PIP RFSM1000
Monolithic Refractory Material Specification
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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1. **Scope**

This Practice describes the requirements for certification and prequalification of the refractory materials used to construct monolithic refractory linings in process equipment and piping. It provides a basis for selection, purchase, and quality control of refractory materials. Included are the material property, testing, documentation, storage, and shipping requirements for industrial refractory lining materials used to construct monolithic refractory linings in process equipment and piping. These materials can be installed by gunning, casting, pumping, or hand packing as specified.

2. **References**

Applicable parts of the following industry codes and standards 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.

**Industry Codes and Standards**

- **American Petroleum Institute (API)**
  - API Standard 560 – *Fired Heaters for General Refinery Service*
  - API Standard 936 – *Refractory Installation Quality Control – Inspection and Testing Monolithic Refractory Linings and Materials*

- **ASTM International (ASTM)**
  - ASTM C24 - *Standard Test Method for Pyrometric Cone Equivalent (PCE) of Fireclay and High-Alumina Refractory Materials*
  - ASTM C71 – *Standard Terminology Relating to Refractories*
  - ASTM C113 – *Standard Test Method for Reheat Change of Refractory Brick*
  - ASTM C133 – *Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories*
  - ASTM C134 – *Standard Test Methods for Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick*
  - ASTM C179 – *Standard Test Method for Drying and Firing Linear Change of Refractory Plastic and Ramming Mix Specimens*
  - ASTM C201 – *Standard Test Method for Thermal Conductivity of Refractories*
  - ASTM C704 – *Standard Test Method for Abrasion Resistance of Refractory Materials at Room Temperature*
  - ASTM C865 – *Standard Practice for Firing Refractory Concrete Specimens*
  - ASTM E1172 – *Standard Practice for Describing and Specifying a Wavelength-Dispersive X-Ray Spectrometer*
3. **Definitions**

With the exception of the terms listed in this section, terms used in this Practice are defined in accordance with ASTM C71 and API Standard 936 (Section 3 and Appendix A). 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.

**abrasion resistant refractory**: Refractory resistant to physical abrasion by impinging particles (e.g., catalyst). Abrasion resistant refractory is classified on the basis of volume loss (in accordance with ASTM C704-S1) as follows:

- **Mild Abrasion Resistant**: greater than 8-15 cm³
- **Severe Abrasion Resistant**: greater than 4-8 cm³
- **Extreme Abrasion Resistant**: 4 cm³ or less

**certification**: Determination that an industrial refractory product meets all of the requirements to be classified as a specific type of refractory in accordance with Appendix A

**compliance data sheet**: Data sheet provided by the manufacturer listing physical and chemical property values that the manufacturer certifies or guarantees to be met by each sample tested using the specified procedure in Appendix A. For example, see API Standard 936, Annex B, for further requirements and a sample of compliance data sheet.

**continuous use temperature limit**: A temperature provided by the manufacturer for long-term use of the refractory lining, based upon a defined amount of refractoriness of the specified material as measured by a pyrometric cone equivalent (PCE) test per ASTM C24

**critical service**: Service in which the presence and proper functioning of the refractory is vital to the continued operation of the process or the maintenance of safe working conditions or environment

**green density**: Bulk density of refractory castable, usually a gunned sample, measured after initial curing but before any heat dryout including the oven air drying at 110°C (230°F)

**industrial refractory**: Packaged and pre-blended refractory product offered with material data sheets, installation information, Safety Data Sheets (SDS), and other safety and handling information

**lot**: Portions of a batch included in one order and shipped together

**manufacturer**: Party who formulates, blends, and packages the refractory material

**material prequalification**: Determination that the as-manufactured refractory material to be shipped to the purchaser meets all of the requirements for the specified type of refractory in accordance with Appendix A, the manufacturer’s compliance data sheet and other more stringent values agreed upon by the manufacturer and the purchaser

**monolithic refractory**: A blend of aggregate and a bonding agent (e.g., cement) which may be supplied in a dry form that, when mixed with water or other specified fluid, forms a fluid mixture for installation at the site. Alternatively, refractory may be supplied in a solid form as a pliable or plastic material. After curing and dryout, refractory forms a solid lining conforming to the geometry of the lined item.
monolithic refractory lining: Refractory installed in place, forming a continuous, solid lining of the desired shape and thickness, and placed over a surface for protection from the surrounding atmosphere. The lining protects the surface from abrasion or acts as an insulator, shielding the surface from excess heat or both.

noncritical service: Service in which the presence and proper functioning of the refractory is not vital to the continued operation of the process or maintenance of safe working conditions or environment

normal duty: Service in which the primary property of interest for the refractory is insulating or resistance to heat transfer. A limited amount of abrasion resistance may be necessary, but severe physical abuse is not expected.

organic dryout fiber – Thin organic fibers (e.g., polypropylene, polyethylene) added to the dry mix castable or plastic refractory that are intended to burn out as the refractory is heat dried. The resulting interconnected small capillary channels aid the escape of steam generated in the lining’s interior as heat dryout progresses, preventing a buildup of internal steam pressure.

owner: Party who owns the facility wherein the refractory lining is to be used

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

refractory: A non-metallic, ceramic material that is unresponsive to the expected surrounding atmosphere. It has properties of thermal resistance to heat and thermal shock, physical/mechanical resistance to pressure, tensile force, friction and impact including abrasion, and chemical resistance to gas, liquids including many acids, melts and slags

severe duty: Service that is highly abrasive and/or an aggressive chemical environment

specimen: Individual piece of refractory to be tested. May be formed or cut to the required size and shape.

supplier: Party responsible for providing the packaged refractory to the installation site. The supplier may or may not be the same as the manufacturer.

4. Requirements

4.1 Data Submittals

4.1.1 Conflicts, Exceptions, and Deviations

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 the purchaser.

4.1.2 Regulations and Safety Data Sheets (SDS)

4.1.2.1 Refractory materials shall be in accordance with all applicable federal, state, and local codes and regulations for storage, handling, safety, and environmental requirements.
4.1.2.2 The latest issue of the applicable manufacturer’s SDS shall be provided for each product and to each installation site and complied with during the installation of monolithic refractory linings.

4.1.2.3 The SDS shall include all hazards and cautions associated with the handling, storage, and use of the product, and the appropriate counter measures to be taken to prevent and react to any event of personnel harm (short-term or long-term) that may occur.

4.1.3 Candidate Material

The manufacturer of the monolithic refractory material shall provide a refractory performance record of successful service in the same or very similar application for evaluation by the purchaser.

Comment: Adherence to technical data is not sufficient to ensure adequate refractory performance in the field. Technical data is a means of characterizing a candidate material as being (or not being) a reasonable choice for a given application.

4.1.4 Material Properties Information

4.1.4.1 The latest issue of the applicable manufacturer’s product data sheets and compliance data sheets shall be provided for each product and to each installation site.

4.1.4.2 If alternate product property values are agreed upon by the manufacturer and the purchaser, the alternate values shall be shown as an addendum to the compliance data sheets for the specific project.

4.1.4.3 Bulk green density values shall be provided for materials to be installed by pneumatic gunning. The density shall be determined from a gunned sample.

4.1.4.4 The results of material prequalification testing shall be provided, including the optimal water content if installation is to be by casting. The test results shall be approved by the purchaser before shipment of the product.

4.1.4.5 The presence of organic dryout fibers in any refractory product shall be clearly and prominently indicated on the manufacturer’s property data sheets and product packaging.

4.1.4.6 Where applicable, the requirements of API Standard 560 shall be met.

4.1.4.7 The monolithic refractory’s continuous use temperature limit shall be greater than the design hot face or interface temperature.

4.1.4.8 The design hot face temperature shall be the calculated hot face temperature plus 165°C (300°F).

4.1.4.9 The design interface temperature shall be the calculated interface temperature plus 165°C (300°F).

4.1.5 Mixing and Placement Instructions

4.1.5.1 Complete, step-by-step, instructions shall be provided for mixing all of the refractory components and water (or other specified fluid, e.g., phosphoric acid), including the type of mixer, mixing time and optimal total water (fluid) content.
4.1.5.2 Special placement instructions and/or cautions beyond those normally used for the chosen method of refractory placement, where warranted, shall be provided.

4.1.6 Water Curves

4.1.6.1 Water curves shall be provided showing the effect of variations in the water content of the refractory upon the as-installed refractory properties.

4.1.6.2 The variations shall be both above and below the recommended mixing water content for each material and method of installation.

4.1.6.3 The range of water content shall be plus or minus 10 percent of the optimal amount or an alternate range specified by the manufacturer.

4.1.6.4 Properties at all water contents within the specified range shall be in accordance with the requirements of Appendix A and the manufacturer’s compliance data sheets or other values agreed with the purchaser.

4.1.7 Curing and Heat Dryout Schedules

4.1.7.1 Recommended curing and heat dryout schedules for each refractory material shall be provided.

4.1.7.2 For curing of hydraulic setting materials, the air-setting procedure shall be provided, including the means of moisture retention using curing compounds or other methods, temperature limitations, and the required hold time at ambient temperature.

4.1.7.3 For curing of plastic refractory materials, the air setting requirements (e.g., hold time and temperature), firing temperature, heat-up and cool-down rates, and hold times shall be provided.

4.1.7.4 The manufacturer’s heat dryout schedule shall specify hold temperatures (if required), minimum hold times at each temperature, maximum heating and cooling rates for each material and any other requirements pertaining to the proper heat drying of the material. If not provided by the manufacturer the heat dryout schedule shall be in accordance with API Standard 936, Section 10.

4.2 Refractory Properties

4.2.1 General

4.2.1.1 The monolithic refractory purchased for each installation site shall be of the type specified in the contract documents (e.g., purchaser’s specifications and drawings). The type shall be as defined in Appendix A.

4.2.1.2 Refractory materials shall be formulated for, and appropriate for, the method of installation specified in the contract documents. These materials shall not be used with another method of installation, unless approved by the purchaser.

4.2.1.3 All of the granular components shall be provided in a single premixed bag or other container. An acceptable exception is a specifically provided premeasured material added to optimize the mix for a different method of application.
4.2.1.4 If a fluid other than water (e.g., an activator) is to be mixed with the granular material, the manufacturer shall provide the fluid in a premeasured container.

4.2.1.5 Monolithic refractory materials shall not contain asbestos.

4.2.1.6 Monolithic refractory materials shall not contain Portland cement.

4.2.1.7 Except for plastic refractories (see Type 10 in Appendix A), the as-shipped refractory shall not contain metal reinforcing fibers.

*Comment:* Metal fibers shall only be added at the installation site as a part of the pre-installation mixing process.

4.2.1.8 If metal fibers are required in plastic refractories (see Type 10 in Appendix A), the fibers shall be well distributed throughout the as-shipped plastic refractory.

4.2.1.9 If approved by the purchaser, organic dryout fibers shall be permitted for dense refractories (see Type 4 through Type 11 in Appendix A).

   a. The fibers shall be provided in the as-shipped refractory.
   
   b. The fibers shall be randomly distributed throughout the refractory mix.
   
   c. The refractory containers shall be clearly marked that organic fibers are included in the product.

4.2.2 Certification

4.2.2.1 General

1. Refractory material shall be certified as complying with the requirements of one of the refractory types listed in Appendix A before being considered for installation in any equipment.

2. Certification shall include testing of refractory properties.

3. Testing methods, procedures and the resultant property values shall be in accordance with the requirements of Appendix A and, if more stringent, the manufacturer’s guaranteed values for the applicable monolithic refractory type.

4.2.2.2 Sampling

1. Samples shall be taken from randomly selected bags or containers of refractory material.

2. An entire, previously unopened bag of castable refractory material shall be mixed for the preparation of specimens for testing. Use of partial bags shall not be permitted.

3. Specimens for testing of plastic refractory material shall be obtained from an entire previously unopened box or container. Use of partial boxes or containers shall not be permitted.
4.2.2.3 Testing

1. The requirements of this section shall apply to the properties listed on the manufacturer’s compliance data sheets. All of the properties defined by Appendix A shall be used to evaluate candidate materials for a refractory type.

2. The specimen requirements (i.e., preparation, quantity, and shape) and testing for each property shall be in accordance with the ASTM test procedure listed in Appendix A, modified by API Standard 936 as noted.

3. Special forming, curing, or other techniques to enhance the test results shall not be permitted.

4. Testing shall include density, cold crushing strength, and permanent linear change.

5. For materials intended for severe duty service, abrasion resistance testing shall also be performed.

6. The test result values for each specimen making up the sample shall be in accordance with the requirements of Appendix A or, if more stringent, the manufacturer’s compliance data sheet.

7. The test result values for any specimen in the sample shall not differ from the average of the sample by more than plus or minus 20 percent of the average values.

8. The purchaser may accept manufacturer’s certified data or require additional tests for thermal conductivity, chemistry, etc., as necessary to determine that the refractory material meets process requirements.

4.2.3 Material Prequalification

4.2.3.1 General

1. The requirements of this section shall be used for prequalification of monolithic refractory material.

Comment: Prequalification testing is intended to determine if the product has been properly manufactured.

2. Each monolithic refractory product to be used shall have been certified in accordance with Section 4.2.2.

3. Material prequalification testing shall include pre-shipment testing by the manufacturer and retesting or requalification before use, if required (see Sections 4.2.4.1 and 4.2.4.2).

4. Before shipment from the manufacturer’s facility to the installation site, each lot, or portion thereof, of each refractory type shall be prequalified to be in accordance with the required test values.

5. Samples shall be tested at the manufacturer’s facility or, if specified by purchaser, at an independent laboratory approved by purchaser.
6. If purchaser chooses to witness the testing, the purchaser shall be notified of the time and place of the testing as specified in the contract documents. Notice shall be given far enough in advance of the testing so that the purchaser may arrange to be present.

7. Testing shall be performed far enough in advance that the material can be replaced without affecting the delivery schedule, should replacement be necessary.

4.2.3.2 Sampling

1. The first pallet of each lot of each material shall be tested.

2. For critical and severe duty services, samples shall be taken from every pallet of refractory material.

3. For normal duty services, samples shall be taken from every third pallet of each lot of refractory material.

4. For noncritical services, samples shall be taken from every fifth pallet of each lot of refractory.

5. All samples shall be taken from the material to be shipped, i.e., they shall not come from a portion of the batch not included in the shipment.

6. Bags or boxes shall be randomly taken from various locations on the pallets, not just from the top.

7. An entire, previously unopened bag of castable refractory material shall be mixed for the preparation of specimens for testing. Use of partial bags shall not be permitted.

8. Plastic refractory material specimens for testing shall be obtained from an entire previously unopened box or container. Use of partial boxes or containers shall not be permitted.

4.2.3.3 Testing

1. The specimen requirements (i.e., preparation, quantity, and shape) and testing for each property shall be in accordance with the ASTM test procedure listed in Appendix A, modified by API Standard 936 as noted.

2. Special forming, curing, or other techniques to enhance the test results shall not be permitted.

3. Testing shall include density, cold crushing strength, and permanent linear change.

4. For materials intended for severe duty service, abrasion resistance testing shall also be performed.

5. The test result values for each specimen making up the sample shall be in accordance with the requirements of Appendix A or, if more stringent, the manufacturer’s compliance data sheet or other values agreed with purchaser.
6. The test result values for any specimen in the sample shall not differ from the average of the sample by more than plus or minus 20 percent of the average values.

7. The results of the material prequalification testing, including the optimal water content if installation of castable refractory material is to be by casting, shall be provided to the purchaser. In addition to the test results, the following information shall be provided:
   a. Refractory product name and manufacturer
   b. Batch number
   c. Date of manufacture
   d. Pallet number
   e. Water (or proprietary fluid) content for castable installation methods other than dry gunning.
   f. Mixing time for castables
   g. Date of testing
   h. Name of the testing agency

**4.2.4 Retesting**

4.2.4.1 If the refractory material is not used within four months of the date of its initial prequalification test, the material shall be requalified/retested before it is used.

4.2.4.2 Material requalification/retesting shall also be performed if the refractory material shows evidence of minor damage or moisture, or if it has been exposed to excessive heat or cold.

4.2.4.3 Successful retesting qualifies the refractory material for an additional three months.

4.2.4.4 Retesting shall be performed by a qualified laboratory approved by the purchaser.

4.2.4.5 Retesting shall be completed far enough in advance of using the refractory material to permit replacement of the material without affecting the progress of the project.

4.2.4.6 The retest sampling, required tests, test procedures, and acceptance criteria shall be the same as for the initial prequalification testing, in accordance with Section 4.2.3.

4.2.4.7 The retest results shall not differ by greater than 20 percent from the prequalification values.

4.2.4.8 If the retest samples do not pass the testing requirements, the sampled lot shall be rejected and not used.
4.3 Storage

4.3.1 General

4.3.1.1 Refractory materials shall be kept in their original and unopened packaging and kept dry until they are installed.

4.3.1.2 Refractory material shall be stored on an elevated, ventilated platform, supported by a concrete slab or a compacted, durable surface sloped to direct moisture away from the material.

4.3.1.3 Refractory material shall not be stored on grass, soil, or other non-compactov surface, or any area where moisture can collect, stand, or come into contact with the material.

4.3.2 Weather Protection

4.3.2.1 The stored refractory material shall be protected by a weatherproof covering above and on all sides.

4.3.2.2 The covering shall be arranged so that moisture cannot come into contact with the material, bags or boxes.

4.3.2.3 The covering shall be arranged so that moisture cannot pond or collect and is directed away from the material.

4.3.2.4 Care shall be taken to avoid high humidity under the covering.

4.3.3 Temperature

4.3.3.1 During storage, castable refractory material shall be maintained at a temperature between 5°C (40°F) and 38°C (100°F).

4.3.3.2 During storage, plastic refractory material shall be maintained at a temperature between 5°C (40°F) and 30°C (90°F).

4.3.3.3 For a minimum of 24 hours before use, refractory material shall be maintained at a temperature between 10°C (50°F) and 27°C (80°F).

4.3.4 Shelf Life

4.3.4.1 The acceptable shelf life (i.e., the maximum time between manufacture and use) of the refractory material shall be clearly specified by the manufacturer.

4.3.4.2 The shelf life for moldable plastic refractory material shall not be greater than four months.

4.3.4.3 The shelf life for refractory materials other than that in Section 4.3.4.2 shall not be greater than 12 months.

4.3.5 Discarding Criteria

Refractory materials shall be discarded immediately if the following apply:

a. Bags or boxes have been previously opened

b. Castable refractory material has agglomeration or lumps that cannot easily be broken down by hand (i.e., between the thumb and forefinger)

c. Plastic refractory material is not pliable (e.g., already dried or hardened)
d. Material has become wet

e. Material is otherwise damaged

f. Material has exceeded its shelf life

4.4 Shipping, Packaging, and Marking

4.4.1 General

4.4.1.1 During shipment, refractory material shall be protected during shipment from moisture exposure, heat or cold, or other factors that can affect its properties or performance.

4.4.1.2 Refractory material shall be shipped by means that minimize time in transit and in-transit storage.

4.4.1.3 Refractory materials shall be ordered to minimize the time between manufacture and use.

4.4.1.4 If refractory material is taken from the existing stock, the material shall be the most recently manufactured material.

4.4.2 Packaging

4.4.2.1 Refractory material shall be shipped in waterproof bags, pails, or boxes secured on pallets.

4.4.2.2 Other shipping methods (e.g., super sacks) may be used, if the methods are in accordance with all requirements of this Practice and other contract documents, are approved by the purchaser, and a means of obtaining representative samples is used including resealing of the container, if required.

4.4.2.3 The actual weight shall be within plus or minus two percent of the nominal weight marked on each container.

4.4.2.4 Pallets shall contain 1800 Kg (4,000 pounds) or less of material.

4.4.2.5 Pallets shall not contain material from more than one batch and date of manufacture.

4.4.2.6 The packaging on each pallet shall be enclosed by plastic (e.g., polyethylene) stretch-wrap or shrink-wrap.

4.4.2.7 The wrap shall cover all sides of the shipment, including the underside.

4.4.2.8 The wrap shall be completely sealed so that moisture cannot enter or become trapped within the wrap.

4.4.2.9 A desiccant shall be provided on each pallet to prevent the accumulation of moisture within the wrap in the event of condensation (e.g., because of a temperature decrease).

4.4.2.10 The refractory material shall be protected from mechanical damage.

4.4.2.11 The wrap shall not be removed, cut, or opened until the refractory material is to be used. If damaged during handling (e.g., by a forklift), the damage shall be repaired.
4.4.2.12 If a bag is removed for sampling and testing, the plastic wrap shall be immediately resealed.

### 4.4.3 Marking

4.4.3.1 The following information shall be included with each bag and pallet of material:

- a. Product brand name
- b. Manufacturer’s name
- c. Plant of manufacture
- d. Shift
- e. Manufacturing line (if more than one)
- f. Batch identification
- g. Date of manufacture
- h. Presence of organic fibers, if applicable

4.4.3.2 Each bag or box of material shall show its weight, mixing instructions and the mixing water range where applicable, and any special cautions and/or requirements for storage, handling, mixing, application, curing and heat drying, etc.

4.4.3.3 Pallet numbering shall be as follows:

- a. Pallets in each lot shall be identified by lot or order number.
- b. Pallets of refractory material in each lot shall be numbered consecutively, beginning with number one.
- c. The total number of pallets in a lot shall be included in the identifying number (e.g., 3 of 7).

4.4.3.4 Material identification signs shall be posted prominently on at least two opposing sides of each pallet.
# Appendix A – Monolithic Refractory Material Compliance Requirements

<table>
<thead>
<tr>
<th>Properties (Note 5)</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 3LI</th>
<th>Type 4</th>
<th>Type 5</th>
<th>Type 6</th>
<th>Type 7</th>
<th>Type 8</th>
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<td>&lt;720 (45)</td>
<td>720 – 1040</td>
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<td>10 (1400)</td>
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<td>14 (2000)</td>
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<td>0 to -0.5</td>
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<tr>
<td>Cold Crushing Strength, MPa (psi) per ASTM C133 (Minimum)</td>
<td>980 (1800)</td>
<td>980 (1800)</td>
<td>1205 (2200)</td>
<td>1205 (2200)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1650 (3000)</td>
<td>1870 (3400)</td>
</tr>
<tr>
<td>Modulus of Rupture, MPa (psi) per ASTM C133 (Minimum)</td>
<td>0.17 (1.2)</td>
<td>0.20 (1.4)</td>
<td>0.26 (1.8)</td>
<td>0.26 (1.8)</td>
<td>0.40 (2.8)</td>
<td>0.65 (4.5)</td>
<td>1.08 (7.5)</td>
<td>0.94 (6.5)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Abrasion Loss (cm³) per ASTM C704 with Supplementary Requirements S1 (Maximum)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>15 (Note 10)</td>
<td>15 (Note 10)</td>
<td>15 (Note 10)</td>
<td>14 (Note 10)</td>
<td>8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Permanent Linear Change Range (%) per ASTM C113 (Note 11)</td>
<td>0 to -0.9</td>
<td>0 to -0.8</td>
<td>0 to -0.8</td>
<td>0 to -0.3</td>
<td>0 to -0.4</td>
<td>0 to -0.3</td>
<td>0 to -0.3</td>
<td>0 to -0.3</td>
<td>0 to -0.5</td>
<td>0 to -0.5</td>
<td>0 to -0.5</td>
<td>0 to -0.6</td>
</tr>
<tr>
<td>Continuous Use Temperature Limit, °C (°F) (Minimum)</td>
<td>980 (1800)</td>
<td>980 (1800)</td>
<td>1205 (2200)</td>
<td>1205 (2200)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1315 (2400)</td>
<td>1650 (3000)</td>
<td>1870 (3400)</td>
</tr>
<tr>
<td>Thermal Conductivity - W/m·K (Btu·in/h·ft·°F) per ASTM C201 and C417, Ascending Curve (Maximum)</td>
<td>0.17 (1.2)</td>
<td>0.20 (1.4)</td>
<td>0.26 (1.8)</td>
<td>0.26 (1.8)</td>
<td>0.40 (2.8)</td>
<td>0.65 (4.5)</td>
<td>1.08 (7.5)</td>
<td>0.94 (6.5)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Chemistry per ASTM E1172</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1.0 wt% Fe₂O₃ Maximum</td>
<td>N/A</td>
<td>N/A</td>
<td>65 wt% SiO₂ Minimum</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>94 wt% Al₂O₃ Minimum</td>
</tr>
</tbody>
</table>
Appendix A – RFSM1000 (continued)

Monolithic Refractory Material Compliance Requirements

NOTES:

1. Data is for proprietary, industrial, preblended mixes only and is not applicable to field mixes. Manufacturer’s requirements govern if they are more stringent than the requirements in the Table.

2. Property values shall be met by each specimen in the sample.

3. N/A indicates that the property test is not applicable.

4. Samples for testing do not include metal reinforcing fibers, except plastic refractory specified to be metal-reinforced, see 4.2.1.7.

5. All values are based upon the specified ASTM test, as modified by API Standard 936.

6. Specimens are fired to the indicated temperature in accordance with ASTM C865, then cooled and tested at room temperature.

7. All specimens shall be prepared by the method to be used for field installation.

8. Values are based upon specimens prepared by ramming.

9. Type 11 is also known as tabular alumina castable.

10. For vibratory cast samples, cold crushing strength is 48 MPa (7,000 psi), and abrasion loss is 10 cm³.

11. The value shown is the total (i.e., green to fired) shrinkage.

12. Testing shall be in accordance with ASTM C179, as modified by API Standard 936.

13. Test shall be conducted at the mean sample temperature shown.