IRM-SU-5207-A

Refractory Linings for Sulfur Recovery Unit Main Reaction Furnaces

Operating Environment: Onshore

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<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Description</th>
<th>Author</th>
<th>Technology Leader</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>11/08</td>
<td>Initial release.</td>
<td>K. Young</td>
<td>—</td>
</tr>
<tr>
<td>A</td>
<td>06/13</td>
<td>General revision. Title change.</td>
<td>K. Young</td>
<td>B. Chaloner-Gill</td>
</tr>
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</table>
Summary of Changes

1. Revised technical content is indicated by change bars in the right margin.
2. Deleted, moved, and combined requirements, as well as editorial changes, are listed below.

<table>
<thead>
<tr>
<th>Initial Release</th>
<th>Rev. A</th>
<th>Description</th>
<th>Type of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>—</td>
<td>Sect. 2.3</td>
<td>Added Section 2.3, Conflict Resolution and Order of Precedence.</td>
<td>Addition.</td>
</tr>
<tr>
<td>Sect. 1.0 #3</td>
<td>Sect. 2.3 #2</td>
<td>Moved to Section 2.3.</td>
<td>Moved requirement.</td>
</tr>
<tr>
<td>Sect. 4.1</td>
<td>Sect. 4.1</td>
<td>Deleted items #2 and #3, renumbered item #1a as item #1, and renumbered #1b as item #2.</td>
<td>Delete and renumber.</td>
</tr>
<tr>
<td>Sect. 5.0–7.0</td>
<td>Sect. 7.0–9.0</td>
<td>Added Section 5.0 and 6.0, renumbered remaining.</td>
<td>Addition and renumber.</td>
</tr>
<tr>
<td>Sect. 7.2, 7.3</td>
<td>Sect. 9.3, 9.4</td>
<td>Added Section 9.2, Insulating Firebrick; renumbered following sections.</td>
<td>Addition and renumber.</td>
</tr>
<tr>
<td>—</td>
<td>Sect. 10.0–11.0</td>
<td>Added Section 10.0 and 11.0</td>
<td>Addition.</td>
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</table>
1.0 **Scope**

This specification defines the materials used in sulfur recovery unit main reaction furnace refractory linings, the prequalification testing of these materials, the design of the linings, and the installation of the materials.

2.0 **References**

1. The following documents are referenced herein and are considered part of this specification.
2. Unless otherwise specified in Section 2.1 or Section 2.2, use the latest edition of the referenced documents.

2.1 **Purchaser Documents**

IRM-SU-4785 Purchasing Specification—Monolithic Refractories

[IRM] GC-N1268 Monolithic Refractory Material Requirements

2.2 **Industry Codes and Standards**

*ASTM International (ASTM)*

C16 Standard Test Method for Load Testing Refractory Shapes at High Temperatures

C20 Standard Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity, and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water

C133 Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories

C134 Standard Test Methods for Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick

C155 Standard Classification of Insulating Firebrick

C583 Standard Test Method for Modulus of Rupture of Refractory Materials at Elevated Temperatures

*Deutsches Institut für Normung (DIN) (German Institute for Standardization)*

51068 Testing of ceramic raw and basic materials – Determination of resistance to thermal shock – Water quenching method for refractory bricks

*International Organization for Standardization (ISO)*

5022 Shaped refractory products—Sampling and acceptance testing
2.3 Conflict Resolution and Order of Precedence

1. Supplier shall submit any conflicts among the inquiry documents in writing to Owner for resolution.

2. If conflicts arise between the project specification and this document, the project specification shall take precedence.

3.0 Acronyms

AQL Acceptable Proportion of Defective Items
IFB Insulating Firebrick

4.0 Refractory Materials

4.1 Main Reaction Furnace Refractory Lining Systems

1. Tubesheet shall consist of hexagonal or square head ferrules surrounded by GC-N1268 Type A castable material. If grouting mortar is used, it shall be a 94-percent aluminum phosphate-bonded type.

2. Shell shall consist of high-alumina, creep-resistant brick hotface with insulating firebrick (IFB) backup. The mortar for the bricks shall be specified by Supplier of the bricks.

4.2 Materials

1. Castable materials shall meet the requirements listed in specification IRM-SU-4785 and drawing GC-N1268.

2. Insulating firebrick shall meet the requirements contained in ASTM C155.

3. High-alumina, creep-resistant brick shall meet the requirements contained in Section 9.3.

4. Square or hexagonal head ferrules shall be the two-piece type and shall meet the requirements contained in Section 9.4.

5.0 Shell Lining Design

1. The shell lining design shall consist of creep-resistant, high-alumina brick backed with insulating firebrick.

2. The lining thicknesses shall be chosen to obtain an operating shell temperature between 400°F and 550°F (205°C and 290°C).

3. The maximum operating temperature for the unit shall produce a maximum midpoint temperature in the hotface brick of 2850°F (1565°C). If calculations show that this temperature will be exceeded, then materials other than those listed in this specification shall be used in the lining design.

4. The minimum hotface lining thicknesses shall conform to Table 1. These thicknesses are based on 3-inch (76-mm) series brick.
Table 1: Minimum Hotface Lining Thicknesses

<table>
<thead>
<tr>
<th>Hotface Brick Thickness</th>
<th>Maximum Hotface, Inside Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>inches</td>
<td>mm</td>
</tr>
<tr>
<td>4.5</td>
<td>114</td>
</tr>
<tr>
<td>6</td>
<td>144</td>
</tr>
<tr>
<td>9</td>
<td>229</td>
</tr>
</tbody>
</table>

5. Expansion joint design documentation shall be approved by Owner.
6. Flat wall designs shall not be used.
7. Choke rings or baffle walls shall be tied into the hotface layer.
8. Tongue-and-groove brick shall not be used.
9. Large penetrations, such as manways, shall be lined with brick rings with a compression ring at the hotface.
10. Small penetrations shall be core drilled through the hotface brick. If the penetration is large enough that less than half a brick will be created by core drilling, then the penetration shall be installed using a brick ring.
11. Castables shall not be used in the hotface lining. Castables may be used in the backup lining at penetrations.
12. The brick mortar used shall conform to manufacturer’s recommendations.
13. Type C plastics shall not be used in the hotface lining.
14. The brick lining shall be designed so that there are no bonding requirements on the mortar.

6.0 Tube Sheet Lining Design

1. The tube sheet lining shall consist of a ferrule lining for the tubes, surrounded by a layer of type A castable between the ferrules and the shell lining.
2. The size and layout of the ferrules shall be provided by the ferrule Supplier.
3. The ceramic fiber paper covering the head of the ferrule shall cover the full length of the head, that is, there shall be no recess at the hotface.
4. The castable layer shall be anchored using 3-inch (76-mm)-long, Inconel® 601, “wavy V”-type anchors.

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1 Inconel is a registered trademark of Special Metals Corporation.
7.0 Pre-Shipment Testing of Materials

7.1 General Requirements

1. The chemistry of refractory materials shall be certified by manufacturer.
   a. Manufacturer shall furnish the documentation required to verify that this certification is valid.
   b. If the chemistry certification cannot be justified to Purchaser’s satisfaction, the material shall be rejected.

2. The material properties specified in this document shall be the minimum values for each type of material.
   a. The refractory manufacturers shall supply guarantee material property values for each material that they provide. The guarantee values shall meet or exceed the values specified in this specification or in GC-N1268.
   b. These guarantee values shall be used to determine if the supplied material meets the quality parameters.

3. Material Supplier shall be responsible for the testing costs.

7.2 Monolithic Materials

Monolithic refractory materials shall be prequalified as defined in IRM-SU-4785 prior to shipment, unless otherwise specified by Purchaser.

7.3 Brick

1. One sample of brick from every batch or from every 5500 pounds (2.5 metric tons) shall be taken for destructive testing.
   a. Testing for complex shapes may require more frequent testing.
   b. Exceptions or alternate proposals to the testing shall be submitted to Purchaser for review and acceptance.

2. The sample shall be cut in half and visually inspected for defects.
   a. Half the sample shall be tested, either by manufacturer or by an independent laboratory, to ensure that the material’s physical properties meet specifications.
   b. The remaining half of the sample shall be kept until all material has been certified as acceptable.

3. If a sample does not meet the specifications for internal defects or for any physical property, the batch shall be sampled in accordance with ISO 5022 with an acceptable proportion of defective items (AQL) of 4.0 percent. If subsequent testing shows that the shape exceeds the AQL, the batch shall be rejected.

4. For sidewall, cone, and throat bricks, random samples shall be taken in accordance with ISO 5022 with an AQL of 6.5 percent for dimensional specifications and 4.0 percent for visual specifications (for example, cracks or chips). If a shape exceeds either AQL, the shape shall be rejected.
7.3.1 **Dimensional Tolerances**

Dimensions shall meet the following tolerances:

1. For dimensions greater than 4 inches (100 mm): ±1.0 percent with a maximum of ±0.08 inches (2.0 mm).
2. For dimensions less than 4 inches (100 mm): ±0.04 inches (1.0 mm).
3. Warpage maximum shall equal 0.004 inch (0.10 mm) per 1 inch (25 mm) of length, measured across the full diagonal of the brick.

7.3.2 **Visual Inspection Guidelines—Cut Surface**

1. Parallel cracks across the face shall be unacceptable unless they are hairline cracks.
2. No more than two cracks per face shall be allowed, with the cracks totaling less than 25 percent of the surface length.
3. Voids shall be acceptable if they are less than 0.4 inches (10 mm) in diameter and 0.2 inches (5 mm) deep, and there are no more than 3 per cut surface.

7.3.3 **Visual Inspection Guidelines—Exterior Surface**

1. Hairline cracks up to 0.008 inches wide × 0.2 inches deep × 0.1 inches long (0.2 mm wide × 5 mm deep × 3 mm long) shall be acceptable. These are usually caused during pressing.
2. Perpendicular (radial) cracks to the hotface shall be acceptable if they are less than 0.02 inches (0.5 mm) wide, less than 0.2 inches (5 mm) deep, and less than 0.6 inches (15 mm) long.
3. Edge cracks that are parallel to the hotface shall be acceptable unless the total combined length is greater than 0.8 inches (20 mm) or the cracks are closer than 2 inches (50 mm) to the hotface.
4. Parallel cracks across the face shall be unacceptable unless they are hairline or surface crazing.
5. The number of cracks allowed in the bricks shall be as follows:
   a. Hotface—a single crack that meets the radial specification.
   b. Other faces—no more than two cracks per face, with the cracks totaling less than 25 percent of the surface length.
6. Edge chips shall be acceptable if they are less than 0.6 inches (15 mm) long and 0.2 inches (5 mm) deep.
7. Corner chips on the coldface shall be acceptable if less than 1.8 inches (45 mm) in peripheral length and 0.3 inches (8 mm) deep. On the hotface, corner chips shall be acceptable if they are less than 1.2 inches (30 mm) in peripheral length and 0.16 inches (4 mm) deep.
8. Voids shall be acceptable if they are less than 0.4 inches (10 mm) in diameter and 0.2 inches (5 mm) deep, and there are no more than six per brick, three per surface, or one on the hotface.
9. No cosmetic repairs shall be allowed.
7.4 Ceramic Ferrules

1. Ten percent of each lot of ferrules shall be measured for dimensional compliance.
   a. Dimensions shall be within ±0.0075 percent of the design value.
   b. If two pieces deviate from this tolerance, another 10 percent of the pieces shall be measured.
   c. If one piece of the second sample set is out of tolerance, the entire lot shall be inspected.

2. Ferrules shall be inspected for cracks, chips, and warpage. If any of these defects are found, that piece shall be rejected.

8.0 Packaging, Shipping, and Storage of Refractories

8.1 Monolithic Refractories

Packaging, shipping, and storage of monolithic refractories shall comply with requirements listed in IRM-SU-4785.

8.2 Shaped Refractories

8.2.1 Packaging and Shipping

1. The minimum packaging for shaped materials shall be palletized with cardboard between the layers and around the outside. External shrink-wrap shall cover the pallets.

2. If shipping overseas, the refractory shall be placed in weather-resistant containers and stored in the hold.

3. When the material is received, it shall be inspected for damage that occurred during shipment.

8.2.2 Storage Requirements

1. Material shall be stored in a dry and weatherproof building. Moderate temperatures (50°F–90°F [10°C–32°C]) shall be kept in the building.

2. Material shall not be piled directly on the floor or ground during storage.
   a. Outside storage immediately prior to or during installation shall be allowed if on firm, level, and well-drained ground.
   b. Material shall not be stacked more than two pallets high, and boards shall be used between layers.
   c. In addition to the shrink-wrap covering, a polyethylene cover or tarpaulin shall be securely placed over the stack of pallets.
9.0 Material Specifications

9.1 Monolithic Refractories

Monolithic refractories shall comply with specifications contained in IRM-SU-4785.

9.2 Insulating Firebrick

Insulating firebrick shall comply with specifications contained in ASTM C155.

9.3 High-Alumina, Creep-Resistant Brick

9.3.1 Required Properties

High-alumina, creep-resistant brick shall meet the requirements contained in Table 2 and Table 3.

Table 2: Chemical Composition for High Alumina

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Weight Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>&gt; 88</td>
</tr>
<tr>
<td>SiO₂</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Na₂O + K₂O</td>
<td>&lt; 0.2</td>
</tr>
</tbody>
</table>

Table 3: Physical Properties for High Alumina

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>Measurement Standard</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Density</td>
<td>ASTM C134</td>
<td>&gt; 185 lb/ft³ (2.96 g/cm³)</td>
</tr>
<tr>
<td>Apparent Porosity</td>
<td>ASTM C20</td>
<td>&lt; 18%</td>
</tr>
<tr>
<td>Cold Crushing Strength</td>
<td>ASTM C133</td>
<td>&gt; 11,000 psi (75.7 MPa)</td>
</tr>
<tr>
<td>Modulus of Rupture at 70°F (21°C)</td>
<td>ASTM C133</td>
<td>&gt; 2300 psi (15.8 MPa)</td>
</tr>
<tr>
<td>Hot Modulus of Rupture at 2700°F (1482°C)</td>
<td>ASTM C583</td>
<td>&gt; 1200 psi (8.26 MPa)</td>
</tr>
<tr>
<td>Load Test 25 psi (0.17 MPa) Load, 100 Hours at 3000°F (1649°C)</td>
<td>ASTM C16</td>
<td>&lt; 0.5% Linear Subsidence</td>
</tr>
</tbody>
</table>
9.3.2 Acceptable Materials

Acceptable materials for high-alumina, creep-resistant brick shall be as shown in Table 4.

Table 4: Acceptable High-Alumina Materials

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Material Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANH Refractories Company® (Harbison-Walker)®</td>
<td>Korundal XD®</td>
</tr>
<tr>
<td>Gouda Vuurvast</td>
<td>AK 94 M</td>
</tr>
<tr>
<td>Resco® Products, Inc.</td>
<td>Rescal® 90 XD</td>
</tr>
</tbody>
</table>

9.4 Ceramic Ferrules

9.4.1 Required Properties

Ceramic ferrules shall meet the requirements contained in Table 5 and Table 6.

Table 5: Chemical Composition for Ceramic Ferrules

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Weight Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>&gt; 94</td>
</tr>
<tr>
<td>SiO₂</td>
<td>4.0 typical</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>&lt; 0.2</td>
</tr>
<tr>
<td>Na₂O + K₂O</td>
<td>&lt; 0.2</td>
</tr>
</tbody>
</table>

Table 6: Physical Properties for Ceramic Ferrules

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>Measurement Standard</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Density</td>
<td>ASTM C134</td>
<td>&gt; 185 lb/ft³ (2.96 g/cm³)</td>
</tr>
<tr>
<td>Apparent Porosity</td>
<td>ASTM C20</td>
<td>&lt; 21%</td>
</tr>
<tr>
<td>Modulus of Rupture 70°F (21°C)</td>
<td>ASTM C133</td>
<td>&gt; 10,000 psi (68.8 MPa)</td>
</tr>
<tr>
<td>Modulus of Rupture 2700°F (1482°C)</td>
<td>ASTM C583</td>
<td>&gt; 2000 psi (13.8 MPa)</td>
</tr>
<tr>
<td>Thermal Shock Resistance</td>
<td>DIN 51068</td>
<td>&gt; 30 cycles</td>
</tr>
</tbody>
</table>

² ANH Refractories Company and Harbison-Walker are trademarks or registered trademarks of ANH Refractories Company. Korundal XD is a registered trademark of Harbison-Walker Refactories Corporation. Resco and Rescal are registered trademarks of Resco Products, Inc.
9.4.2 Acceptable Materials

Acceptable materials for ceramic ferrules shall be as shown in Table 7.

Table 7: Acceptable Ceramic Ferrule Materials

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Ceramics Limited</td>
<td>94% Alumina Thermal Shock Resistant</td>
</tr>
<tr>
<td>Blasch Precision Ceramics</td>
<td>94% Alumina</td>
</tr>
</tbody>
</table>

10.0 Installation

10.1 Brick Installation

1. Brick shall be laid with dipped mortar joints and brick joints shall be completely filled with mortar.
2. Brick joints shall be a nominal 1/32 inch (0.8 mm) thick with a maximum thickness of 1/16 inch (1.6 mm)
3. Joints on brick rings shall be installed so that joints are staggered from one ring to another and there are no straight-through joints.
4. No brick shall be cut to less than one-half of its original dimension.

10.2 Ferrule Installation

1. Ceramic ferrules shall not be reused after they have been in service. Heating and cooling weakens the ferrules, making their suitability for another cycle questionable.
2. The section inserted into the tube opening shall have enough ceramic fiber paper on it so that it fits snugly into the tube.
3. The hotface of the ferrule assembly shall be in the same plane as the other ferrules in the tubesheet lining. The thickness of the ceramic fiber gasket between the ferrule head and tubesheet shall be adjusted to achieve this.
4. Gaps between the ferrule heads greater than 1/8-inch (3-mm) thickness shall be filled with ceramic fiber paper or ceramic fiber moldable.
5. Hotface edges of the ceramic fiber paper between the ferrule heads shall be covered with 94 percent alumina, phosphate-bonded mortar. No mortar shall be placed between the ferrule heads.

11.0 Dry Out/Heat Up

1. Refractory lining shall be cured and dried in accordance with manufacturer’s recommendations.
2. The heat-up rate for a previously dried lining shall not exceed 100°F (56°C) per hour.