PIP RFSB1000
Brick 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.

This Practice is subject to revision at any time.

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1. Scope

This Practice describes the requirements for certification and prequalification of the refractory materials used to construct brick refractory linings in equipment and piping and provides a basis for purchase and quality control of brick and mortar refractory materials before installation.

This Practice describes the material property, testing, documentation, storage, and shipping requirements for industrial refractory materials used to construct brick refractory linings in equipment and piping.

This Practice includes dense firebrick, shapes, insulating firebrick (IFB) and refractory mortars.

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.

2.1 Industry Codes and Standards

- ASTM International (ASTM)
  - ASTM C24 – Standard Test Method for Pyrometric Cone Equivalent (PCE) of Fireclay and High Alumina Refractory Materials
  - ASTM C27 – Standard Classification of Fireclay and High-Alumina Refractory Brick
  - ASTM C133 – Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories
  - ASTM C155 – Standard Classification of Insulation Firebrick
  - ASTM C199 – Standard Test Method for Pier Test for Refractory Mortars
  - ASTM C201 – Standard Test Method for Thermal Conductivity of Refractories
  - ASTM C1655 – Standard Classification of Fireclay and High-Alumina Mortars
3. Definitions

With the exception of the terms listed in this section, terms used in this Practice are defined in accordance with 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:

**batch**: Brick refractory material produced in one kiln run of a specific composition. For mortar a batch is a mixture run.

**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 or B of this Practice as applicable.

**industrial refractory**: Refractory brick, shapes and mortar offered with data sheets, installation information, Safety Data Sheets (SDSs), and other safety and handling information

**compliance data sheet**: Data sheet listing property values that the manufacturer certifies or guarantees will be met by each sample tested. The values in the compliance data sheet shall comply with values in Appendix A or B and, if more stringent, shall include the manufacturer’s guaranteed values and any other values as agreed upon with the purchaser.

**lining**: Refractory brick 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.

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

**manufacturer**: Party who manufactures the refractory brick, shapes or mortar

**material prequalification**: Determination that the as-manufactured refractory material to be shipped to the site meets all of the requirements for the specified type of refractory in accordance with the compliance data sheet

**owner**: Party who owns the facility wherein the refractory will 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 material that has a high melting point and ability to retain its physical shape and chemical identity when subjected to environmental conditions

**supplier**: Party who furnishes 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 (SDSs)

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 Complete and current Safety Data Sheets (SDSs) shall be provided for each product and to each location where the product is to be used.

4.1.2.3 The SDSs 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 and long-term) that may occur.

4.1.3 Material Properties Information

4.1.3.1 Manufacturer’s standard technical data sheets shall be provided for each product and to each site where the product is to be used.

4.1.3.2 Compliance data sheets shall be provided for each product and to each site where the product is to be used.

4.1.3.3 If alternate product property values are agreed upon with the purchaser, this information shall be included on the compliance data sheets.

4.1.3.4 The results of material prequalification testing shall be provided. The results shall be approved by the purchaser before shipment of the product.

4.1.4 Mixing and Placement Instructions

4.1.4.1 Complete, step-by-step instructions shall be provided for mixing the refractory mortar components and water, including the optimal total water content.

4.1.4.2 Special placement instructions and/or cautions beyond those typically used for the chosen method of refractory mortar placement shall be provided.

4.1.5 Curing and Heat Dryout Schedules

4.1.5.1 Recommended heat dryout schedules shall be provided for each refractory brick lining.
4.1.5.2 Heat dryout schedules shall be in accordance with the manufacturer’s recommendations. A manufacturer’s heat dryout schedule shall specify the following:
   a. Hold temperatures (if required) and the maximum temperature to be achieved.
   b. Minimum hold times.
   c. Maximum heating and cooling rates for each material.
   d. Other requirements pertaining to the proper heat drying of the material.

4.2 Refractory Properties

4.2.1 General

4.2.1.1 The refractory installed in each location shall be of the type specified in the contract documents (e.g., purchaser’s specifications and drawings) and defined in Appendices A and B of this Practice.

4.2.1.2 Asbestos shall not be permitted in refractory materials.

4.2.2 Certification

4.2.2.1 General

1. Refractory products shall be certified before being considered for installation in any process equipment.
2. Certification shall include testing of refractory properties.
3. Testing methods and procedures, and the resultant property values, shall be in accordance with the requirements of Appendices A and B of this Practice for the applicable refractory type.

*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. Use of refractory materials with a successful record of service in the same or very similar application is recommended before making the selection.

4.2.2.2 Sampling

1. Specimens shall be cut from 230-mm (9-inches) straight brick provided by the manufacturer as produced, using the same material, manufacturing process and equipment to be used for normal brick production.
2. Large shapes shall be cut down in size to the appropriate test specimen dimensions. Cutting shall be by water-cooled diamond blade saw.
3. Select representative samples of mortar sufficient for the required testing.
4. The number of specimens shall be sufficient to conduct tests required in accordance with Appendices A and B.
4.2.2.3 Testing

1. Brick
   a. The requirements of this section shall apply to the properties listed on the manufacturer’s compliance data sheets to evaluate candidate brick for a type as defined by Appendix A.
   b. The specimen requirements (i.e., preparation, number, and shape) and testing for each property shall be in accordance with the ASTM test procedure listed in Appendix A.
   c. Special techniques to enhance the test results shall not be permitted.
   d. Testing shall be in accordance with Appendix A and may include chemistry, pyrometric cone equivalent (PCE), density, cold crushing strength, modulus of rupture (MOR), thermal conductivity, and reheat change.
   e. Each test specimen result shall be in accordance with the requirements of the compliance data sheet.
   f. The test result values for any specimen in the test sample shall not differ from the average of the sample by greater than plus or minus 20 percent of the average values.
   g. The purchaser may require additional tests as necessary to meet process requirements.

2. Mortar
   a. The requirements of this section shall apply to the properties listed on the manufacturer’s compliance data sheets to evaluate candidate mortar for a type as defined by Appendix B.
   b. The specimen requirements (i.e., preparation, number, and shape) and testing for each property shall be in accordance with the ASTM test procedure listed in Appendix B.
   c. Special techniques to enhance the test results shall not be permitted.
   d. Each test specimen result shall be in accordance with the requirements of the compliance data sheet.
   e. The test result values for any specimen in the test sample shall not differ from the average of the sample by greater than plus or minus 20 percent of the average values.
   f. The purchaser may require additional tests as necessary to meet process requirements.

4.2.2.4 Tolerance Requirements

1. Dense Brick
   a. For all standard sized brick dimensions (e.g., 230 by 115 by 75 mm (9 by 4.5 by 3 inches) or 230 by 115 by 65 mm (9 by 4.5
by 2.5 inches), etc.) and shapes, the following tolerances shall apply:

1) For 115 mm (4.5 inches) and smaller dimensions, plus or minus 0.5 mm (0.02 inch)
2) For greater than 115 mm (4.5 inches) up to 345 mm (13.5 inches) dimensions, plus or minus 1 mm (0.04 inch)
3) For greater than 345 mm (13.5 inches) dimensions, plus or minus 1.5 mm (0.06 inch)

b. For all standard sized brick and shapes, the following surface warpage tolerances shall apply:

1) For 115 mm (4.5 inches) and smaller dimensions, plus or minus 0.25 mm (0.01 inch)
2) For greater than 115 mm (4.5 inches) up to 345 mm (13.5 inches) dimensions, plus or minus 0.5 mm (0.02 inch)
3) For greater than 345 mm (13.5 inches) dimensions, plus or minus 1.0 mm (0.04 inch)

c. For standard brick, the brick shall be stacked 10 brick high on the largest surface (e.g., 230 by 115 mm (9 by 4.5 inches)) and the total height measured. The height tolerance shall be plus or minus 0.5 percent of the nominal height.

d. For brick or shapes designed to produce a contour geometry, the design number of pieces shall be laid out in the contour with 1 mm (0.04 inch) shims for mortar joints and the inside dimension of the contour measured. The dimensional tolerance shall be plus or minus 0.5 percent of the design value.

2. Insulating Firebrick

a. For pressed insulating firebrick sizes and shapes, the dimensional tolerances in Section 4.2.2.4 Items 1 (a) through (d) shall apply.

b. For machined insulating firebrick shapes, all the dimensional tolerances shall be plus or minus 0.5 mm (0.02 inch).

4.2.2.5 Visual and Dimensional Inspection – Acceptance/Rejection Criteria

1. Brick or shape which shows cracking shall be rejected.

2. Brick or shape with suspected cracks may be tapped with a brick hammer and, if the refractory does not break and rings solid, the refractory may be used.

3. Brick or shape with missing corners or chips from edges, with any dimension greater than the thickness of the proposed mortar joint, shall be rejected.

4. Brick or shape with voids or pockets, with any dimension greater than 3 mm (1/8 inch) on the surface, shall be rejected.
4.2.3 Material Prequalification

4.2.3.1 General

1. The requirements of this section shall be used for prequalification of brick and mortar to be installed:
   
   *Comment:* Prequalification testing is intended to determine if the product has been properly manufactured and can be expected to perform similarly to product of the same brand identification that has been certified for the application.

   *Comment:* Prequalification visual and dimensional inspection is intended to determine if the product has been properly manufactured in accordance with the specifications.

2. Material prequalification shall include testing and visual inspection before shipment from the manufacturer’s facility.

3. Each lot, or portion thereof, shall be certified as being in accordance with the required test values and visual inspection criteria before shipment from the manufacturer’s facility.

4. Samples shall be tested and visually inspected at the manufacturer’s facility or, at the purchaser’s discretion, at an independent laboratory approved by the purchaser.

5. Purchaser may choose to witness the testing and visual inspection. If so, the purchaser shall be notified of the time and place as specified in the contract documents. Notice shall be given far enough in advance so that the purchaser or the authorized purchaser’s representative may arrange to be present and the material can be replaced without affecting the delivery schedule should replacement be necessary.

4.2.3.2 Sampling

1. Sampling of brick shall be in accordance with Table 1.

<table>
<thead>
<tr>
<th>Number of pieces</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25</td>
<td>2</td>
</tr>
<tr>
<td>26 – 100</td>
<td>5</td>
</tr>
<tr>
<td>101 – 250</td>
<td>10</td>
</tr>
<tr>
<td>251 - 500</td>
<td>20</td>
</tr>
<tr>
<td>501 – 1000</td>
<td>25</td>
</tr>
<tr>
<td>&gt; 1000</td>
<td>4%</td>
</tr>
</tbody>
</table>

2. All samples shall be taken from the brick to be shipped. Samples shall not come from a portion of a batch not included in the shipment.
3. Brick shall be randomly selected from various locations on the pallets, not just from the top.

4. One randomly selected mortar container shall be taken from each mixer batch.

4.2.3.3 Brick Testing

1. The requirements of this section shall apply to the properties listed on the manufacturer’s compliance data sheets to evaluate candidate brick for a type as defined by Appendix A of this Practice.

2. The specimen requirements (i.e., preparation, number, and shape) and testing for each property shall be in accordance with the ASTM test procedure listed in Appendix A of this Practice.

3. Special techniques to enhance the test results shall not be permitted.

4. Testing shall be in accordance with Appendix A and may include chemistry, PCE, density, cold crushing strength, MOR, thermal conductivity, and reheat change.

5. Each test specimen result shall be in accordance with the requirements of the compliance data sheet.

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

7. The purchaser may require additional tests as necessary to meet process requirements.

8. The results of the material prequalification testing shall be reported to the purchaser.

9. In addition to the test results, the refractory product name and manufacturer, batch number, date of manufacture, pallet number, date of testing and the name of the testing agency shall be provided.

4.2.3.4 Mortar Testing

1. Mortar shall be tested in accordance with the requirements of Appendix B.

2. The specimen requirements (i.e., preparation, number, and shape) and testing for each property shall be in accordance with the ASTM test procedure listed in Appendix B.

3. Special techniques to enhance the test results shall not be permitted.

4. Each test specimen result shall be in accordance with the requirements of the compliance data sheet.

5. The test result values for any specimen in the test sample shall not differ from the average of the sample by greater than plus or minus 20 percent of the average values.
6. The purchaser may require additional tests as necessary to meet process requirements.

7. The results of the mortar prequalification testing shall be reported to the purchaser.

8. In addition to the test results, the refractory product name and manufacturer, batch number, date of manufacture, pallet number, water content and mixing time, date of testing and the name of the testing agency shall be provided.

4.2.3.5 Mortar Retesting

1. If the mortar is not used within one year or manufacturer’s shelf life, whichever is less, the mortar shall be requalified/retested immediately before use. Material more than 18 months from date of manufacture shall be discarded.

2. Material requalification/retesting shall also be performed if the packaging or mortar has been exposed to heat or cold beyond the manufacturer’s recommended storage temperature.

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

4. The 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.

5. The retest results shall not differ by greater than 20 percent from the prequalification values, and shall be in accordance with the compliance data sheet.

6. If the samples do not pass the testing requirements, the sampled lot shall not be used.

4.2.3.6 Visual Inspection, Dimensional Inspection, and Tolerance Requirements

1. Brick shall be in accordance with the tolerance requirements of Section 4.2.2.4.

2. Brick shall be in accordance with the visual inspection requirements of Section 4.2.2.5.

3. Brick that is not in accordance with Section 4.2.2.4 or 4.2.2.5 shall not be used.

4.3 Storage

4.3.1 General

4.3.1.1 Brick and mortar materials 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 materials.
4.3.1.2 Brick and mortar materials shall not be stored on grass, soil, or other non-compact surface or any area where moisture may collect, stand, or come into contact with the materials.

4.3.2 Weather Protection

4.3.2.1 The stored brick and mortar materials 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 materials.

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

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

4.3.3 Discarding Criteria

The following materials shall not be used and shall be discarded immediately:

a. Bags or containers of mortar which are damaged, wet or open before use.

b. Mortar which contains lumps of hard material which cannot be broken up during mixing.

c. Brick or shapes which are broken, chipped, or damaged during transit or storage and are not in accordance with Section 4.2.2.5.

4.4 Shipping, Packaging and Marking

4.4.1 General

4.4.1.1 Brick and mortar shall be secured and protected from moisture exposure, heat or cold beyond the manufacturer’s recommended storage temperature, mechanical damage or other factors that may affect its properties or performance.

4.4.1.2 Brick and mortar shall be shipped by means that minimizes its time in transit and in-transit storage.

4.4.1.3 Mortar shall be ordered to minimize the time between its manufacture and use.

4.4.1.4 If mortar is taken from the existing stock, the mortar shall be the most recently manufactured material and shall not be older than 3 months from date of manufacture.

4.4.2 Packaging

4.4.2.1 Mortar shall be shipped in polyethylene-lined bags, pails, or boxes grouped on pallets.

4.4.2.2 Other shipping means for mortar may be used if in accordance with all requirements of this Practice and other contract documents and approved by the purchaser. A means of obtaining representative samples shall be provided, including resealing of the container if required.
4.4.2.3 The actual weight of mortar shall be within plus or minus 2 percent of the nominal weight marked on each container.

4.4.2.4 Pallets of brick or mortar shall hold 1800 kg (4,000 pounds) or less of the material.

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

4.4.2.6 The product on each pallet shall be enclosed by plastic wrap.

4.4.2.7 The plastic wrap shall cover all sides of the shipment, including the underside, between the brick or mortar and the pallet.

4.4.2.8 The plastic 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 (inside the plastic wrap) to prevent the accumulation of moisture within the plastic wrap in the event of condensation (e.g., because of a temperature decrease).

4.4.2.10 The plastic wrap shall not be removed, cut, or opened until the brick or mortar is to be used.

4.4.2.11 If material is removed for sampling and testing, the plastic wrap shall be immediately resealed.

4.4.3 Marking

4.4.3.1 Each brick or shape shall have the product’s name or identification stamped into the brick surface.

4.4.3.2 Each container of mortar and each pallet of brick or mortar shall include the following information:
   a. Product brand name
   b. Manufacturer’s name
   c. Plant of manufacture
   d. Shift
   e. Manufacturing line (if more than one)
   f. Lot and batch identifications
   g. Date of manufacture
   h. Purchase order number (applies to each pallet)

4.4.3.3 Each container of mortar shall include the following information:
   a. Container weight
   b. Mixing instructions
   c. Mixing or tempering water range as required
   d. Special cautions and/or requirements for storage, handling, mixing, application, curing, heat drying, etc.
4.4.3.4 Pallet numbering shall be in accordance with the following:
   a. The pallets of brick and mortar in each lot shall be numbered consecutively, beginning with 1.
   b. The total number of pallets in the lot shall be included in the identifying number (e.g., 3 of 7).

4.4.3.5 Material identification signs shall be posted prominently on all four sides of each pallet.
Appendices

Appendix A – Refractory Brick Compliance Requirements
  Table A-1 - Dense Refractory Brick Compliance Requirements
  Table A-2 - Specialty Dense Refractory Brick Compliance Requirements
  Table A-3 - Insulating Firebrick (IFB) Compliance Requirements

Appendix B - Refractory Mortar Compliance Requirements
### Table A-1 – Dense Refractory Brick Compliance Requirements (Note 4)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Classification</th>
<th>Fireclay Brick</th>
<th>High-Alumina Brick (% Al₂O₃ Content)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Medium Duty</td>
<td>Semi-Silica</td>
</tr>
<tr>
<td>Density, kg/m³ (lb/ft³) per</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM C134 (Minimum)</td>
<td></td>
<td>2,050 (128)</td>
<td>1,840 (115)</td>
</tr>
<tr>
<td>Apparent Porosity</td>
<td></td>
<td>17%</td>
<td>27%</td>
</tr>
<tr>
<td>Per ASTM C20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold Crushing Strength, MPa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(psi) per ASTM C133 (Min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modulus of Rupture, MPa</td>
<td></td>
<td>3.5 (500)</td>
<td>2.1 (300)</td>
</tr>
<tr>
<td>Hot Load Test per ASTM C16</td>
<td></td>
<td>N/A</td>
<td>0.2-2.0% @</td>
</tr>
<tr>
<td>Deformation at Temperature (Note 5)</td>
<td></td>
<td>@1450°C (2640°F)</td>
<td>@1450°C (2640°F)</td>
</tr>
<tr>
<td>Reheat Permanent Linear Change per ASTM C113 (Note 6)</td>
<td></td>
<td>0-0.5% C @1350°C (2460°F)</td>
<td>0-0.5% E @1400°C (2550°F)</td>
</tr>
<tr>
<td>Pyrometric Cone Equivalent (PCE) per ASTM C24 (Minimum)</td>
<td></td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>Thermal Conductivity - K, W/mK ((Btu·in)/(h·ft²·°F)) per ASTM C201 at 425°C (800°F) (Maximum)</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Al₂O₃ (wt. %)</td>
<td></td>
<td>34 ± 2</td>
<td>N/A</td>
</tr>
<tr>
<td>SiO₂ (wt. %)</td>
<td></td>
<td>60 ± 2</td>
<td>72 (Minimum)</td>
</tr>
<tr>
<td>Fe₂O₃ (wt. %) (Maximum)</td>
<td></td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Data is for proprietary, industrial brick only and is not applicable to pre-cast castable shapes.
2. Testing shall comply with the requirements of Sections 4.2.2.3.1 or 4.2.3.3 as applicable.
3. N/A indicates that the property test is not available.
4. Dense Brick classifications are in accordance with ASTM C27.
5. All values are contraction except where shown as “+”.
6. E indicates expansion, C indicates contraction.
## Table A-2 – Specialty Dense Refractory Brick Compliance Requirements

<table>
<thead>
<tr>
<th>Classification</th>
<th>Alumina Magnesia Carbon Brick</th>
<th>Phosphate Bonded High Alumina Brick</th>
<th>Alumina-Chrome Brick</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.0% Magnesia</td>
<td>5.7% Magnesia</td>
<td>6.7% Magnesia</td>
</tr>
<tr>
<td>Density, kg/m$^3$ (lb/ft$^3$)</td>
<td>2.860 (180)</td>
<td>2.800 (175)</td>
<td>3.200 (200)</td>
</tr>
<tr>
<td>Apparent Porosity ASTM C20 (percent)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Cold Crushing Strength, MPa (psi) per ASTM C133 (Minimum)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Modulus of Rupture, MPa (psi) per ASTM C133 (Minimum)</td>
<td>15.9 (2,300)</td>
<td>17.9 (2,520)</td>
<td>25.9 (3,750)</td>
</tr>
<tr>
<td>Reheat Permanent Linear Change per ASTM C113 (@ Temperature) (Note 4)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Al$_2$O$_3$ (wt.%) (Minimum)</td>
<td>78.0</td>
<td>81.0</td>
<td>88.2</td>
</tr>
<tr>
<td>SiO$_2$ (wt.%) (Maximum)</td>
<td>8.0</td>
<td>8.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Fe$_2$O$_3$ (wt.%) (Maximum)</td>
<td>0.2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Other (wt. %)</td>
<td>8 - 12 MgO</td>
<td>5 - 6.5 MgO</td>
<td>6 - 7.5 MgO</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Data is for proprietary, commercial brick only and is not applicable to pre-cast castable shapes.
2. Testing shall comply with the requirements of Sections 4.2.2.3.1 or 4.2.3.3 as applicable.
3. N/A indicates not applicable.
4. E indicates expansion. C indicates contraction.
### Table A-3 – Insulating Firebrick (IFB) Compliance Requirements

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>20</th>
<th>B4</th>
<th>23</th>
<th>2300 LI</th>
<th>B5</th>
<th>2500</th>
<th>2600 LI</th>
<th>26</th>
<th>2800 LI</th>
<th>28</th>
<th>2900</th>
<th>30</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, kg/m³ (lb/ft³) per ASTM C134 (Minimum)</td>
<td>500 (31.2)</td>
<td>800 (50)</td>
<td>500 (31.2)</td>
<td>480 (30)</td>
<td>800 (50)</td>
<td>800 (50)</td>
<td>800 (50)</td>
<td>800 (50)</td>
<td>890 (55.6)</td>
<td>900 (56.2)</td>
<td>1100 (68.8)</td>
<td>1,020 (63.8)</td>
<td>1,260 (78.1)</td>
</tr>
<tr>
<td>Cold Crushing Strength, MPa (psi) per ASTM C133 (Minimum)</td>
<td>0.8 (116)</td>
<td>2.0 (290)</td>
<td>1.0 (145)</td>
<td>1.2 (174)</td>
<td>2.0 (290)</td>
<td>1.8 (261)</td>
<td>1.6 (232)</td>
<td>2.0 (290)</td>
<td>2.0 (290)</td>
<td>2.5 (305)</td>
<td>3.0 (363)</td>
<td>2.1 (305)</td>
<td>3.5 (508)</td>
</tr>
<tr>
<td>Modulus of Rupture, MPa (psi) per ASTM E228 (Maximum)</td>
<td>0.7 (102)</td>
<td>1.2 (174)</td>
<td>0.7 (102)</td>
<td>1.0 (145)</td>
<td>1.2 (174)</td>
<td>1.2 (174)</td>
<td>1.5 (218)</td>
<td>1.8 (261)</td>
<td>1.8 (261)</td>
<td>2.0 (290)</td>
<td>2.0 (290)</td>
<td>305 (2.1)</td>
<td></td>
</tr>
<tr>
<td>Permanent Linear Change, Maximum % Per ASTM C210 (Note 3)</td>
<td>0.6</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Hot Load Strength, % Deformation after 90 minutes per ASTM C16 (Maximum)</td>
<td>0.1 @ 1100°C @ 0.034MPa (210°F @ 5 PSI)</td>
<td>0.2 @ 1230°C @ 0.034MPa (2246°F @ 5 PSI)</td>
<td>0.1 @ 1300°C (2372°F)</td>
<td>0.2 @ 1230°C (2246°F)</td>
<td>0.2 @ 1230°C (2246°F)</td>
<td>0.1 @ 1260°C (2322°F)</td>
<td>0.2 @ 1260°C (2322°F)</td>
<td>0.3 @ 1260°C (2322°F)</td>
<td>0.2 @ 1320°C (2408°F @ 10 PSI)</td>
<td>0.1 @ 1370°C (2498°F @ 10 PSI)</td>
<td>0.2 @ 1300°C (2498°F @ 10 PSI)</td>
<td>0.2 @ 1300°C (2498°F @ 10 PSI)</td>
<td>0.2 @ 1370°C (2498°F @ 10 PSI)</td>
</tr>
<tr>
<td>Thermal Conductivity - K, W/mK (Btu/in/h-ft²-°F) at 600°C (1112°F) per ASTM C162 (Maximum)</td>
<td>0.22 (1.54)</td>
<td>0.30 (2.09)</td>
<td>0.22 (1.54)</td>
<td>0.14 (0.98)</td>
<td>0.30 (2.09)</td>
<td>0.28 (1.96)</td>
<td>0.27 (1.89)</td>
<td>0.32 (2.23)</td>
<td>0.34 (2.37)</td>
<td>0.42 (2.86)</td>
<td>0.39 (2.72)</td>
<td>0.50 (3.49)</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃ (%) (Minimum)</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>37</td>
<td>45</td>
<td>50</td>
<td>58</td>
<td>55</td>
<td>67</td>
<td>64</td>
<td>70</td>
<td>73</td>
<td>77</td>
</tr>
<tr>
<td>SiO₂ (%) (Minimum)</td>
<td>50</td>
<td>50</td>
<td>48</td>
<td>44</td>
<td>48</td>
<td>45</td>
<td>39</td>
<td>41</td>
<td>31</td>
<td>32</td>
<td>28</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>Fe₂O₃ (%) (Maximum)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.7</td>
<td>1.0</td>
<td>0.9</td>
<td>0.7</td>
<td>0.9</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
<td>0.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

NOTES:
1. Data is for proprietary, industrial brick only and is not applicable to pre-cast castable shapes.
2. Testing shall comply with the requirements of Sections 4.2.2.3.1 or 4.2.3.3 as applicable.
3. All values are contraction except where shown as “+”.
4. IFB classifications 20, 23, 25, 28, 30 and 32 are in accordance with ASTM C155. Other classifications are per manufacturer specialty materials.
# Appendix B – Refractory Mortar Compliance Requirements

<table>
<thead>
<tr>
<th>Classification</th>
<th>Fireclay Mortar (Note 1)</th>
<th>High-Alumina Mortar (wt. % Al₂O₃ Content) (Note 1)</th>
<th>Phosphate Bonded Alumina Mortar (wt. % Al₂O₃) (Note 2)</th>
<th>Chrome-Alumina Mortar (wt% Cr₂O₃) (Note 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medium Duty</td>
<td>High Duty</td>
<td>Super Duty</td>
<td>70</td>
</tr>
<tr>
<td>Refractoriness Test per ASTM C199</td>
<td>No Flow @ 1400°C (2550°F)</td>
<td>No Flow @ 1500°C (2730°F)</td>
<td>No Flow @ 1600°C (2910°F)</td>
<td>No Flow @ 1705°C (3100°F)</td>
</tr>
<tr>
<td>Cold Bonding Strength per ASTM C198 Using Modulus of Rupture, MPa (psi) per ASTM C133</td>
<td>4.5 (650)</td>
<td>4.5 (650)</td>
<td>5.5 (800)</td>
<td>5.3 (775)</td>
</tr>
<tr>
<td>Al₂O₃ (wt%) (Minimum)</td>
<td>30</td>
<td>40</td>
<td>54</td>
<td>67</td>
</tr>
<tr>
<td>SiO₂ (wt%) (Typical)</td>
<td>60</td>
<td>53</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>Fe₂O₃ (wt%) (Maximum)</td>
<td>1.4</td>
<td>1.2</td>
<td>1.1</td>
<td>1.5</td>
</tr>
<tr>
<td>P₂O₅ (wt%) Minimum</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Cr₂O₃ (wt%) (Minimum)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**NOTES:**
1. Fireclay and high-alumina mortars are per ASTM C1655.
2. Phosphate-bonded and chrome-alumina mortars are vendor proprietary classifications.
3. N/A indicates not applicable.
4. Testing shall comply with the requirements of Sections 4.2.2.3.2 or 4.2.3.4 as applicable.