PIP RFTM1000
Monolithic Refractory Installation Qualification, Inspection, and Testing
PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

In an effort to minimize the cost of process industry facilities, this Practice has been prepared from the technical requirements in the existing standards of major industrial users, contractors, or standards organizations. By harmonizing these technical requirements into a single set of Practices, administrative, application, and engineering costs to both the purchaser and the manufacturer should be reduced. While this Practice is expected to incorporate the majority of requirements of most users, individual applications may involve requirements that will be appended to and take precedence over this Practice. Determinations concerning fitness for purpose and particular matters or application of the Practice to particular project or engineering situations should not be made solely on information contained in these materials. The use of trade names from time to time should not be viewed as an expression of preference but rather recognized as normal usage in the trade. Other brands having the same specifications are equally correct and may be substituted for those named. All Practices or guidelines are intended to be consistent with applicable laws and regulations including OSHA requirements. To the extent these Practices or guidelines should conflict with OSHA or other applicable laws or regulations, such laws or regulations must be followed. Consult an appropriate professional before applying or acting on any material contained in or suggested by the Practice.

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# PIP RFTM1000
Monolithic Refractory Installation Qualification, Inspection, and Testing

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**Data Form**  
RFTM1000-F – Inspection Hold Point and Sign-Off Schedule
1. **Introduction**

1.1 **Purpose**

This Practice provides requirements for quality control and quality assurance for the installation of monolithic refractory lining materials.

1.2 **Scope**

This Practice covers the general requirements for testing and inspecting of monolithic refractory linings. Test and inspection methods include installer prequalification, production sample testing, in-progress installation inspection, and final inspection of the completed lining.

2. **References**

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 **Process Industry Practices (PIP)**

- PIP CTSL1000 – Application of Internal Coatings
- PIP RFIA1000 – Refractory Anchor and Accessory Installation Details (under development)
- PIP RFSA1000 – Refractory Anchor and Accessory Material Specification (under development)
- PIP RFSM1000 – Monolithic Refractory Material Specification
- PIP RFSM2000 – Monolithic Refractory Installation Specification
- PIP RFTA1000 – Refractory Anchor and Accessory Installation Qualification, Inspection, and Testing

2.2 **Industry Codes and Standards**

- American Petroleum Institute (API)
- American Society for Testing and Materials (ASTM)

3. **Definitions**

With the exception of the terms listed in this section, terms used in this Practice are defined in accordance with *API Standard 936* (Section 3 and Appendix A) and *ASTM C71*. If a definition as used in this Practice differs from the one listed in the referenced documents, the modified definition is included in the following listing:

*installer:* Party responsible for installing the refractory material
installer’s inspector: Installer’s authorized representative, responsible for the quality control of all materials, installations, and workmanship provided by the installer, and any of the installer’s subcontractors or vendors

owner: Party who owns the facility wherein the refractory lined equipment will be used

purchaser: Party who awards the contract to the installer. The purchaser may be the owner or the owner’s authorized agent.

purchaser’s inspector: Purchaser’s authorized representative with authority to act in the interest of, and on behalf of, the purchaser in all quality assurance matters. The inspector shall be experienced in the evaluation of monolithic installation techniques and completed linings.

4. Requirements

4.1 General

4.1.1 Conflicts, Exceptions, Deviations, and Substitutions

4.1.1.1 All conflicts between the referenced documents and this Practice shall be submitted in writing to the purchaser for clarification and resolution before proceeding.

4.1.1.2 All exceptions, deviations, and substitutions to the requirements of this Practice and in referenced documents shall be approved by purchaser.

4.1.2 Regulations and Material Safety Data Sheets (MSDS)

4.1.2.1 Refractory materials shall be in accordance with all applicable federal, state, and local codes and regulations on storage, handling, safety, and environmental requirements.

4.1.2.2 The latest issue of the refractory manufacturer’s product data sheets, application instructions, and MSDS shall be available at the installation site and complied with during the installation of monolithic refractory linings.

4.1.3 Notification

Purchaser’s inspector shall be given adequate notice before the start of all work and hold points, so that the inspector can witness the work.

4.2 Monolithic Refractory Lining Anchors

The qualification of anchor welders, selection of anchors, anchor installation, anchor testing, and inspection shall be in accordance with PIP RFIA1000, PIP RFSA1000, and PIP RFTA1000.

4.3 Materials Prequalification

All monolithic refractories to be installed shall be certified by prequalification testing in accordance with PIP RFSM1000.
4.4 Surface Preparation and Coating

4.4.1 Surface preparation for the installation of refractory anchors shall be in accordance with PIP RFIA1000.

4.4.2 Surface preparation for the installation of refractories shall be in accordance with PIP RFSM2000.

4.4.3 All inspections and tests shall be performed that are necessary to assure that surface preparation for coatings and coating application are in accordance with PIP CTSL1000.

4.5 Installer Prequalification

4.5.1 General

4.5.1.1 Before installation and using the materials and equipment to be used for the installation work, it shall be demonstrated that the installation personnel are capable of meeting the specified quality standards.

4.5.1.2 The demonstration shall be performed by simulating the installation work and sampling and testing the applied materials in accordance with this Practice, PIP RFSM1000, and PIP RFSM2000.

4.5.1.3 The refractory installation work shall not be started until installer prequalification tests have been completed and approved by purchaser.

4.5.1.4 Scheduling of personnel for prequalification testing shall be performed in a manner that does not interfere with the refractory installation schedule.

4.5.1.5 The purchaser and purchaser’s inspector shall be notified of the time and location of all work and prequalification testing.

4.5.1.6 Test samples shall be identified and prepared for testing by the approved testing laboratory. The test results shall be documented.

4.5.2 Pneumatic Installation

4.5.2.1 Panel Configuration

1. A 900-mm (3-foot) by 900-mm (3-foot) by 100-mm (4-inch) deep test panel shall be prepared using plywood and sealed with a parting agent to prevent castable bonding.

2. Anchors identical to those to be used in the installation work shall be attached to the panel inside surface with bolts through to the backside. The anchor pattern shall duplicate that of the specification requirement for each material tested.

3. The panel shall be designed to permit the removal of the sides and back without damaging the interior-gunnited lining.
4.5.2.2 Test

1. The panel shall be supported overhead at a 45-degree angle to imitate gunning overhead.

2. Each prequalifying nozzleman shall gun one panel for each material to be installed. The gunning shall be observed for technique by purchaser’s inspector.

3. After completing the panel, the nozzleman shall cutback the surface as required in accordance with the installation specification, and apply the curing compound. The cutback and curing compound application shall be observed for technique by purchaser’s inspector.

4. The panel shall be permitted to cure for 24 hours before inspection.

4.5.2.3 Crew Coordination

1. During gunniting, the gun nozzle shall be situated so that the gun operator cannot observe the nozzleman.

2. A minimum of 45 m (150 feet) of gunite hose shall be used for the test panel gunning.

3. The gun operator and nozzleman shall be connected by headphones or radio to duplicate actual field conditions.

4. The purchaser’s inspector shall observe and note coordination of the effort between the nozzleman and gun operator.

4.5.2.4 Examination

1. The panels shall be stripped after 24 hours.

2. The purchaser’s inspector shall determine bulk green density by weighing the unbroken sample and dividing the weight by the volume determined from the sample dimensions.

3. After determining the bulk green density, the panels shall be broken apart by hammer blows to check for voids, laminations, entrapped rebound, poor consolidation, and shadowed anchors.

4. The purchaser’s inspector shall determine the acceptability of the nozzleman and crew based on observations of technique, checking the broken panel for defects, and the panel bulk green density, which shall be equal to the refractory manufacturer’s values plus or minus 5 percent based on gunned samples.
4.5.3 **Casting, Vibration Casting, and Self-Flow Installation**

### 4.5.3.1 Mock-Up Configurations

1. A mock-up shall be prepared that simulates the most difficult piece of the installation work or in accordance with the size and shape agreed in the refractory installation contract.

2. For casting installations, the mock-ups shall be as follows:
   a. The casting mock-up shall simulate forming and placement procedures, anchor placement, installation of refractory around nozzle protrusions, and fit-up tolerances.
   b. The mock-up shall be the same thickness and the same anchor system as the in situ lining.
   c. The anchor system shall be attached to the test panel such that the form or backing plate can be removed and the installed refractory examined from both sides.
   d. The backing plate shall be coated with a parting agent to permit easier removal from the applied refractory.

3. For vibration casting installations, the mock-ups shall demonstrate the adequacy of vibration equipment and equipment attachment configurations.

4. For self-flow (i.e., pouring and pump casting) installations, only vibration to be used in the actual installation shall be permitted in the mock-up.

### 4.5.3.2 Tests and Examination

1. Test Specimens
   a. Test specimens shall be prepared from materials sampled from the mixes prepared for casting in the mock-up.
   b. The test specimens shall be formed in molds using the same level of agitation as the mock-up.
   c. The test specimens shall be tested in accordance with *PIP RFSM1000* for the following characteristics:
      1. Density
      2. Permanent linear change
      3. Cold-crushing strength
      4. Abrasion resistance (for mild, severe and extreme abrasive services)

2. Mock-Up Casting
   a. Refractory cast in the mock-up shall be air cured for 24 hours and then stripped of forms for visual inspection.
b. The applied lining shall be homogeneous and free of segregation and shall meet the tolerances specified in the contract documents.

3. Satisfactory examination and test results, based upon the most stringent of the following requirements, shall be used to qualify the mixing and installation procedures and determine mix water levels:
   a. *PIP RFSM1000*, Appendix A
   b. The manufacturer’s compliance data sheet
   c. Other values agreed with purchaser

### 4.5.4 Thin Erosion-Resistant Refractory Installation

#### 4.5.4.1 Panel Configuration

1. A 300-mm (12-inch) by 300-mm (12-inch) test panel shall be lined by each applicator. Panel depth shall be the same as the lining to be installed.

2. The anchoring system (i.e., anchor type and spacing) shall be the same as in the in situ installation.

3. The anchor system shall be attached to a backing plate such that the backing plate can be removed and the applied refractory lining examined from the backside.

4. The backing plate shall be coated with a parting agent to permit easier removal from the applied refractory.

#### 4.5.4.2 Test and Examination

1. Test Specimens
   a. Test specimens shall be prepared from materials sampled from the mixes applied to the panels.
   b. The test specimens shall be formed in molds using the same placement method as for the test panel.
   c. Specimens shall be tested for density, permanent linear change, and abrasion resistance in accordance with *PIP RFSM1000*.

2. Test Panel
   a. Mixing, application techniques (e.g., pneumatic ramming or handpacking) and orientation (e.g., sidewall or overhead) shall be the same as the designated in situ installation method.
   b. After refractory placement, the test panels shall be permitted to air cure for 24 hours.

3. Satisfactory examination and test results, based upon the most stringent of the following requirements shall be used to qualify the mixing and installation procedures and determine mix water levels if applicable:
   a. *PIP RFSM1000*, Appendix A
b. The manufacturer’s compliance data sheet
c. Other values agreed with purchaser

4.5.5 Rammed Plastic Lining Installation

4.5.5.1 Panel Configuration
1. A 600-mm (24-inch) by 300-mm (12-inch) test panel shall be pneumatically ram packed by each applicator.
2. The panel shall be the same thickness and the same anchor system as the lining to be installed.
3. The anchor system shall be attached to the back of the test panel such that the backing plate can be removed and the installed refractory examined from the backside.
4. The backing plate shall be coated with a parting agent to permit easier removal from the applied refractory.

4.5.5.2 Test and Examination
1. The test panel refractory shall be installed by pneumatic ramming in a manner simulating the designated in situ installation method.
2. The test panel shall be placed in the same position as the designated in situ installation (e.g., down hand, vertical, or overhead position).
3. After refractory installation is complete, the test panel backing plate shall be removed, the installed refractory examined for consolidation and voids, and then broken apart to determine consistency.
4. If the material prequalification results and applied refractory workability is approved by purchaser’s inspector, additional test specimens or testing is not required.
5. Satisfactory results shall serve to qualify the equipment, techniques, and application.

4.5.6 Handpacked Castable Lining Installation

4.5.6.1 Panel Configuration
1. A test panel, 300 mm (12 inches) by 300 mm (12 inches) by the thickness of the lining to be installed, shall be handpacked by each applicator.
2. The anchor system for the test panel shall be identical to that used for the lining to be installed.
3. The back plate of the test panel shall be coated with a parting agent to permit easier removal.

4.5.6.2 Test and Examination
1. The castable shall be mixed to a consistency to permit handpacking.
2. The test panel shall be placed in the same position as the in situ installation (e.g., down hand, vertical, or overhead).
3. Test samples of the handpacked castable shall not be required if the castable has met the prequalification requirements of *PIP RFSM1000*, and the area installed is less than 0.25 square meters (2.5 square feet).

4. After installation in the test panel, the castable shall be coated with a curing compound and permitted to air cure for 24 hours.

5. After the 24-hour air cure, the back plate of the test panel shall be removed and the castable visually examined for voids and proper consolidation.

6. Satisfactory results shall serve to qualify the equipment, techniques, and application.

### 4.6 Production Samples

#### 4.6.1 General

4.6.1.1 Production samples shall be taken in accordance with this Practice during the installation process.

4.6.1.2 Production sample testing shall be in accordance with *PIP RFSM1000*.

4.6.1.3 Testing results shall be in accordance with the most stringent of the following requirements:

    a. *PIP RFSM1000*
    b. The manufacturer’s compliance data sheet
    c. Other values agreed upon by the purchaser

4.6.1.4 Variation of testing results shall be permitted in accordance with *API Standard 936*, Table 3.

#### 4.6.2 Sample Numbering

4.6.2.1 The production samples shall be given a tag number with a “P” prefix.

4.6.2.2 The purchaser has the right and responsibility to take a test sample “for cause” and shall number these samples with a “T” series number.

4.6.2.3 Each series of numbers (i.e., P and T) shall be consecutive for the job regardless of the location in the unit or the type of installation method.

#### 4.6.3 Production Sample Testing Report

4.6.3.1 A Production Sample Testing Report shall be prepared for each material type. The report shall record and track the data from the production tests.

4.6.3.2 The Production Sample Testing Report shall be used for recording the following data for material placed each day:

    a. Material name
    b. Method of installation
    c. Production number – either P or T series
    d. Pallet number – marked on pallet by refractory manufacturer
e. Date and time sample taken
f. Location description—sample map referencing locations of samples and installation points
g. Location code—agreed layout of lined areas
h. Installer
i. Weight percent stainless steel needles (fibers) used in the mix.
j. Weight percent water used in the mix
k. Water temperature
l. Shell temperature
m. Material temperature
n. Mix temperature
o. Ambient temperature
p. Unusual weather condition

4.6.4 Preparation and Test Frequency of Production Samples
4.6.4.1 Dense Gunned Refractory Sampling Procedure for Type 5 through Type 11 (Reference PIP RFSM1000, Appendix A)

1. Sample Collection Basket
   a. A wire basket 300 mm by 300 mm by 100 mm (12 inches by 12 inches by 4 inches) made of 13-mm (1/2-inch) square wire mesh shall be hung on the shell in the area to be gunned.
   b. Refractory shall be gunned into the basket during normal refractory placement using the same methods as for the refractory placement.
   c. The sample basket refractory shall be removed from the shell, coated with curing compound, remain inside the unit, protected from damage and rebound materials, and left undisturbed for a 24-hour air cure.
   d. From the sample basket, the following sample configurations shall be extracted:
      (1) Three 50-mm (2-inch) cubes for cold-crushing strength testing.
      (2) One 230-mm by 50-mm by 50-mm (9-inch by 2-inch by 2-inch) bar for permanent linear change testing.
      (3) Two 115-mm by 115-mm by 25-mm (4.5-inch by 4.5-inch by 1-inch) plate samples for density and abrasion resistance testing.
2. Sampling Frequency
   a. During the first week of refractory installation, gun test samples at the rate of one sample per item, ring or location, per day, per material, per mixing station, per nozzleman.
   b. If acceptable test results are obtained during the first week, the test sampling frequency may be reduced to three tests per week, per nozzleman, as agreed with purchaser’s inspector.

3. Sample Test Failures
   a. A failed test result shall require that the testing frequency specified in Section 4.6.4.1.2.a be restarted.
   b. If during the course of the installation, two samples of a particular material fail, Section 4.6.4.1.2.a shall be followed for that material for the remaining installation.

4.6.4.2 Insulating Gunned Refractory Sampling Procedure for Type 1 through Type 4 (Reference PIP RFSM1000, Appendix A)

1. Sample Collection Basket
   a. A wire basket 300 mm by 300 mm by 100 mm (12 inches by 12 inches by 4 inches) made of 13-mm (1/2-inch) square wire mesh shall be hung on the shell in the area to be gunned.
   b. Refractory shall be gunned into the basket during normal refractory placement using the same methods as for the refractory placement.
   c. The sample basket refractory shall be removed from the shell, coated with curing compound, remain inside the unit protected from rebound and damage, and left undisturbed for a 24-hour air cure.
   d. From the sample basket, the following sample configurations shall be extracted:
      (1) Three 50-mm (2-inch) cubes for cold-crushing strength testing.
      (2) One 230-mm by 50-mm by 50-mm (9-inch by 2-inch by 2-inch) bar for permanent linear change and density testing.

2. Sampling Frequency
   a. During the first week of refractory installation, gun test samples at the rate of one sample per day, per material, per mixing station, per nozzleman.
   b. If acceptable test results are obtained during the first week, the test sampling frequency may be reduced to one test per week, per nozzleman, as agreed with purchaser’s inspector.
3. Sample Test Failures
   a. A failed test result shall require that the testing frequency specified in Section 4.6.4.2.2.a be restarted.
   b. If during the course of the installation, two samples of a particular material fail, Section 4.6.4.2.2.a shall be followed for that material for the remaining installation.

4.6.4.3 Cast, Self-Flow, Thin Erosion-Resistant Castable, and Vibration Cast Mix Sampling Procedure

1. Sample Sizes
   a. For the dense refractory castable samples, a sample of adequate size shall be prepared, using the same technique used for installation, for the extraction of the following sample configurations:
      (1) Three 50-mm (2-inch) cubes for cold-crushing strength testing.
      (2) One 230-mm by 50-mm by 50-mm (9-inch by 2-inch by 2-inch) bar for permanent linear change testing.
      (3) Two 115-mm by 115-mm by 25-mm (4.5-inch by 4.5-inch by 1-inch) plates for density and abrasion resistance testing.
   b. Abrasion-resistance samples are not required for cast-insulating castables, and the density shall be determined from the permanent linear change bars.
   c. Alternatively, samples may be produced in molds the same size as the required shapes to be tested.

2. Sampling Frequency
   Samples shall be produced at the rate of one sample per item or location, per day, per mixing station, per material, per crew.

4.6.4.4 Thin Erosion-Resistant Plastic Refractory Sampling Procedure

1. Sample Size
   a. Samples shall be two 115-mm by 115-mm by 25-mm (4.5-inch by 4.5-inch by 1-inch) plates for abrasion resistance testing.
   b. At a random time during the installation operation, as determined by the purchaser’s inspector, a sample of the plastic materials shall be taken.

2. Sampling Frequency
   Samples shall be taken at the rate of one sample per material, per shift, per installer.
4.6.5 Procedure for Nonconforming Production Test

4.6.5.1 Production sample retesting shall be in accordance with PIP RFSM1000.

4.6.5.2 If sample testing indicates that the properties are not in accordance with Section 4.6.1.3, the retest procedure shall be as follows:
   a. Additional test coupons shall be cut from the nonconforming sample.
   b. The additional test coupons shall be retested for the nonconforming physical properties.
   c. If the retest passes the required criteria, the lining shall be deemed acceptable.
   d. If the retest of the sample fails, the area from which the questionable sample was taken shall be determined. The area identified shall have one sample cut out and submitted for retesting for the nonconforming properties.
   e. If the results are outside the limits of acceptability, the lining section shall be removed and replaced in accordance with PIP RFSM2000.

4.7 Inspection

4.7.1 Hold Points

4.7.1.1 During refractory installation, the refractory shall be inspected at each of the hold points listed on purchaser’s PIP RFTM1000-F Inspection Hold Point and Sign-Off Schedule.

4.7.1.2 In-progress inspection of the refractory installation shall confirm that refractory, anchor system and layout, and lining design details including any required coatings are in accordance with the contract documents.

   Comments: “In-progress” refers to continuous monitoring at regular intervals throughout the duration of the work.

4.7.1.3 Work shall not progress until all parties listed on purchaser’s PIP RFTM1000-F have signed off at each hold point in the order as shown on the form.

4.7.1.4 Repairs, as indicated during the inspection, shall be completed in accordance with PIP RFSM2000.

4.7.2 Hammer Testing

4.7.2.1 Except for the following refractory types, installed castable refractory shall be hammer tested after curing of each layer:
   a. Heat-setting, thin, erosion-resistant linings
   b. Ultralightweight, insulating castable. See PIP RFSM1000, Appendix A, Type 1).

4.7.2.2 Hammer testing shall be performed using the ball end of a 225-g (8-ounce) ball-peen hammer.

4.7.2.3 Floors or bottom heads shall be tested on 900-mm (3-foot) centers maximum.
4.7.2.4 Material installed in the vertical walls or overhead surfaces shall be tested on 450-mm (18-inch) centers maximum.

4.7.2.5 Areas around nozzles, corners, refractory expansion joints, or changes in direction shall be tested on 150-mm (6-inch) centers maximum.

4.7.2.6 Refractory areas ringing hollow during hammer testing shall be removed the full depth of the refractory layer, and repaired in accordance with PIP RFSM2000.

4.7.3 Cracking/Visual

4.7.3.1 The lining shall be inspected after thermal drying for size and distribution of cracking. All surface voids, inclusions, and visible cracks shall be investigated.

4.7.3.2 The distribution of cracking shall be such that no section can dislodge during operation.

4.7.3.3 Indications of multiple voids or cracks in a small area shall be further inspected or removed.

4.7.3.4 Spalled or unbonded material shall be repaired.

4.7.3.5 Defects greater than 3 mm (1/8 inch) wide, 300 mm (12 inches) long, and one-half of layer thickness shall be repaired using a repair procedure submitted to and accepted by the purchaser.

4.7.3.6 Any crack wider than 6 mm (1/4 inch) shall be repaired.

4.7.3.7 Any void or inclusion that is greater than either of the following dimensions shall be repaired:
   a. 25 mm (1 inch) in any dimension
   b. One-fourth of the layer thickness

4.7.3.8 Repairs shall be performed in accordance with the requirements of PIP RFSM2000.

4.7.4 Set Time

Material that has not achieved initial set within the shorter of 24 hours or the refractory manufacturer’s recommended set time shall be completely removed.
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