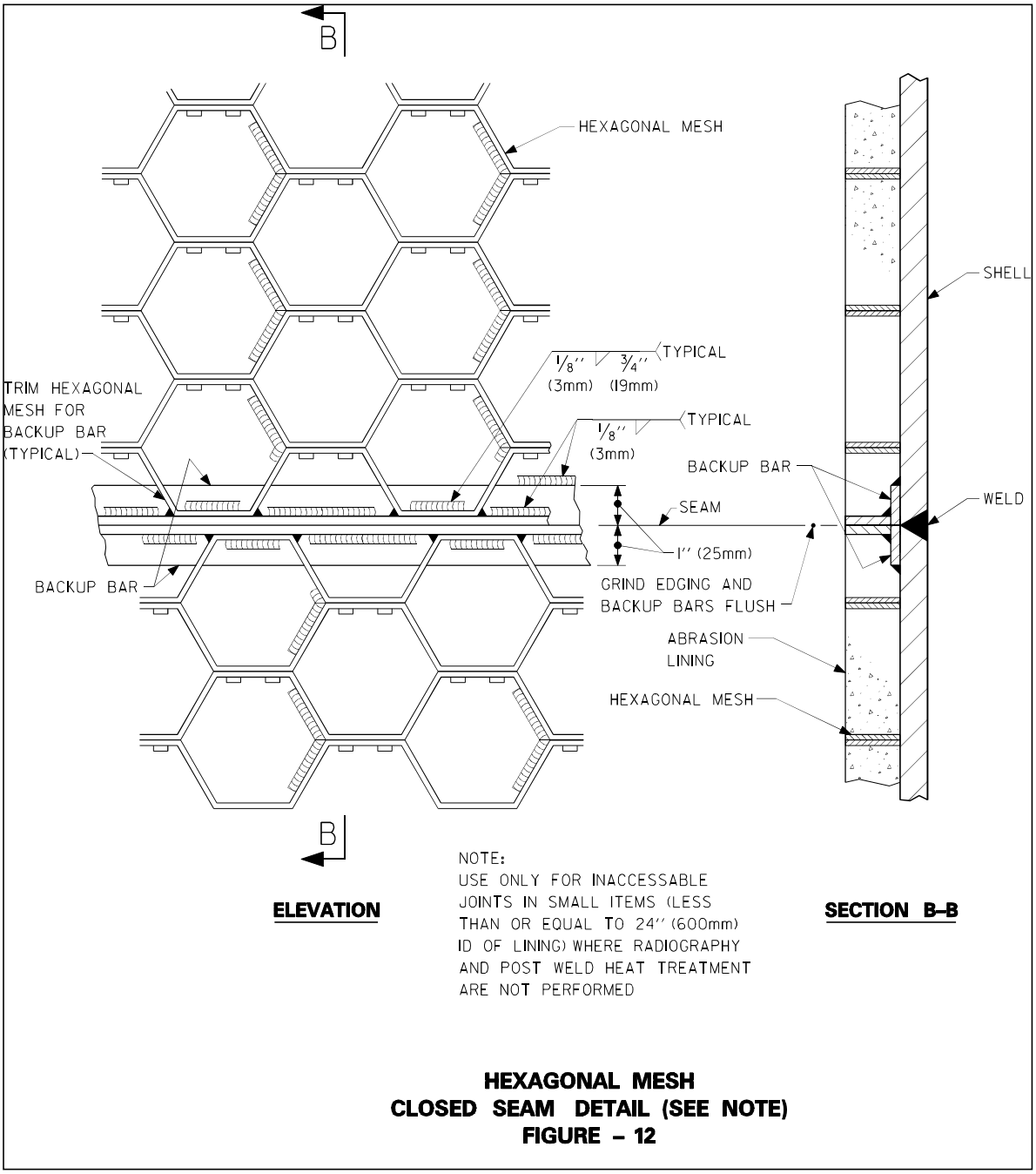


NOTES: (R)

1. INCREASE REFACTORY GAP AS REQUIRED TO PERMIT RADIOGRAPHY (AND HEAT TREATMENT, IF PERFORMED) WITHOUT REFRACTORY DAMAGE AND TO ALLOW HIGH QUALITY INSTALLATION.
2. INSTALL ANCHORS AND REFRACTORY AFTER COMPLETION OF SEAM WELDING AND NON-DESTRUCTIVE EXAMINATION. INSTALL ANCHORS BEFORE AND REFRACTORY AFTER HYDROSTATIC TESTING.
3. INSTALL ANCHORS AFTER COMPLETION OF SEAM WELDING AND NON-DESTRUCTIVE EXAMINATION AND BEFORE PWHT AND HYDROSTATIC TESTING.
4. INSTALL REFRACTORY AFTER SEAM WELDING, NON-DESTRUCTIVE EXAMINATION, PWHT, AND HYDROSTATIC TESTING.

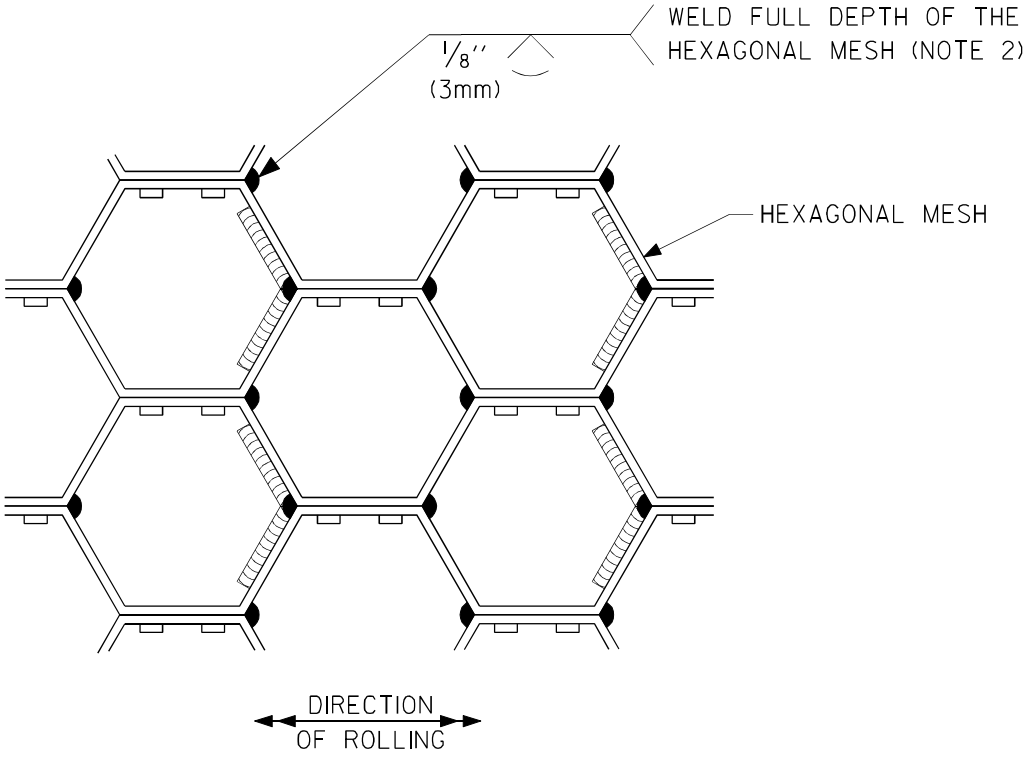
HEXAGONAL MESH SEAM DETAILS
FIGURE – 11

Figure 12 Hexagonal Mesh Closed Seam Detail



HEXAGONAL MESH
CLOSED SEAM DETAIL (SEE NOTE)
FIGURE – 12

Figure 13 Tightly Rolled Hexagonal Mesh

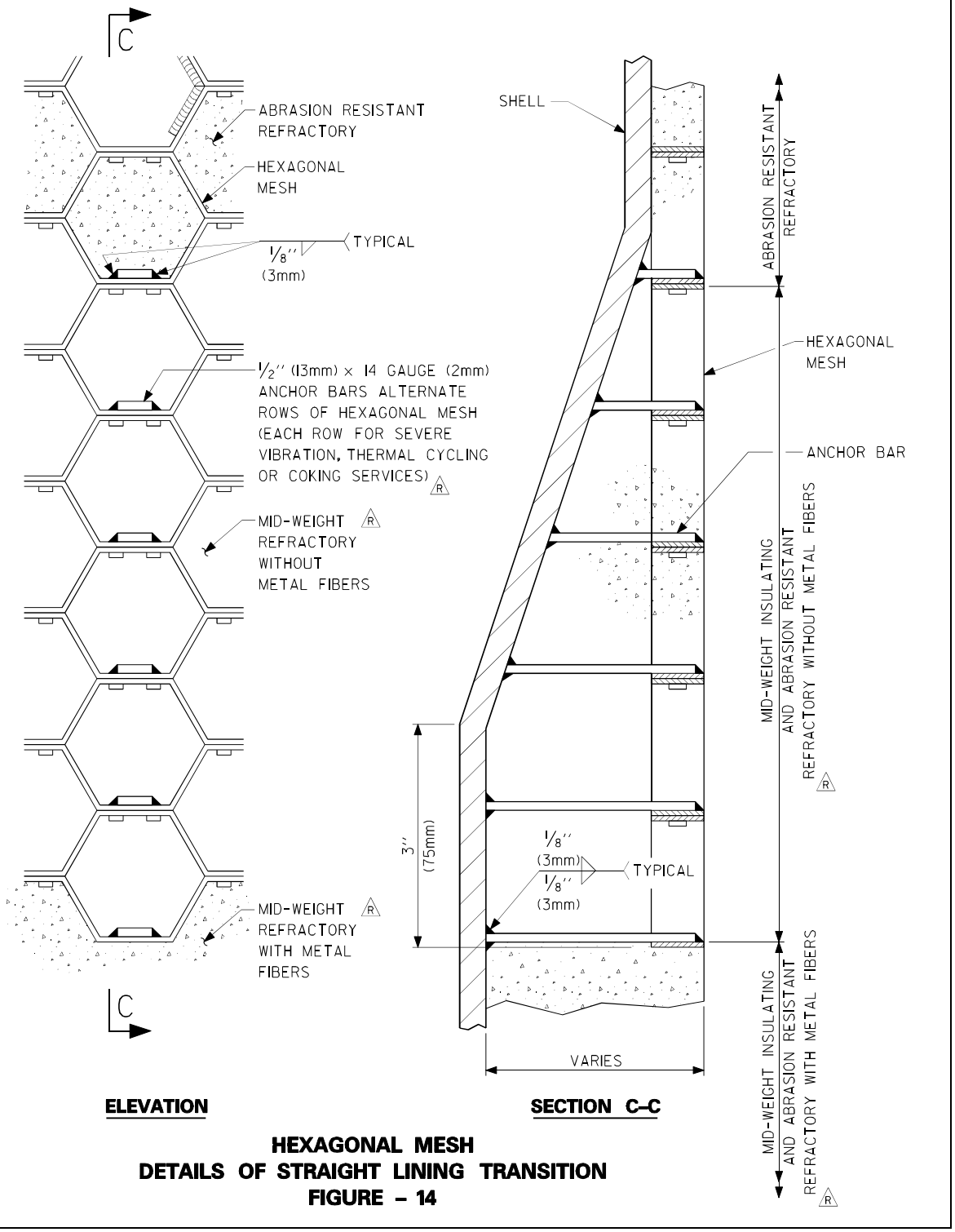


NOTES:

1. TIGHTLY ROLLED IS DEFINED AS AN INSIDE CURVATURE DIAMETER LESS THAN 12'' (300mm) FOR 3/4'' (19mm) HEXAGONAL MESH AND LESS THAN 18'' (450mm) FOR 1'' (25mm) HEXAGONAL MESH. STIFFENING WELDS MAY BE USED WITH LARGER CURVATURES.
2. COMPLETE THE WELD BEFORE FORMING THE HEXAGONAL MESH.

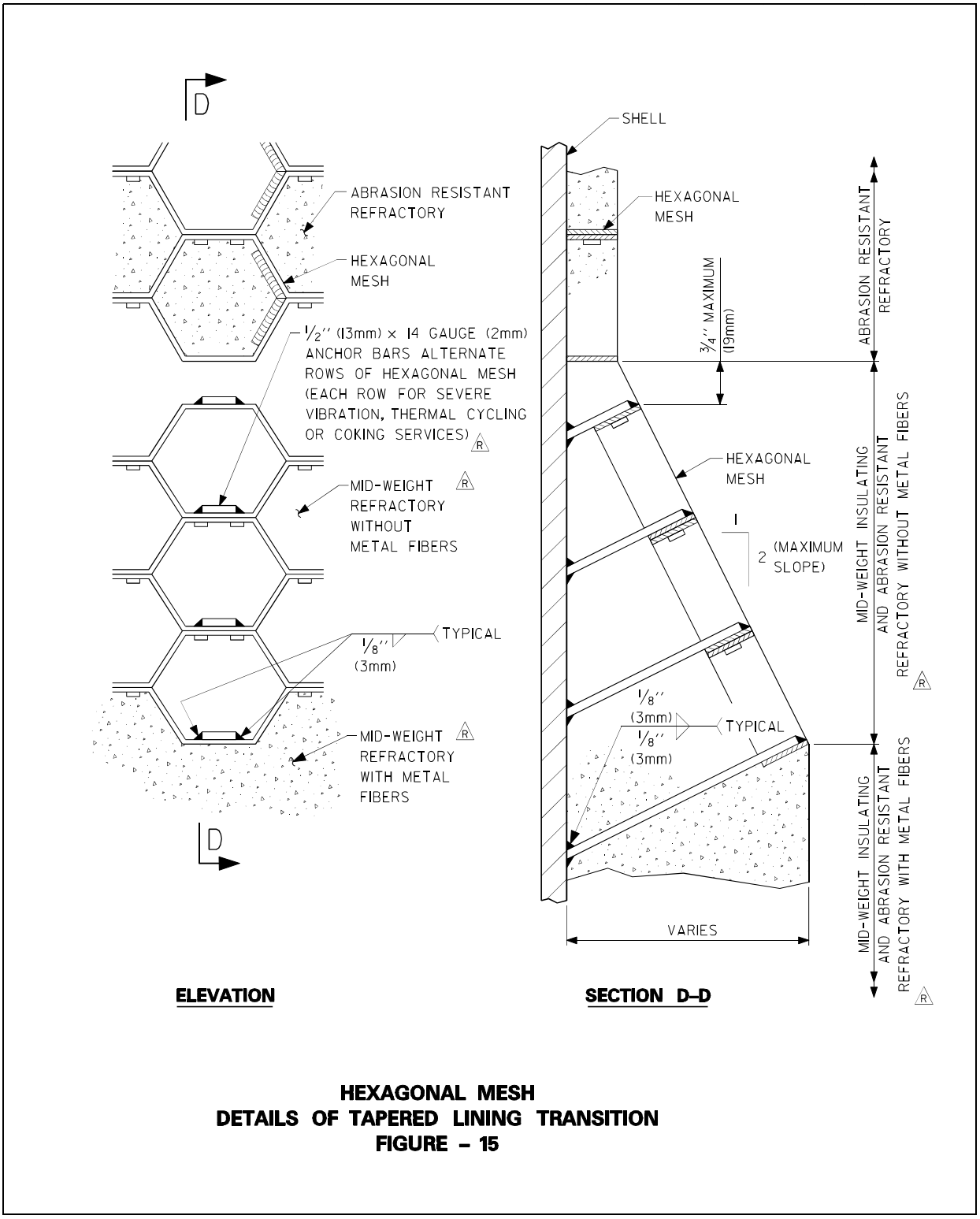
TIGHTLY ROLLED HEXAGONAL MESH
FIGURE – 13

Figure 14 Hexagonal Mesh Details of Straight Lining Transition



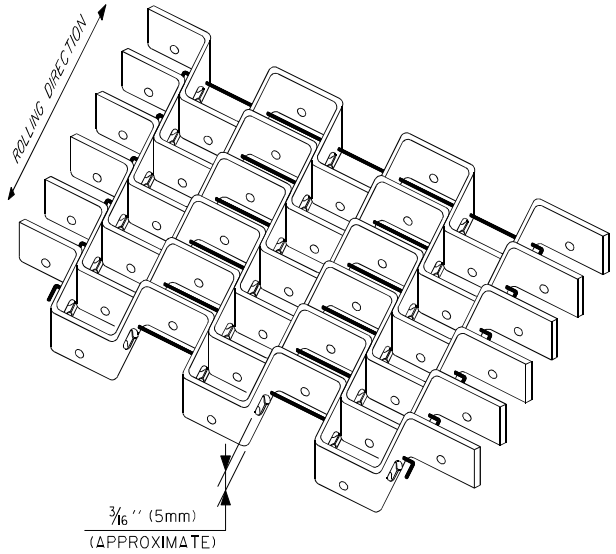
HEXAGONAL MESH
DETAILS OF STRAIGHT LINING TRANSITION
FIGURE – 14

Figure 15 Hexagonal Mesh Details of Tapered Lining Transition

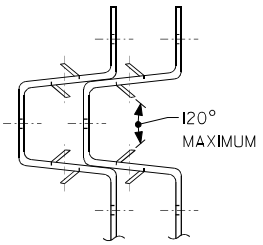


HEXAGONAL MESH
DETAILS OF TAPERED LINING TRANSITION
FIGURE – 15

Figure 16 Flexible Mesh
Figure 17 Alternate Flexible Mesh with Lances
Figure 18 Flexible Mesh

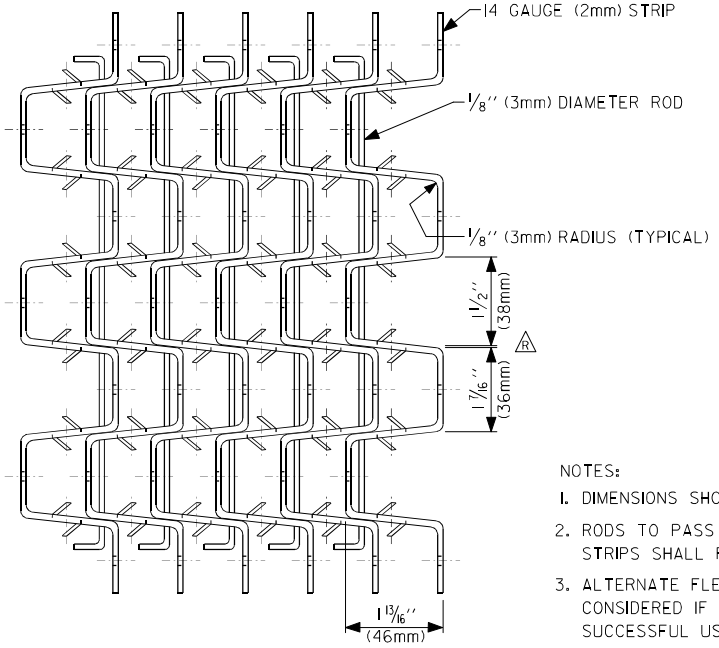


FLEXIBLE MESH
FIGURE – 16



NOTE:
LANCES ARE PERMITTED ONLY WHERE SPECIFIED ON THE UOP PROJECT SPECIFICATIONS OR UOP PROJECT DRAWINGS

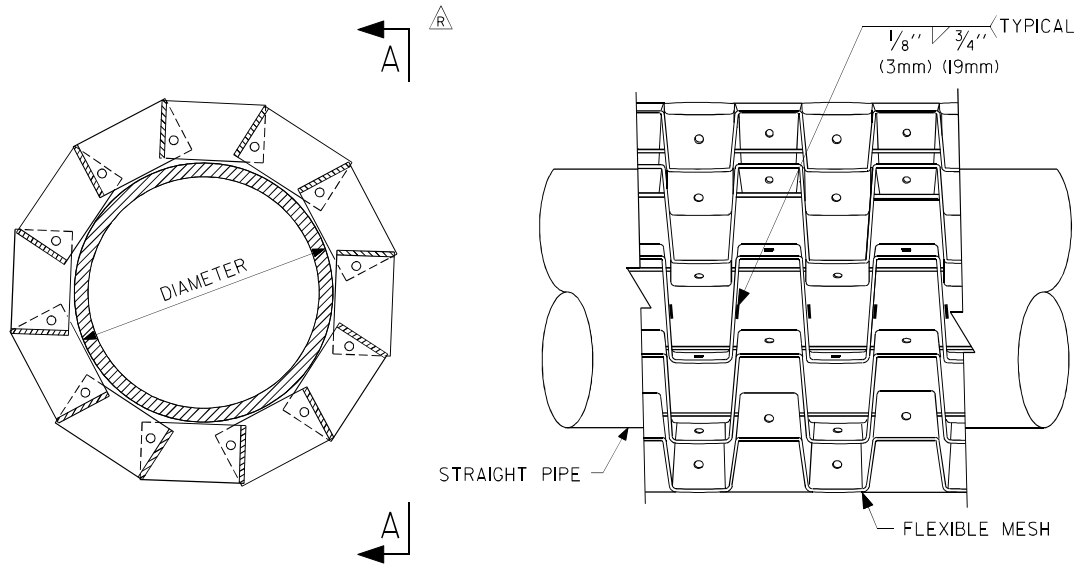
ALTERNATE FLEXIBLE MESH
WITH LANCES (SEE NOTE)
FIGURE – 17



NOTES:
1. DIMENSIONS SHOWN ARE APPROXIMATE.
2. RODS TO PASS THROUGH HOLES IN THE STRIPS. STRIPS SHALL FREELY ROTATE AT THE ROD.
3. ALTERNATE FLEXIBLE MESH SYSTEMS MAY BE CONSIDERED IF THEY HAVE A RECORD OF SUCCESSFUL USE IN SIMILAR SERVICE.

FLEXIBLE MESH
FIGURE – 18

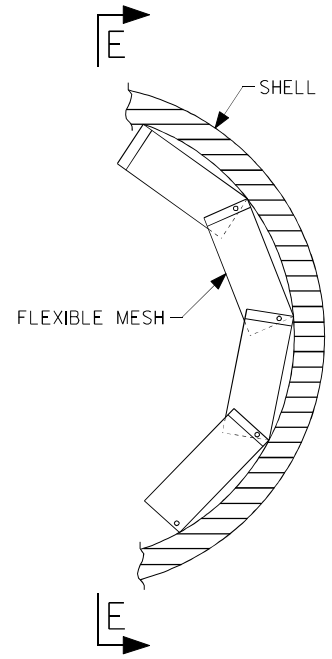
Figure 19 Flexible Mesh Typical Welding Pattern Exterior of a Curved Surface

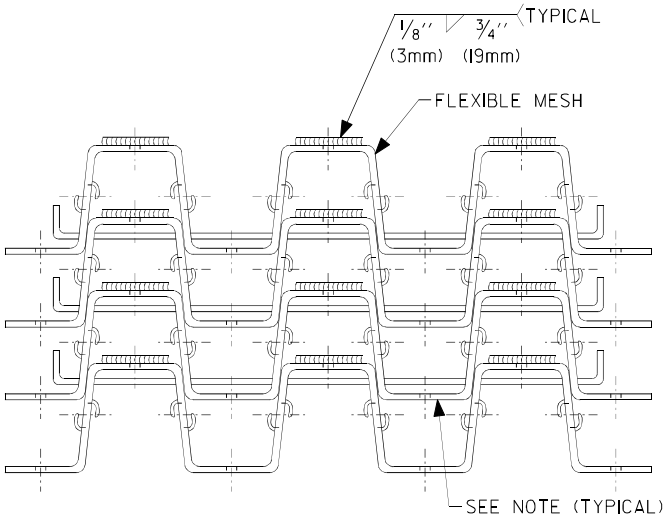


VIEW A–A R

FLEXIBLE MESH TYPICAL WELDING PATTERN
EXTERIOR OF A CURVED SURFACE
FIGURE – 19

Figure 20 Flexible Mesh Typical Welding Pattern Interior of a Curved Surface



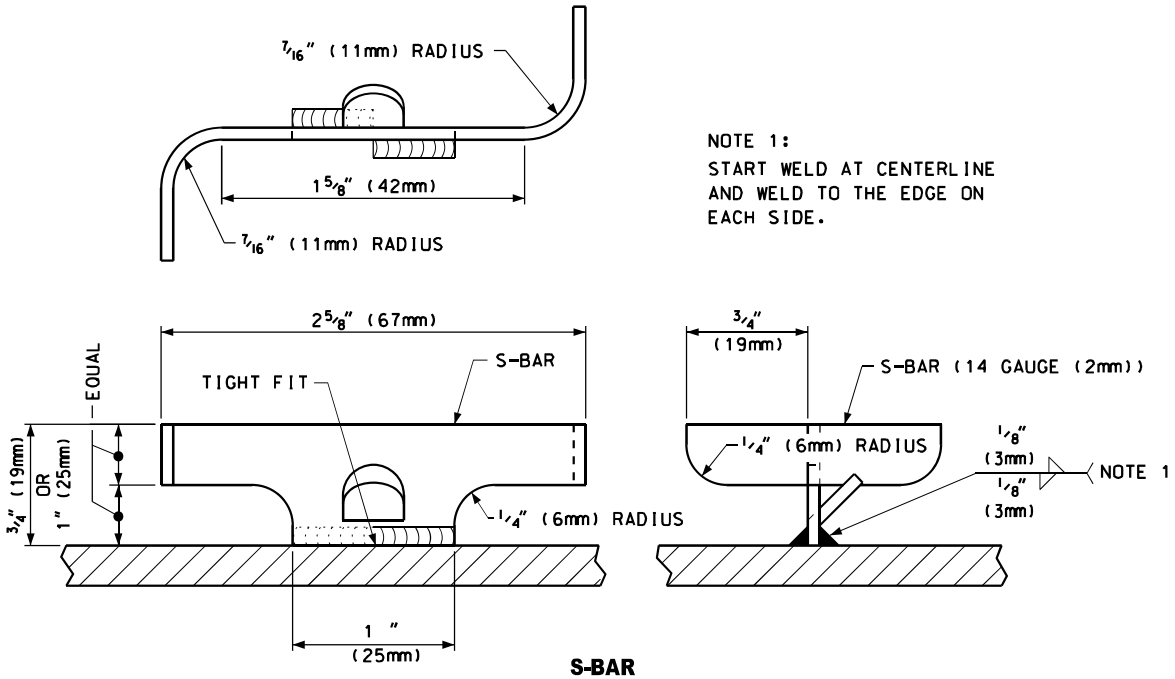


NOTE:
IN COKING AND THERMAL CYCLING SERVICES, OR WHERE SEVERE VIBRATION IS PRESENT, WELD TO THE BACKING METAL.

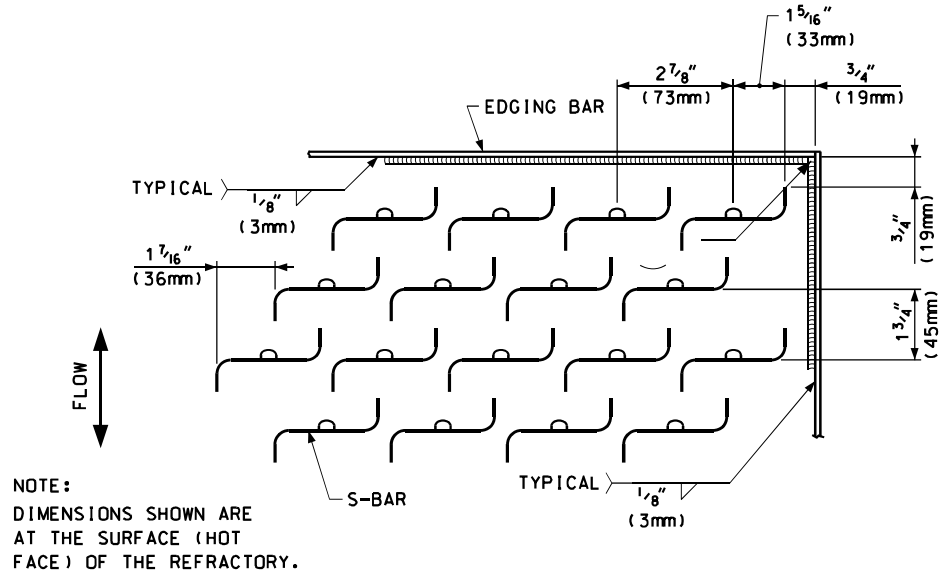
VIEW E–E

FLEXIBLE MESH
TYPICAL WELDING PATTERN
INTERIOR OF A CURVED SURFACE
FIGURE – 20

Figure 21 S-Bar
Figure 22 S-Bar Arrangement

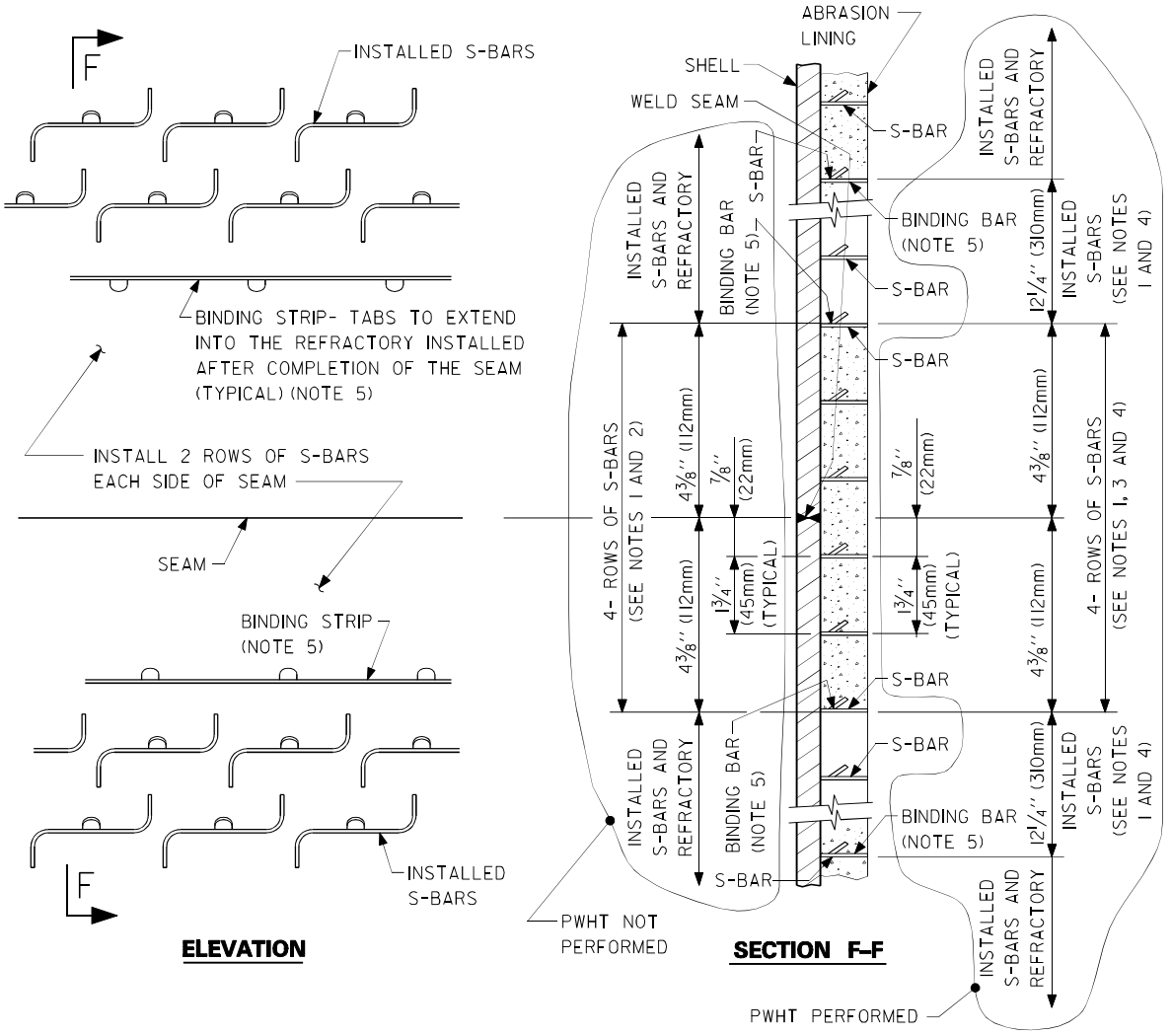


S-BAR
FIGURE - 21



S-BAR ARRANGEMENT
FIGURE - 22

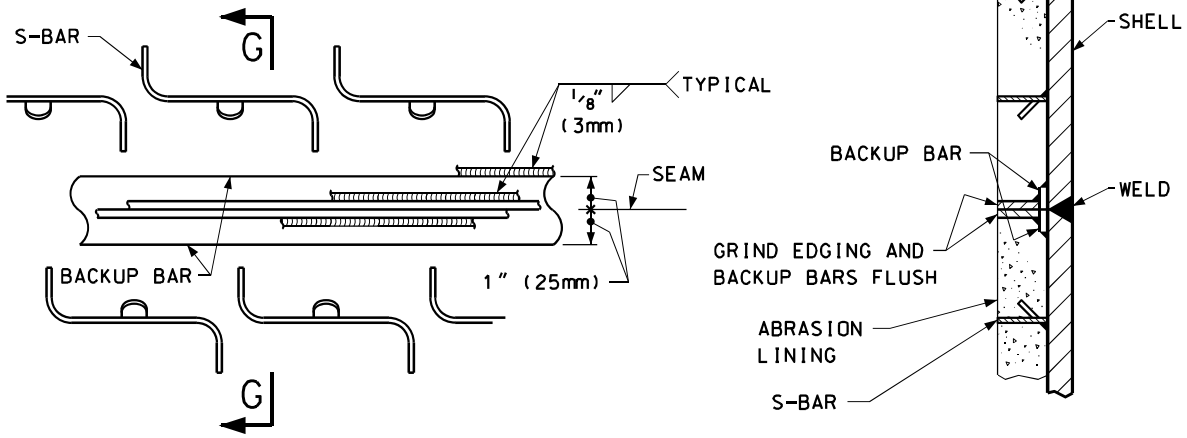
Figure 23 S-Bar Seam Details



NOTES: ⚠R

1. INCREASE REFRACTORY GAP AS REQUIRED TO PERMIT RADIOGRAPHY (AND HEAT TREATMENT, IF PERFORMED) WITHOUT REFRACTORY DAMAGE AND TO ALLOW HIGH QUALITY INSTALLATION.
2. INSTALL ANCHORS AND REFRACTORY AFTER COMPLETION OF SEAM WELDING AND NON-DESTRUCTIVE EXAMINATION. INSTALL ANCHORS BEFORE AND REFRACTORY AFTER HYDROSTATIC TESTING.
3. INSTALL ANCHORS AFTER COMPLETION OF SEAM WELDING AND NON-DESTRUCTIVE EXAMINATION AND BEFORE PWHT AND HYDROSTATIC TESTING.
4. INSTALL REFRACTORY AFTER SEAM WELDING, NON-DESTRUCTIVE EXAMINATION, PWHT, AND HYDROSTATIC TESTING.
5. BINDING BARS ARE ONLY USED AT THE JOINT BETWEEN REFRACTORY INSTALLED BEFORE AND AFTER SEAM WELDING. BINDING BAR REPLACES A ROW OF S-BARS.

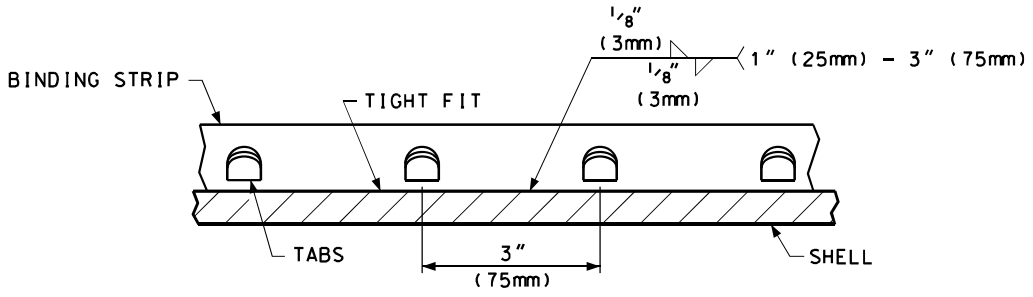
S–BAR SEAM DETAILS
FIGURE – 23



ELEVATION **SECTION G-G**

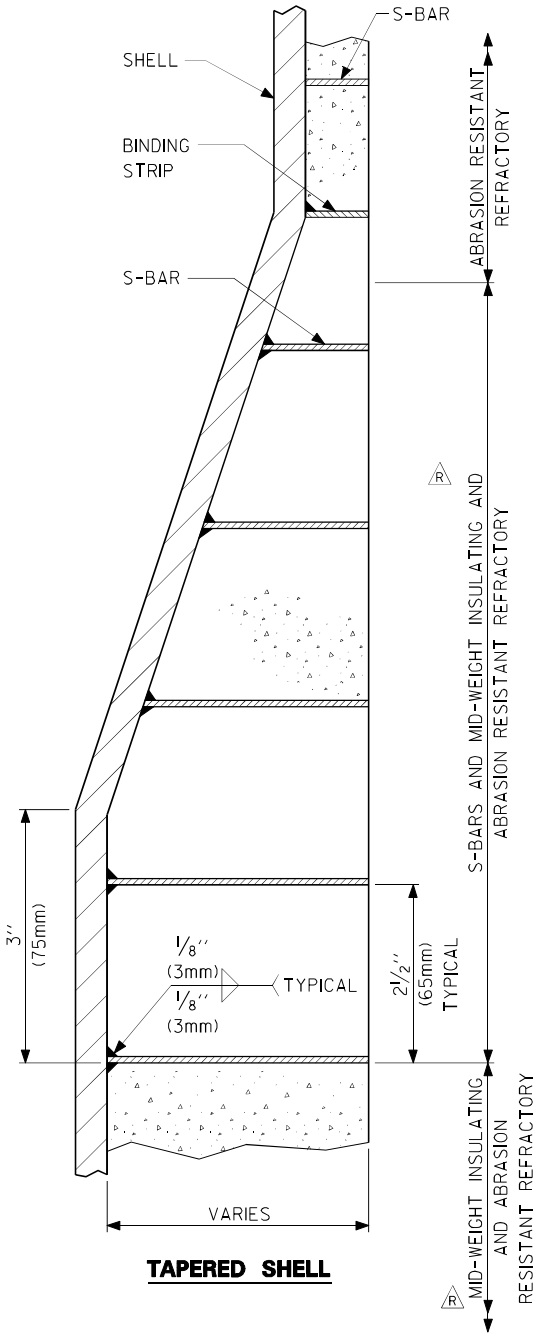
NOTE:
USE ONLY FOR INACCESSABLE JOINTS IN SMALL ITEMS (LESS THAN OR EQUAL TO 24" (600mm) ID OF LINING) WHERE RADIOGRAPHY AND POST WELD HEAT TREATMENT ARE NOT PERFORMED.

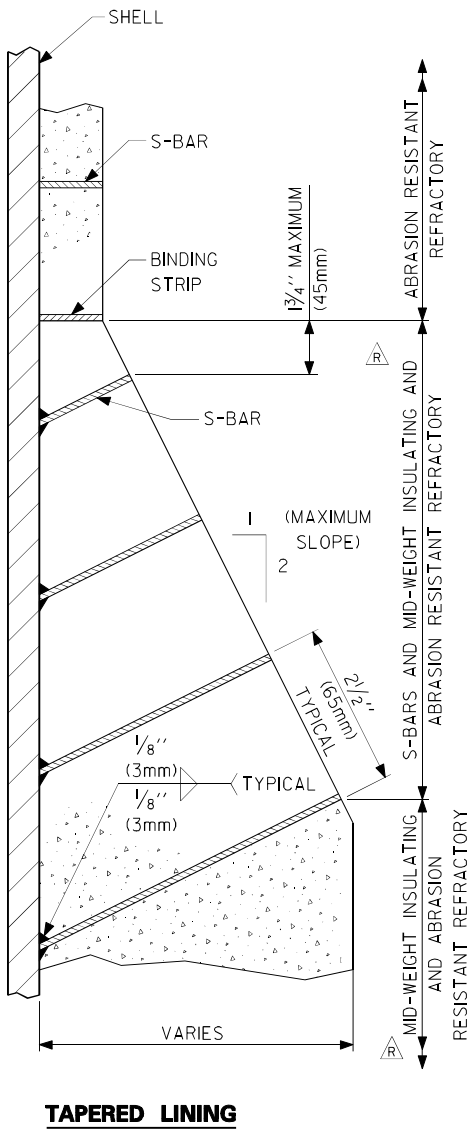
S-BAR CLOSED SEAM DETAIL (SEE NOTE)
FIGURE - 24



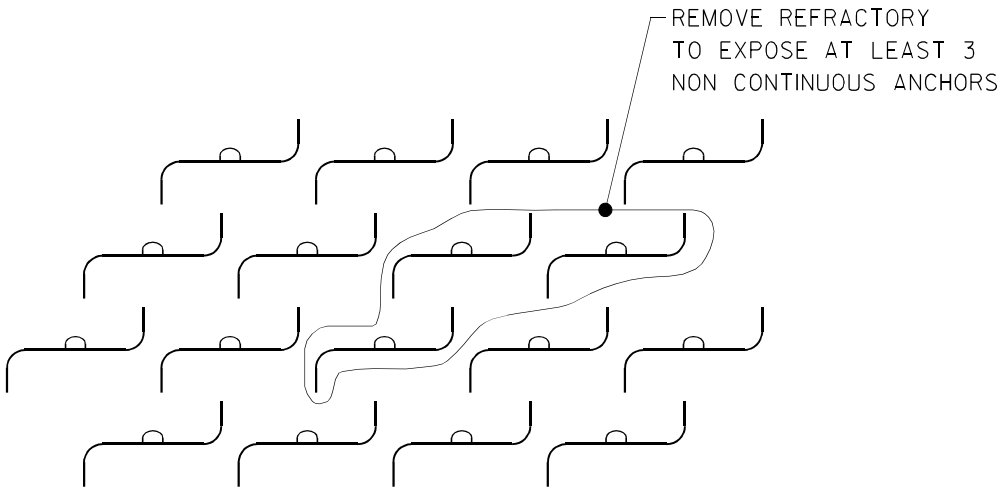
BINDING STRIP
FIGURE - 25

Figure 26 Tapered Lining Transition with S-Bars

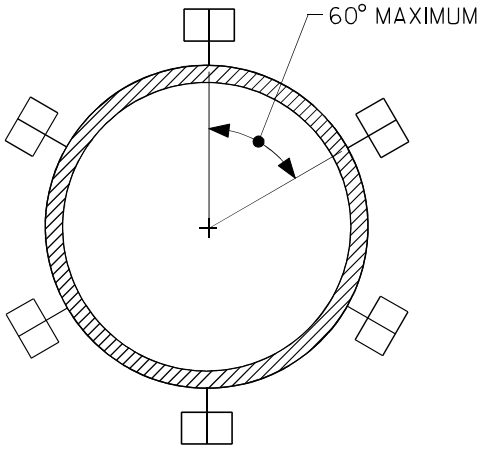




TAPERED LINING TRANSITION WITH S–BARS
FIGURE – 26

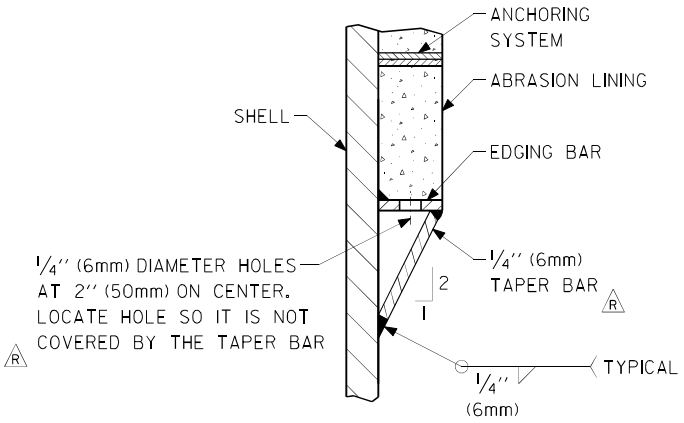


REFRACTORY REPAIR WITH S–BARS
FIGURE – 27

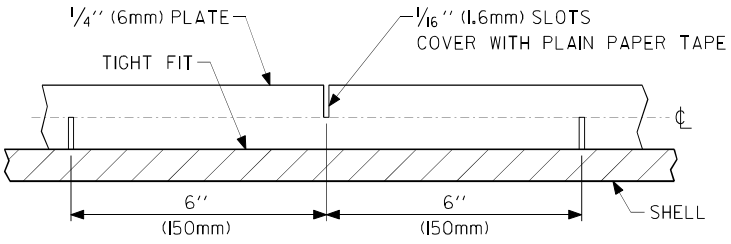


NOTE:
INSTALL S-BARS AXIALLY ON PIPE LESS THAN NPS 24.

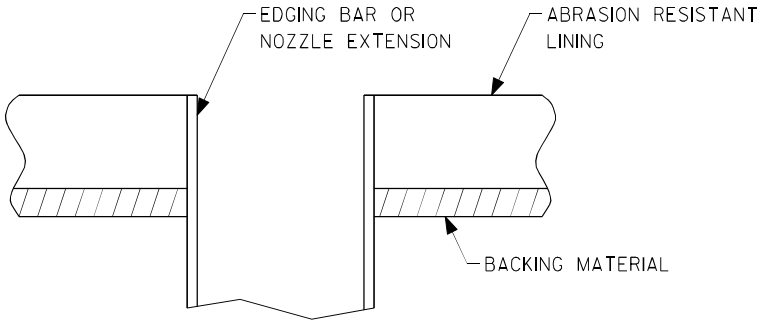
S–BARS INSTALLATION ON SMALL DIAMETER PIPE
FIGURE – 28



CONTINUOUS TAPER BAR
(LINING TERMINATIONS)
FIGURE – 29

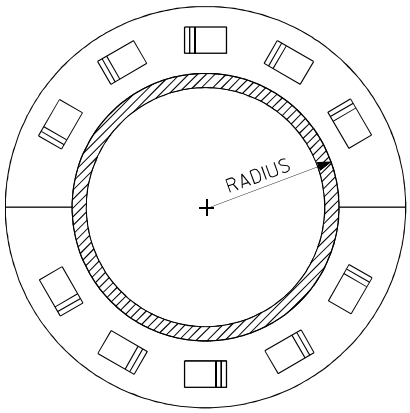


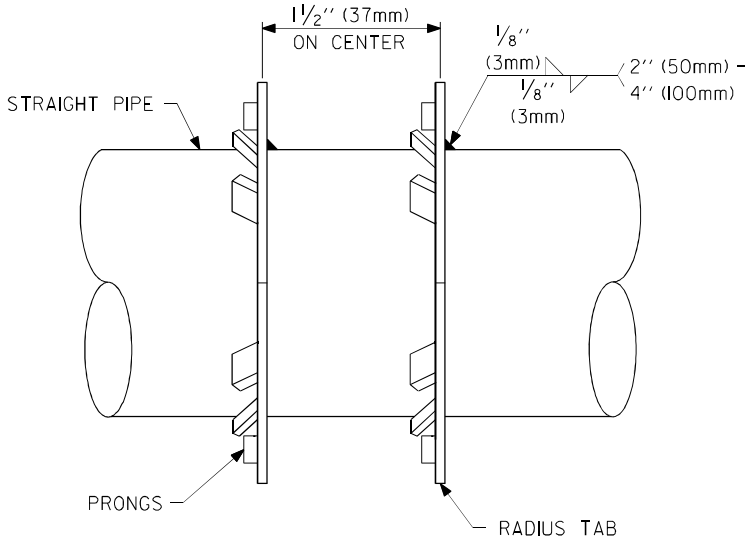
EDGING BAR
FIGURE – 30



NOTE:
WELD HEXAGONAL OR FLEXIBLE MESH TO THE EDGING BAR OR NOZZLE EXTENSION AS SHOWN IN FIGURE 3

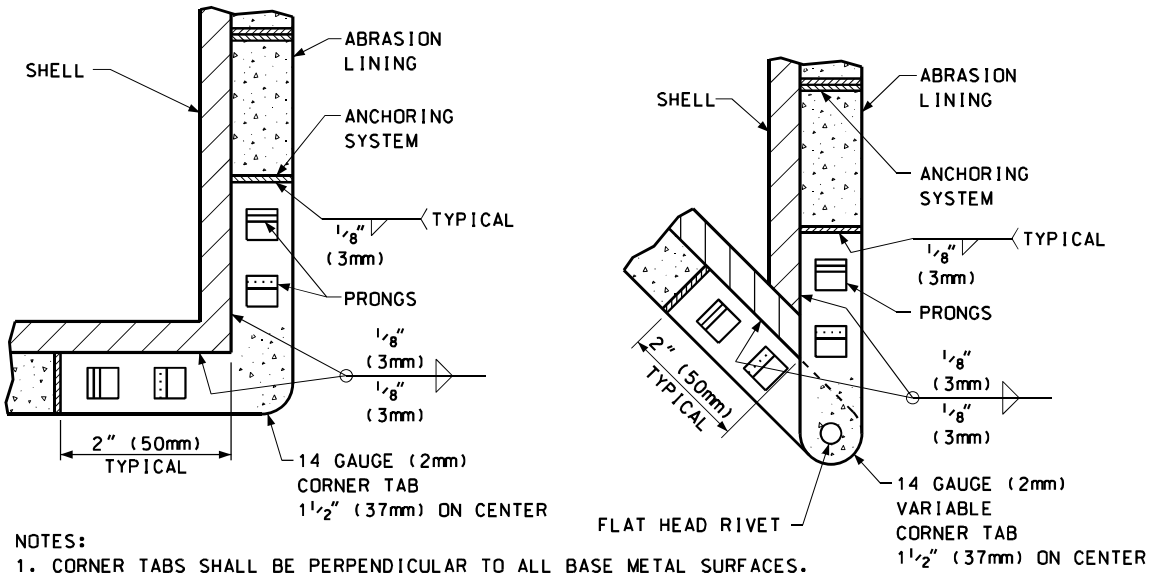
NOZZLE OR OTHER LINING PENETRATION
FIGURE – 31





NOTE:
RADIUS TABS SHALL BE PERPENDICULAR TO ALL BASE METAL SURFACES

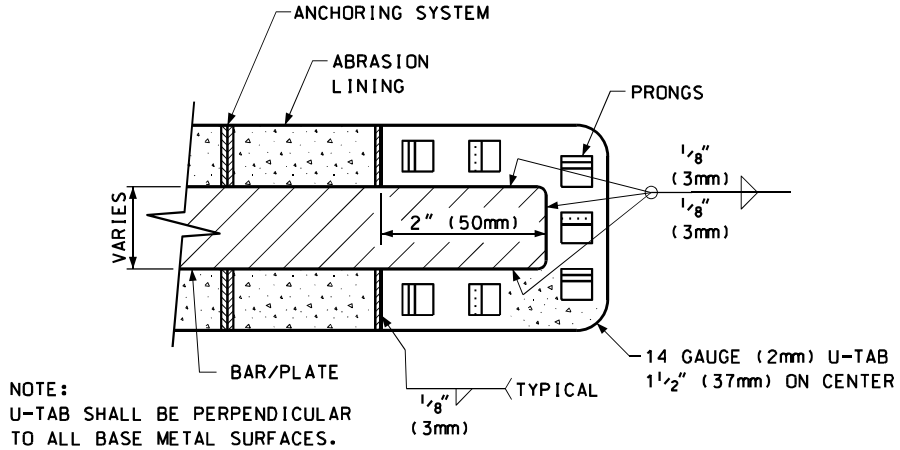
RADIUS TABS
FIGURE – 32



NOTES:
1. CORNER TABS SHALL BE PERPENDICULAR TO ALL BASE METAL SURFACES.
2. USE CORNER TABS ON INSIDE AND OUTSIDE (SHOWN) CORNERS.

90° CORNER TABS **VARIABLE CORNER TABS**

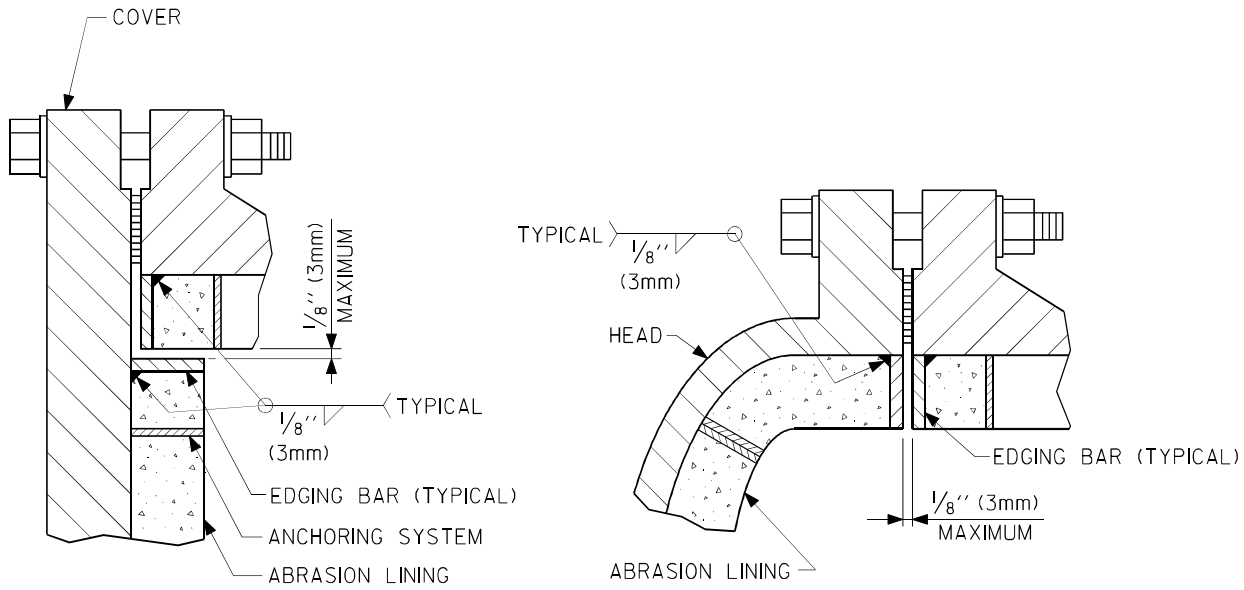
CORNER TABS
FIGURE - 33



NOTE:
U-TAB SHALL BE PERPENDICULAR TO ALL BASE METAL SURFACES.

DETAILS OF U-TAB
FIGURE - 34

Figure 35 Manway, Nozzle, and Head Details



MANWAY, NOZZLE, AND HEAD DETAILS
FIGURE – 35