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Refractory Linings for Pressure Vessels and Piping

GP 19-03-02

Scope

- 1) [I] This Global Practice (GP) covers requirements for refractory linings in pressure vessels, lines, and piping. It shall apply, but not be limited to, Fluid Catalytic Cracking (FCC), Fluid Coking, FLEXICOKING, and reforming units. This GP addresses the following:
 - a) Material selection
 - b) Testing
 - c) Shipment
 - d) Installation
 - e) Inspection
 - f) Curing and dryout
- 2) [I] The following are excluded from this GP:
 - a) Shotcrete (Gunit) linings (Portland cement and sand)
 - b) Brick type linings
 - c) Fired Heater, Incinerator, and Sulfur Combustor linings
- 3) [I] An asterisk (*) indicates that a decision by Purchaser is required or that additional information is furnished by Purchaser.

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1. Required References

[I] This Section lists Practices and Standards that are generically referenced and assumed to be a part of this document. Unless otherwise specified herein, use the latest edition.

[I] These requirements may be superseded by this GP and/or by the Job Specification(s). The requirements set forth in the Job Specification(s) shall supersede the requirements of this GP.

1.1. Global Practices–ExxonMobil Engineering Practices

GP 18-07-01	Welding Procedures
GP 18-12-01	Positive Material Identification
GP 20-01-01	Inspection of Equipment and Materials

1.2. ExxonMobil Data Sheets

ExxonMobil Data Sheets	ExxonMobil Data Sheet Home Page
D190302C01	Execution Data Sheet - Castable Linings

1.3. API–American Petroleum Institute

API RP 936	Refractory Installation Quality Control Guidelines-Inspection and Testing Monolithic Refractory Linings and Materials
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1.4. ASME–American Society of Mechanical Engineers

ASME SEC VIII D1 B PT UW	Part UW Requirements for Pressure Vessels Fabricated by Welding
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1.5. ASTM–American Society for Testing and Materials

ASTM A 167	Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM A 176	Standard Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip
ASTM A 580/A 580M	Standard Specification for Stainless Steel Wire
ASTM A 743/A 743M	Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
ASTM C 181	Standard Test Method for Workability Index of Fireclay and High-Alumina Plastic Refractories

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ASTM C 201	Standard Test Method for Thermal Conductivity of Refractories
ASTM C 704	Standard Test Method for Abrasion Resistance of Refractory Materials at Room Temperature
ASTM C 1113	Standard Test Method for Thermal Conductivity of Refractories by Hot Wire (Platinum Resistance Thermometer Technique)

1.6. SSPC–Society for Protective Coatings

SSPC SP 1	Solvent Cleaning (Steel Structures Painting Manual, Ch 2 - Surface Preparation Specs.)
SSPC SP 3	Power Tool Cleaning (Steel Structures Painting Manual, Ch 2 - Surface Preparation Specs.)
SSPC SP 7	Joint Surface Preparation Standard Brush-Off Blast Cleaning NACE No. 4: 2000 (Steel Structures Painting Manual, Ch 2–Surface Preparation Specs.)

1.7. API RP 936 Certification

In application of this GP, service providers shall have demonstrated knowledge of [API RP 936](#). Individuals requiring certification include:

- 1) Contractor refractory inspectors
- 2) Laboratory test technicians
- 3) Installation field supervisor contractors
- 4) Vendor technical representatives
- 5) OEM/Prime contractor personnel responsible for refractory selection/design

2. Definitions

Term	[I] Description
Contractor	The definition in API RP 936 shall apply. In cases where a general contractor subcontracts the refractory installation, the Owner shall define the responsible parties in the Execution Data Sheet (EDS).
Job Specification	Developed by the Owner or designated representative(s), this documentation defines in detail all the design/installation requirements that are applicable to a specific job. The Job Specification is in addition to the Practices, Codes, and Standards specified in this GP.
Owner's Engineer	Owner's designated representative to resolve technical refractory lining issues.

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Term	[I] Description
Pre-installation qualification	The testing of materials, installation personnel and equipment prior to installation work. Its purpose is to demonstrate ability to comply with the specified requirements.

3. Documentation and Responsibilities

- 1) * [I] Information to be furnished by Owner shall be as follows:
 - a) Provide Job Specification as defined in Section 2.
 - b) Initiate the Execution Data Sheet (EDS) (see Section 1.2).
 - c) Designate the Owner's representative Engineer and Inspector(s).
- 2) [I] Contractor responsibilities include the following. Prior to work execution, Contractor shall:
 - a) * Prepare and obtain approval for installation and dryout procedures. These include methods and order of execution for refractory installation, and for types of equipment to be used in installation. It also applies to the quality control plan, Dryout Index (as defined in [API RP 936](#)) of products being installed, and method of dryout, including equipment and setup to control and monitor dryout heating.
 - b) List of [API RP 936](#) certified personnel.
 - c) * Complete the EDS with required signoffs.
 - d) [S] Provide applicable Materials Safety Data Sheets (MSDS) for conditions of purchase and use and furnish information regarding safety precautions to protect personnel during application and dryout.
 - e) Direct pre-installation qualification testing to ensure that the installation quality requirements are met and documented with applicable water ratios.
- 3) * [I] Equipment Fabricator responsibilities are as follows:
 - a) Equipment Fabricator shall be responsible for lining protection during shipment and erection of equipment with refractory installed prior to arrival at job site. Fabricator shall provide shipping instructions, including details of any structures to support the applied linings, to Purchaser for approval by the Owner's Engineer.
 - b) Equipment Fabricator shall submit the anchor heat-treatment report to Contractor for review prior to anchor installation.

4. Refractory Material Preparation Prior to Shipment

- 1) [R] All shipments shall have each batch and refractory type clearly identified on the containers.
- 2) [R] The water ratio used in qualification testing shall be marked on the refractory containers (except for Type 2h).
- 3) [R] For Type 2h lining materials:

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- a) Refractory shall be pre-sliced at a thickness of $1\frac{1}{4}$ – $1\frac{3}{4}$ in. (30–45 mm) and then packaged in heat-sealed plastic wrap.
- b) The recommended workability index range and that used for the qualification testing shall be marked on the containers and included with the installation instructions.

5. Design and Installation of Linings

Refer to details shown on Figures A–1 through A–16 in the Appendix.

5.1. Refractories

- 1) * [R] The EDS shall be approved and pre-installation qualification of materials and applicators shall be satisfactorily completed before installation may commence.
- 2) [R] Installation Contractor shall ensure that installed physical properties are within the limits specified in Tables 3 and 4, with the allowances specified in [API RP 936](#). To this end, Installation Contractor shall specify any additional pre-qualification testing per Section 9.1, Item (2) that is necessary to meet this obligation.
- 3) [R] Refractories containing calcium silicate type binders (Portland cement) shall not be used at temperatures above 800°F (427°C).
- 4) [S] Refractories shall not contain asbestos or asbestos additives.
- 5) [R] Loose rust, scale, and other foreign matter shall be removed from all surfaces in contact with refractory per SSPC SP 3 or SSPC SP 7. Oil and grease shall be removed using solvent wipe per SSPC SP 1.

5.2. Metal Fiber Reinforcement

- 1) [R] Fiber reinforcing shall not be used in refractory for Hexmetal linings.
- 2) [R] Unless otherwise specified, metal fibers shall be of 304SS material, 1 in. (25 mm) long fibers that meet the following requirements:
 - a) Cold-drawn fibers shall be 0.013 in. (0.33 mm) diameter with chemical requirements per [ASTM A 580/A 580M](#).
 - b) Melt-extracted fibers shall be 0.013–0.016 in. (0.33–0.41 mm) equivalent diameter with chemical requirements per [ASTM A 743/A 743M](#).
 - c) Fibers made by a "Sheet Chopping" process shall be 0.010 x 0.022 in. (0.25 x 0.56 mm) with chemical requirements per [ASTM A 167](#) or [ASTM A 176](#). Straight, corrugated or zigzag type fibers are acceptable.
- 3) [R] Cold drawn fibers shall be used for casting installations unless otherwise specified or approved. Melt-extracted or chopped fibers shall be used for gunning and hand packed applications unless otherwise specified or approved.
- 4) [R] When metal fiber use is specified, the added fiber content in the refractory shall be 3.5 percent by weight. Material to which metal fibers have been added shall be designated with an "f" following the refractory type. For example, Type 3f is Type 3 refractory to which metal fibers have been added.

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5.3. V and Y Anchors

- 1) [R] V-anchors for single component linings shall be as follows:
 - a) Design and layout for single layer linings shall be per Figure A-1 and Figure A-2. Either straight tine or Wave V-anchors are acceptable.
 - b) For cast and gunned installations, anchor tips shall be 0 in. minimum to 1 in. (25 mm) maximum from the refractory lining surface.
 - c) For gunned single layer linings behind shrouds, V-anchor tips shall be flush with the specified lining surface to provide for accurate measurement of the applied lining thickness.
 - d) For cast pipe linings, anchors are not required if the lining ID is 26 in. (660 mm) or less, provided that the lining thickness is 3 in. (75 mm), or more.
- 2) [R] Y-anchors for dual-layer linings shall be per Figure A-3. When installed by gunning, the first layer shall be gunned with the stud-welded threaded stud in place, with tape or plastic caps covering the exposed threads. The "V" portion shall then be attached before the second layer is gunned.
- 3) [R] Anchors shall be of the hand-weldable type. Stud gun weldable anchors shall not be used unless approved by Owner's Engineer.
- 4) [R] Austenitic stainless steel V and Y anchors shall be supplied in the fully solution-annealed condition. Solution annealing shall be performed after the anchor is formed.
- 5) [R] Metallurgy shall be based on the maximum long-term temperature to which the anchor is exposed at a depth of 1 in. (25 mm) from the lining hot face. Selection shall be as listed in Table 1.

Table 1: V-Anchor Metallurgy

Maximum Permissible Anchor Temperature [1 in. (25 mm) from Hot Face]		Metallurgy ⁽¹⁾
°F	°C	
1000	540	Carbon Steel 0.30 wt percent Carbon max.
1200	650	12 percent Cr (410S, 405)
1600	870	Austenitic Stainless Steel
Note (1) Metallurgy selection for anchors in high H ₂ S service (i.e., reforming) shall be approved by the Owner's Engineer.		

- 6) [R] Anchors shall be color coded per Appendix C of [API RP 936](#).

5.4. Hexmetal

- 1) [R] Hexmetal shall meet the general requirements of this Section:
 - a) Hexmetal shall be fabricated from strips of the following thickness:
 - i) Carbon steel = 0.105 ± 0.007 in. (12 Gauge, 2.5 mm metric equivalent).
 - ii) Alloy steels = 0.078 ± 0.004 in. (14 Gauge, 2.0 mm metric equivalent).

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- b) Hexmetal (Figure A-4) shall be 1 in. (25 mm) deep and measure approximately $1\frac{7}{8}$ in. (48 mm) between parallel sides. Two tabs approximately $\frac{1}{4}$ in. wide by $\frac{1}{2}$ in. long (6 mm by 13 mm) shall protrude into each hexagon. The tabs shall be located at the center of the hexagon depth, unless otherwise specified. Hexmetal depths of $\frac{3}{4}$ in. (19 mm) and/or $1\frac{1}{2}$ in. (38 mm) may only be used if approved by the Owner's Engineer.
 - c) Hexmetal strips shall be tightly joined at each contact point by double tab clinches so that adjoining strip walls shall not separate by more than $\frac{1}{16}$ in. maximum (as measured front and backside) when rolled and installed. The mesh shall be resistant to bending and sufficiently rigid so that it will not flex between points of attachment to the shell.
 - d) Flexible Hexmetal, using hinged sections, is permitted only for lined components less than 10 in. (250 mm) diameter or spray shield applications; each cell shall contain at least 2 tabs.
 - e) Hexmetal metal and termination strips shall be austenitic if attached to Austenitic components, such as 300 series stainless steels, and ferritic if attached to ferritic components, such as carbon steel or 12 percent Cr. PMI shall be made at a 5 percent random frequency based on the number of pieces and number of strips in the Hexmetal.
 - f) Hexmetal shall be installed in panels as large as practical to minimize the extent of joints in the applied lining. Joints between panels shall be offset to avoid continuous seams in the direction of process flow.
 - g) Metal fiber reinforcing and organic fiber burnout material shall not be used in refractory for Hexmetal linings.
- 2) [R] Hexmetal attached directly to plate shall conform to the following:
- a) Orientation shall be with strips perpendicular to the direction of process flow.
 - b) Welding and metal termination strips (when used) shall be as shown in Figure A-5.
 - c) Joints between adjacent Hexmetal panels shall have ends welded to the plate with a maximum gap of $\frac{1}{2}$ in. (13 mm) per Figure A-6.
 - d) Edging for linings in severe erosion applications such as cyclones shall be refractory lined per Figure A-7.
- 3) [R] Hexmetal used in dual-layer linings with stud supports shall conform to the following:
- a) Orientation on curved surfaces shall be with strips parallel to the direction of rolling (i.e., the Hexmetal is rolled in the "hard" direction).
 - b) Stud layout and spacing shall be per Figure A-8, Detail A.
 - c) Stud and heads shall be as shown in Figure A-8, Detail B.
 - d) Hexmetal shall be welded to stud heads along all points of contact with a $\frac{3}{16}$ in. (4 mm) fillet weld per Figure A-8, Detail C.
 - e) Terminations shall be made using continuous termination strips or a combination of bridging and termination strips as in Figure A-8, Detail D.
 - f) Joints between adjacent Hexmetal panels shall be made using strip tie-ins welded to the Hexmetal as shown in Figure A-9. Tie-ins shall be secured by welding to the adjacent Hexmetal through the full depth of the strips and at any contacting stud supports.

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5.5. Hexalt Anchors

- 1) [R] Hexalt anchor alternatives to Hexmetal per the [API RP 936](#) definition are acceptable when repairing areas 2 ft² (0.18 m²) or smaller. Use in larger areas and/or fit-up between Hexmetal sheets shall be subject to approval by the Owner's Engineer.

- 2) [R] Acceptable Hexalt anchoring includes the following:

Flexible Hexmetal	Causeway Steel Products Limited
Half Hexcels	Five Ash Works, Dover Road East
	Northfleet, Kent
	DA11 0RF, England
	Tel: +44 (0) 1474 567871
K-Bar™	Kraemer Gunite, Inc.
	P.O. Box 305
	Richwood Road
	Pitman, NJ 09071, USA
	Tel: (832) 227-8097
Hexcel	Discovery Associates, Inc.
	P.O. Box 31
	Fairview Village, PA 19409
	Tel: (800) 446-0918, Fax: (610) 631-9365

Proposals to use alternative Hexalt anchor designs or suppliers shall be submitted for Owner's Engineer's review and approval.

- 3) * [R] Hexalt designs, welding, and layout patterns shall be subject to approval by Owner's Engineer.

5.6. Welding

- 1) * [R] Welding procedure(s) for refractory anchorage attachment shall conform to [GP 18-07-01](#) and shall be approved by the Owner's Engineer prior to start of fabrication.
- 2) [R] If postweld heat treatment (PWHT) of the equipment is required, refractory anchorage shall be installed prior to PWHT.
- 3) [R] Surface preparation for anchorage attachment welds shall be:
 - a) Per [ASME SEC VIII D1 B PT UW](#)-32.
 - b) Spot-ground to obtain clean metal for welding. New shells that have been blast-cleaned need not be spot-ground, provided any subsequent accumulation of rust or foreign material may be effectively removed by brushing at weld locations.
- 4) [R] When Hexmetal is to be welded to flat plate and the resulting assembly rolled, one weld per 2 ft² (0.25 m²) of the attachment welds shall be examined for cracks by the liquid dye penetrant method after rolling.

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