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SCOPE

- I **1.1** This practice covers requirements for material selection, shipment, installation, inspection, and testing of hydraulic and chemical setting, refractory linings for vessels, lines, and piping. All articles of API RP-936 shall be treated as mandatory requirements of this practice, except as modified herein.
 - * Additional documents such as design and/or installation specifications may be required to define job-specific details.
- I **1.2** **Shotcrete (gunite) linings** (Portland cement and sand) are **not covered** by this practice.
- I **1.3** **An asterisk (*)** indicates that a decision by the Purchaser is required or that additional information is furnished by the Purchaser.

SUMMARY OF ADDITIONAL REQUIREMENTS

- I **2.1** **Table 1** lists the practices, code, standards, and specification which shall be used with this practice.

TABLE 1

PRACTICES			
IP 18-12-1	Positive Materials Identification	IP 20-1-1	Inspection of Equipment and Material
CODE, STANDARDS, AND SPECIFICATION			
ASME Code Section VIII Pressure Vessels, Division 1 API Standard API 936 Refractory Installation Quality Control Guidelines		SIS Standard 05 59 00 Pictorial Surface Preparation Standards SSPC SSPC Specification SP3 Power Tool Cleaning	

DOCUMENTATION

- I *** 3.1** **The Installation Contractor shall have overall responsibility for supplying** the Owner's Engineer with **information** as outlined below. The Owner's Engineer shall stipulate that this **information** be supplied at the time of the bid or before work execution.
- I **3.2** **The following property data shall be provided** for all refractories to be installed in accordance with the specified procedures. This data shall be generated on cast specimens for cast materials, on hand packed specimens for hand packed materials, and on cast and gunned specimens for gunned materials based on procedures specified by the Owner. Refractory properties shall be verified by independent laboratory tests on recent (< 1 year) production samples.
 - a. Compressive strength.
 - b. Erosion loss by **ASTM C704** (Types 1, 2a, 2h, 3 and 3lx).
 - c. Permanent linear change.
 - d. Dry density.
 - * e. Thermal conductivity (Types 3, 3lx, 4, 5 and 6) as measured for a mean temperature of 1000°F (540°C). Thermal conductivity test method used and any adjustments shall be stipulated.
 - f. Water ratio to be used for qualification tests and installation for each refractory type supplied.
 - g. Vendor's requirements for storage and expected shelf life.
 - h. Maximum long term use temperature.
 - i. Identity of any organic fiber additives to allow for accelerated dryout.
 - S j. **Materials Safety Data Sheets** (for purchase and use within the U.S.A.). For other conditions of purchase and use, vendor shall furnish information on safety precautions to be taken during application and dryout for personnel protection.

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- I ♦ * 3.3 Installation and **dryout procedures** shall be submitted to the Purchaser for approval by the Owner's Engineer prior to refractory installation. Procedures shall detail the following:
 - a. Methods of how refractory will be installed, equipment to be used in installation and a quality control plan.
 - b. Method of dryout, including equipment and setup to control and monitor dryout heating.
- R * 3.4 **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 instruction, including details of any structures to support the applied linings, to the Purchaser for approval by the Owner's Engineer.
- I * 3.5 **Welding and inspection procedures for stud attachment** shall be submitted to the Purchaser for approval by the Owner's Engineer prior to start of fabrication.

DEFINITIONS

- I 4.1 **Preinstallation Qualification:** The testing of materials and installation personnel prior to installation work to demonstrate a capability to comply with the specified requirements.

PREPARATION FOR SHIPMENT OF REFRACTORY MATERIAL

- R 5.1 **Shipment of refractories** shall be **scheduled** to insure that they can be installed within 4 months of initial acceptance tests or within 3 months of each succeeding satisfactory requalification test.
- I 5.2 **Each shipment** shall have each **batch and refractory type** clearly **identified** by numbering the containers.
- R 5.3 The **water ratio** used in qualification testing shall be marked on the refractory **containers** (except for Type 2h).
- R 5.4 **For Type 2h lining materials:**
 - a. Refractory shall be **pre-sliced** at a thickness of 1-1/4 to 1-3/4 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.
 - c. **For installation of Type 2h, additional material** shall be **provided to allow for the discarding of all trimmings** and loose rubble accumulated during ramming into hexmesh.

MATERIALS

- R * 6.1 **Proposals to use different materials, thickness, anchoring systems, or installation methods**, other than those specified, shall be submitted to the Purchaser for approval by the Owner's Engineer at time of proposal.

ALL REFRACTORIES

- R 6.2 **Refractories containing calcium silicate type binders** (Portland cement) shall not be used at temperatures over 800°F (427°C).
- S 6.3 **No refractories** shall contain **asbestos or asbestos additives**.
- R 6.4 **Physical and chemical properties** of refractories shall be per **Table 2A/B** for the type of lining specified.

METALLIC COMPONENTS

- R 6.5 **V-anchors and Y-anchors of austenitic stainless steel** shall be supplied and installed in the **fully solution annealed condition**.
- R ♦ * 6.6 **Metal fiber reinforcing** shall be 1 in. (25 mm) long fibers meeting the following requirements:
 - a. Cold-Drawn fibers shall be 0.013 in. (0.33 mm) diameter with chemical requirements per ASTM A 580.
 - b. Melt-extracted fibers shall be 0.013-0.016 in. (0.33-0.41 mm) equivalent 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.

- R **6.7** **Anchor material** shall be based on the **maximum long term exposure temperature** to which the component will be exposed at a depth of 1 in. (25 mm) from the hot face of the lining. Selection shall be as follows:

MAXIMUM PERMISSIBLE TEMPERATURE OF METALLIC COMPONENT		TYPE OF STEEL
°F	°C	
1000	540	Carbon Steel 0.30 wt% Carbon max.
1200	650	12% Cr (410S, 405)
1600	870	Austenitic Stainless Steel

- R **6.8** **Hexmesh shall meet the following requirements:**

- a. Hexmesh shall be fabricated from strips of the following thickness: carbon steel -0.105 ± 0.007 in. (12 Gauge, 2.5 mm metric equivalent); alloy steels -0.078 ± 0.004 in. (14 Gauge, 2.0 mm metric equivalent).
- * b. **Hexmesh shall be 1 in. (25 mm) deep** and measure approximately 1-7/8 in. (50 mm) between parallel sides. Two tabs approximately 1/4 in. wide by 1/2 in. long (6 x 12 mm) shall protrude into each hexagon. The tabs shall be located at the center of the hexagon depth, unless otherwise specified. 3/4 in. (19 mm) Hexmesh shall only be used with the Owner's Engineer approval.
- c. Hexmesh **strips** shall be **tightly joined** at each contact point by double tab clinches such that adjoining strip walls shall not separate by more than 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" hexmesh**, using hinged sections, is permitted only for lined components less than 10 in. (250 mm) diameter or spray shield applications; and they shall contain tabs.
- ◆ e. **Hexmesh 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% Cr. PMI shall be made at a 5% random frequency based on the number of pieces and number of strips in the hexmesh.

DESIGN AND INSTALLATION OF METALLIC COMPONENTS

SURFACE PREPARATION

- R **7.1** **Loose rust, loose scale and other foreign matter** shall be **removed** from **all surfaces in contact with refractory**. All oil and grease shall also be removed using appropriate methods.

Note: Corresponding designations of the SSPC and SIS standards required by this practice are as follows:

SSPC	SIS
SP3	05 59 00, Grade ST Degree 3

- R **7.2** Surface preparation for stud attachment welds shall be per **ASME Code Section VIII, Par. UW-32**.

HEXMESH

- R **7.3** Hexmesh shall be installed in panels as large as practical to minimize the extent of joints in the applied lining. Joints between hexmesh panels shall be offset to avoid continuous seams in the direction of process flow.

- R **7.4** **Hexmesh 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 1**.
- c. **Joints** between adjacent hexmesh panels shall have ends welded to the plate with a maximum gap of 1/2 in. (13 mm) (**Figure 2**).
- d. **Edging** for linings in severe erosion applications such as cyclones shall be refractory lined per **Figure 3**.

- R **7.5** When the hexmesh is to be welded to flat plate and the resulting assembly rolled, one weld per 2 sq ft (0.25 m²) of the attachment welds shall be examined for cracks by the liquid penetrant method after rolling.

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- R **7.6 Hexmesh used in dual-layer linings** with stud supports shall conform to the following:
- Orientation** on curved surfaces shall be with strips parallel to the direction of rolling (i.e., the hexmesh is rolled in the "hard" direction).
 - Welding and terminations** shall be as shown in [Figure 4](#).
 - Joints** between adjacent hexmesh panels shall be made using strip tie-ins welded to the hexmesh as shown in [Figure 5](#). The tie-ins shall be secured by welding to the adjacent hexmesh through the full depth of the strips and any contacting stud supports.
 - Terminations** shall be made using continuous termination strips or a combination of bridging and termination strips ([Figure 6](#)).

- R **7.7 Metal fiber reinforcing** shall not be used in refractory for hexmesh linings.

ANCHORS

- R **7.8** V-stud anchors for single component linings shall be as follows:
- Design and layout for **single layer linings shall be per [Figure 7](#), Options 1 or 2 and [Figure 8](#)**.
 - For gunned single layer linings **behind shrouds, flush tip** anchor height tolerances shall provide for accurate measurement of the applied lining thickness as required in **Par. 8.3**.
 - * For cast pipe linings, **V-anchors are not required if the lining I.D. is 26 in. (660 mm) or less**, provided the lining thickness is at least 3 in. (75 mm).
- R **7.9** For dual-layer linings, **Y-anchors per [Figure 9](#)** shall be used. When installed by gunning, the first layer shall be gunned with the straight shank in place with tape or plastic caps covering the exposed threads. The "V" portion shall then be attached before the second layer is be gunned.
- R * **7.10** V-anchors and Y-anchors shall be constructed with straight tynes. Under no circumstances shall "wavy" or bent end tynes be used for gunned installations.
- R * **7.11** **Anchors shall be either manually or stud-gun welded** with secure attachment to the base metal without weld undercut.
- R * **7.12** **All anchor weld attachments shall be bend tested**, except austenitic stainless steels where the bend could be exposed to 1000°F (540°C). Bend testing shall be performed by bending the anchor in the vicinity of the weld 15° and back in the direction of greatest resistance without evidence of failure. Austenitic stainless steels where the bend could be exposed to 1000°F (540°C) shall be visually inspected without bending.
- R **7.13** **Qualification tests** shall be made **for anchor welds per ASME VIII Par. UW-27, 28 and 29**, with anchors considered as load carrying non-pressure parts.

FIELD JOINTS IN SINGLE LAYER PIPE LININGS

- R * **7.14** **Refractory lining and joint makeup details** shall be the close-fitting Type A or open Type B joints **as shown in [Figures 10 and 11](#). Flanged joints shall be per [Figure 12](#)**. Alternative methods shall be submitted to the Purchaser for approval by the Owner's Engineer.
- R **7.15** **Type A joints shall be used for all weld connections of refractory lined pipe** except those requiring make-up or deforming for fitup after refractory installation. For Type A joints, all piping shall be match marked and provided with truing rings prior to refractory installation ([Figure 10](#)). Compliance with alignment tolerances shall be the responsibility of the refractory Installation Contractor.
- R **7.16** **Type B joints shall be for welded connections requiring makeup or deforming for fitup during field erection**. The lining shall terminate 8 in. (200 mm) from the end of the pipe as per details shown in [Figure 11](#). Hammering or deforming fully lined pipe to effect joint fitup with other lined pipe is not acceptable.
- I * **7.17** If the castable is installed in piping nozzles or vessel sections prior to their erection, a gap at the end of each section shall be left unlined until the erected sections have been welded.

MANWAY PLUGS AND HEADS

- R * **7.18** **Manway heads shall be per [Figure 11](#)**.
- R * **7.19** **Manway plugs shall be per [Figure 12](#)**.

REFRACTORY INSTALLATION AND REPAIR PROCEDURE

- I 8.1 All **procedures** shall be **approved** and **Preinstallation Qualification** of materials and applicators **satisfactorily completed before actual installation work can begin.**
- I * 8.2 The **Installation Contractor shall be responsible to ensure that installed physical properties** are within the limits specified in **Table 2A/B.** To this end, the Installation Contractor shall specify to the Owner's Engineer any additional prequalification testing per **Par. 10.2** necessary to meet his obligation.
- R ♦ 8.3 Tolerances for specified lining thickness shall be as follows:

COMPONENT	LINING THICKNESS TOLERANCE	
	in.	mm
Vessel Linings	-0, +1/2	-0, +13
Shrouded Linings	-0, +1/4	-0, +6
Pipe Straight Section	± 1/8	± 3
Pipe Curved Section	± 1/4	± 6
Max. step at adjoining sections	± 1/16	± 1.5
Refractory in relation to hexmesh that it is retained in	-0, +1/16	-0, +1.5

- R ♦ * 8.4 For cast installations, the Installation Contractor shall check the concentricity and fitup of the piping and notify the Purchaser of any deviations. Use of mitering on curved sections shall be subject to the approval of the Owner's Engineer. Styrofoam, if used, shall be 2 lb/ft³ (32 kg/m³) minimum density. All forms shall be removed after casting and curing. Burnout of forms is not permitted.
- R 8.5 **All vibration castings shall be made using two or more rotary mechanical vibrators** mounted externally on the equipment or component to be lined. Vibrators shall have a total force equal to at least 100% of the total weight being vibrated. **Each vibrator shall be independently controllable.**
- * Proposals to vibrate forms, or to use other types of vibrators, shall be subject to approval by the Owner's Engineer.
- 8.6 All **Type 2a chemical setting refractories** shall be mixed at the same water content as used for prequalification tests. Refrigeration of refractory and water is permitted to improve workability and/or extend pot life.
- R 8.7 All **Type 2h chemical setting refractories** shall be installed by placing slabs of pre-sliced material on top of the anchors and ramming them roughly perpendicular to the casing shell. Layered application of refractory should be minimized to the greatest extent possible. Trimmings and loose rubble shall be discarded and not reused. Field water addition or re-mixing to recondition a refractory with inadequate workability is unacceptable.

REPAIR OF DEFECTIVE AREAS

- I * 8.8 All repairs shall be approved by the Owner's Engineer. **Figure 13** illustrates an acceptable patch repair for single-layer linings.
- R 8.9 **Defective areas** defined herein **found after curing** shall be removed to the insulating castable in the case of **dual-layer linings**, and to the pipe or vessel wall in the case of **single-layer linings**. Then the refractory shall be reapplied.

CURING AND DRYING PROCEDURES

- R * 9.1 **The vendor's curing and drying procedures** shall be followed where such requirements are more stringent than the requirements given in **Par. 9.3.** Conflicting requirements shall be resolved by mutual agreement between vendor, and the Owner's Engineer.
- R * 9.2 **Hydrostatic testing or flushing of lined vessels and piping** requires the Owner's Engineer approval. Agreement of the vendor is required for hydrostatic testing of chemically bonded refractory.
- R 9.3 **Previously dried linings** may be put in service at heat-up rates of up to 200°F (110°C) per hour unless hydrostatically tested. For equipment which has been hydrostatically tested since dryout, the lining shall be dried per the procedures for a new lining.
- R 9.4 Newly installed cement bonded, refractory linings shall be allowed to cure at 50 to 90°F (10-32°C) for 24 hours minimum before heating.

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- R **9.5** Control of the drying procedure shall be performed using **temperature measuring devices to monitor gas temperature throughout the lined area**. In all cases, these devices must be provided at the heat source and at the gas exits of the lined area. **Drying procedures for new linings** using internal heating shall take into account the following limitations:
- Initial gas temperature of the lined area shall be between 150-300°F (65-150°C) and raised to 400°F (204°C) at 50°F (30°C) per hour. All sections of the lining from gas inlet to outlet shall be held at 250°F (120°C) minimum to 400°F (200°C) maximum for 1-1/2 hours per inch of lining thickness.
 - Heating to the final dryout temperature: Control the gas temperature increase to no more than 100°F/hour (55°C/hour) at any time, including times of temperature loss due to firing interruptions. For dryouts performed prior to unit start, the final gas temperature at any section of the lining shall be the lesser of 3/4 of the design temperature or 950°F (510°C). This temperature shall be held for a minimum of 1-1/2 hours per inch of lining thickness. When dryout is performed as part of unit startup, no hold time is required and heating may proceed to final operating temperature at 100°F/hour (55°C/hour).
 - If the requirements of Subpar. b above cannot be met** for dryouts performed prior to unit startup, the lining shall be considered dry when outside metal shell temperature has been held at 175°F (80°C) for 6 hours. For processes requiring complete lining dryout, shell temperature shall be held at 220°F (105°C) for 6 hours.
 - If external insulation is installed to promote dryout, metal shell temperature during dryout shall not exceed 250°F (120°C).
 - The cooling rate shall not exceed 100°F per hour (55°C per hour).

CHEMICAL SETTING REFRACTORIES (TYPES 2A AND 2H)

- R **9.6** **Air-setting, Type 2a chemically bonded refractory** (phosphate bonded) shall be installed and air cured uncovered for 24 hours at ambient conditions of 50-90°F (10-32°C). Water spray onto the chemical setting castable is prohibited.
- R *** 9.7** After installing **heat-setting, Type 2h refractories**, the new linings shall be held for 72 hours minimum at ambient conditions of 50-90°F (10-32°C). During this 72 hour period, no water shall come in contact with the linings. Type 2h linings shall not be hammer tested or mechanically disturbed since they do not harden until after heat curing. Any transport of lined equipment before firing shall be subject to approval of the Owner's Engineer.
- R **9.8** **Types 2a and 2h phosphate bonded refractories (applied to cyclones etc.) shall be "heated" (including metal shell)** per the following procedure:
- The temperature increase to 400°F (204°C) shall be at a rate of 50°F (30°C) per hour.
 - The temperature shall be raised to 700°F (370°C) at a rate of 100°F (55°C) per hour, and held at 700°F (370°C) for at least one hour, or continued on heating to a higher temperature if warranted by the dryout of other types of refractory within the same dryout heating.
 - The use of steam is prohibited for initial heating of Type 2h linings until they have been exposed to 700°F (370°C) minimum throughout their full thickness. All Type 2h linings shall be "heat soaked" per **Par. 9.8** within 21 days of application.

REPAIRED AREAS IN OLD OR PREVIOUSLY DRIED OUT LININGS

- R **9.9** **Patched areas in old or previously dried out linings, no larger than 5 sq ft (0.46 m²)**, may be put into service after initial cure without dryout.
- R **9.10** **Patched areas larger than 5 sq ft (0.46 m²)** shall be dried out after initial cure by limiting heatup rate to no more than 100°F per hour (55°C per hour) until the gas temperature in the vicinity of the repair reaches 400°F (204°C). This temperature shall be held for 1-1/2 hours for each inch (25 mm) of lining thickness after which time normal unit startup heating can continue. Local heating devices, such as electric heating elements utilized for stress relieving, may be used to complete the initial 400°F (204°C) hold in a separate localized heating prior to startup in order to facilitate normal startup heating in the unit. In this case, cooling rate shall not exceed 100°F per hour (55°C per hour) following the localized heating.
- R **9.11** **Major refractory replacement** involving areas larger than 30 sq ft (3 m²), or summed areas exceeding 20 percent of the total lining installation, shall be cured and dried per the procedures for a new lining.

- R **9.12 Patched areas of phosphate bonded refractories**, regardless of size, shall be "heat-soaked" per the procedures for a new lining.

ADDITIONAL REQUIREMENTS FOR FREEZING CLIMATES

- R *** 9.13 Freezing climates (Climatic Zones B, C, and D)**. Where it is anticipated that a delay will occur between wet curing/air drying stages and heating to final dryout temperature, and freeze-thaw conditions can occur, the lining, except Type 2h, may be allowed to freeze. However, the following steps must be taken:
- The lining shall be air dried after curing, at a temperature greater than 60°F (16°C), for 24 to 48 hours.
 - All openings shall be sealed to prevent the accumulation of superficial water on the lining.
 - The full thickness of the lining shall be raised to 60°F (16°C) before the heating to final dryout temperature is started.
- R **9.14 Type 2h refractories** shall be installed, held at controlled temperatures for 72 hours and heat soaked per **Pars. 9.7** and **9.8** before exposure to the freezing climates of **Par 9.13** is permitted.

INSPECTION AND TESTING

- R **10.1 All test specimen preparation and testing** (including sampling) conducted by the Installation Contractor shall be **witnessed by the Inspector**. Inspection of installed linings shall also be performed by the Inspector. All materials, applicators and equipment shall be satisfactorily qualified prior to lining installation in actual equipment.
- R *** 10.2 All refractories to be installed by gunning, casting or hand packing shall be tested to comply with Table 2A/B property requirements**. Every refractory shall be applied within 4 months of initial acceptance tests or within 3 months of each succeeding qualification test per the procedures herein. This testing shall be arranged by the Installation Contractor in either an independent lab or at the castable manufacturer's plant. The Installation Contractor shall direct testing to assure that the mix water contents, ambient temperature, mix temperature, etc., used provide applicable assurance for his installation quality. The Installation Contractor shall report results to the Owner's Engineer prior to lining installation. Testing shall be subject to spot checks by the Inspector or Owner's Engineer.
- R **10.3** Satisfactory testing of "as-installed" samples shall requalify the batch for an additional 3 months.
- R **10.4 Records shall be kept for positive identification** of refractory type, batch, pallet sampled and water ratios used. Samples shall be taken in chronological order to monitor the production schedule. Where a shipment of one type refractory includes different batches (as designated by bag numbering, separate grouping, or other manner), samples, specimens, and test results shall be kept separate for each batch.
- R **10.5** Sample test results shall meet the requirements in **Table 2A/B**. In the event a sample fails to meet these requirements, the production quantity represented shall be rejected.
- Note:** If test results are within 10% of the acceptable values, the vendor may propose a retesting program for the rejected batch or production run to the Purchaser for approval by the Installation Contractor.
- R **10.6 Additional qualification tests are required for all Type 2h refractories**. Refractory samples shall be tested for ASTM C181 workability. In addition, erosion plate specimens shall be sectioned and inspected after erosion tests are completed. Production quantities represented shall be considered acceptable when the following requirements are met:
- Measured workability indices** are within the manufacturer's recommended range.
 - No significant Lamination or Bloating defects** > 1 in (25 mm) parallel to the eroded face or > 1/16 in. (1.5 mm) perpendicular to the eroded face) are visible in the specimen cross-section.
- R **10.7 For gunned installations, a test panel shall be prepared by each nozzleman** for each type of castable material to be applied. Satisfactory results of the examinations and tests will serve to qualify the mixing and installation procedures, and the nozzlemen.
- R *** 10.8 For cast installations, a mockup simulating the most difficult shape** of the installation shall be made subject to the Owner's Engineer review and approval. The test shall demonstrate that material flow and the proposed vibrator/forming setup are capable of achieving a homogeneous lining structure without voids or entrapped air using the water ratio specified. Test specimens (number and type **per Par. 10.10**) shall be prepared by casting the sample molds under mockup conditions and tested for compliance to **Table 2A/B** requirements.