IN REFRACTORY LININGS:

“IT’S WHAT’S INSIDE THAT COUNTS”

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IN REFRACTORY LINING SYSTEMS

- It’s what’s inside that counts
- If it’s not good inside, it’s not good!
- It doesn’t matter how well a lining is installed
- It doesn’t matter how good the design is
- It doesn’t matter how good the materials are
- The only thing that matters is what’s inside – if it isn’t good inside, it isn’t good, and the war has been lost
WHAT ARE THE ISSUES THAT LEAD TO POOR REFRACTORY QUALITY?

- New refractory material can be bad refractory material
- The refractory installer may not be competent to install the refractory system as specified
- Good anchor installers can do inferior work
- Installation specifications may be lacking in detail
- Installation procedures may be incomplete incorrect, or non-existent
- The refractory design may be impractical or impossible to install
## WHAT ARE THE IMPLICATIONS OF POOR REFRACTORY QUALITY?

- Reduced refractory life: Inferior refractory linings will be replaced sooner than will high quality systems
- Increased maintenance that can lead to increased downtime
- Greater possibility of refractory failure resulting in emergency outage
- The cost of inferior refractory systems can be huge
- Kind of like the old Fram oil filter commercial: You can pay now or pay later

## HOW ARE THESE QUALITY PROBLEMS AVOIDED?

- Refractory Quality Control
  - Refractory material pre-installation certification by laboratory testing
  - Refractory installer pre-installation certification
  - Laboratory testing of field production samples
  - Continuous inspection during refractory lining installation
  - Approved refractory installer installation procedure
REFRACTORY MATERIAL CERTIFICATION
WHY TEST?

• Being new does not necessarily make a refractory material good
• Certification performed prior to refractory shipment from the manufacturer
• Acceptable physical properties are agreed on prior to placing any order
• Making sure that the physical properties of the materials shipped are as specified and agreed upon
• It’s what’s on the wall that counts

REFRACTORY MATERIAL DATASHEETS

Typical Refractory Datasheet

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion Loss</td>
<td>ASTM C 704</td>
</tr>
<tr>
<td>Maximum Service Temperature</td>
<td>2750°F (1510°C)</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>137 lb/ft³ (2192 kg/m³)</td>
</tr>
<tr>
<td></td>
<td>130 lb/ft³ (2080 kg/m³)</td>
</tr>
<tr>
<td>Cold Crushing Strength</td>
<td></td>
</tr>
<tr>
<td>1000°F (540°C)</td>
<td>9000-12000 psi (630-840 kg/cm²)</td>
</tr>
<tr>
<td>1500°F (815°C)</td>
<td>8000-11000 psi (560-770 kg/cm²)</td>
</tr>
<tr>
<td>2500°F (1400°C)</td>
<td>9000-12000 psi (630-840 kg/cm²)</td>
</tr>
<tr>
<td>Modulus of Rupture</td>
<td></td>
</tr>
<tr>
<td>1000°F (540°C)</td>
<td>1500-1900 psi (105-133 kg/cm²)</td>
</tr>
<tr>
<td>1500°F (815°C)</td>
<td>1400-1900 psi (98-126 kg/cm²)</td>
</tr>
<tr>
<td>2500°F (1400°C)</td>
<td>1500-1900 psi (105-133 kg/cm²)</td>
</tr>
<tr>
<td>Permanent Linear Change (%)</td>
<td>-0.1 to -0.3</td>
</tr>
<tr>
<td>Mean Temp. (°F)</td>
<td></td>
</tr>
<tr>
<td>1000°F (540°C)</td>
<td>7.4</td>
</tr>
<tr>
<td>1500°F (815°C)</td>
<td>8.0</td>
</tr>
<tr>
<td>2000°F (1095°C)</td>
<td>8.4</td>
</tr>
<tr>
<td>Conductivity or “K” Factor</td>
<td></td>
</tr>
<tr>
<td>Mean Temp. [BTU/h·ft²·°F/in]</td>
<td>W/m·K</td>
</tr>
<tr>
<td>1000°F (540°C)</td>
<td>7.4</td>
</tr>
<tr>
<td>1500°F (815°C)</td>
<td>8.0</td>
</tr>
<tr>
<td>2000°F (1095°C)</td>
<td>8.4</td>
</tr>
<tr>
<td>Typical Chemical Analysis (%)</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>5.1%</td>
</tr>
<tr>
<td>SiO₂</td>
<td>39.9%</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.7%</td>
</tr>
<tr>
<td>TiO₂</td>
<td>1.2%</td>
</tr>
<tr>
<td>CaO/MgO</td>
<td>6.6%</td>
</tr>
<tr>
<td>Alkalis</td>
<td>0.3%</td>
</tr>
<tr>
<td>Standard Packaging</td>
<td>72 - 55 lb. bags per pallet</td>
</tr>
</tbody>
</table>

Notes: Values are approximate results of standard ASTM tests, unless otherwise noted. Values may vary subject to normal variations in manufacturing, testing and installation procedures in the field.
### REFRACTORY MATERIAL DATASHEETS

- **The Disclaimer**
  - Refractory material manufacturers attach a disclaimer to their advertised data
  - Interpretation: We don’t guarantee you will get what we got

- **Avoiding the Disclaimer**
  - Determine ahead of time what properties are required for the work
  - Look at competitive datasheets
  - If the selected refractory material manufacturer cannot stand behind the properties required, buy somewhere else

### REFRACTORY MATERIAL TESTING

#### WHICH TESTS AND WHY

- **Density or Bulk Density**
  - Weight per unit volume of the refractory concrete
  - A reflection of insulating ability

- **Compressive (Cold Crushing) Strength**
  - The ultimate strength of the material in compression

- **Permanent Linear Change**
  - The percent change in length from the dried to the fired state

- **Abrasion Resistance**
  - A guide to the expected resistance to abrasion in service

- **How valid is the test data/how does it relate to reality?**
  - Room temperature tests/ why is it reliable?
  - Easy and inexpensive tests to perform
  - Red flag tests
REFRACTORY MATERIAL TESTING

Compression Modulus of Rupture

Abrasion Resistance Modulus of Rupture Measurements

Typical Laboratory Specimens

INSTALLER CERTIFICATION

- Not every refractory installer is able to do the work as specified even if he has done the same work in the past
- Installer demonstrates ability to do the work in advance of the actual refractory installation
- The installer uses Owner specifications and agreed-upon written installation procedures
- The adequacy of installer personnel is confirmed
- The adequacy of installer equipment is confirmed
INSTALLER CERTIFICATION
HOW IS IT DONE?

Vibration Casting  Pneumatic Ramming

Pneumatic Gunning

FIELD PRODUCTION TESTING
WHY TEST?

- A certified installer can do bad work
- Field sampling and testing keeps the installer alert to quality
- A record is provided of what’s on the wall, and it’s what’s on the wall that counts
- In event of failure, the owner has the knowledge to make an informed engineering decision regarding the problem
- If testing is not faithfully performed, quality suffers and cost goes up
REFRACTORY INSPECTION
WHY INSPECT?

- To confirm that the agreed upon specifications and procedures have been followed
- To provide a documented record of what has been installed on the wall, where it counts
- To provide information from which the owner can make educated refractory engineering decisions
- To assist the owner in making quality assessments of new or existing refractory lining systems
- Most importantly, to make certain that all refractory installations are of the best reasonable quality, that good service should be expected.

TYPICAL AREAS OF REFRACTORY INSPECTION

- Review material test reports
- Monitor site storage of refractory material
- Initial inspection of existing systems with repair recommendations
- Assure steel surfaces are properly repaired for refractory installation
- Verify refractory anchoring systems are as specified and properly installed
### TYPICAL AREAS OF REFRACTORY INSPECTION

#### Refractory Anchor Inspection

![Ref refractory anchor inspection](image1)

#### Surface Preparation

![Surface preparation](image2)

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#### TYPICAL AREAS OF REFRACTORY INSPECTION

#### Refractory Installation by Pneumatic Gunning

![Refractory installation by pneumatic gunning](image3)

#### Refractory Installation by Pneumatic Ramming

![Refractory installation by pneumatic ramming](image4)
TYPICAL AREAS OF REFRACTORY INSPECTION

Refractory Installation by Vibration Casting

Thermal Drying

Maintaining Lining Thickness

Visual Inspection and Hammer Testing
TYPICAL AREAS OF REFRACTORY INSPECTION

- Monitor all aspects of refractory preparation and installation:
  - Water content
  - Temperature control
  - Mixing time
  - Lining thickness
  - Joint construction
  - Form installation
  - Ambient curing procedures
  - Drying and firing
  - Visual inspection
  - Hammer testing

TYPICAL AREAS OF REFRACTORY INSPECTION
TYPICAL AREAS OF REFRACTORY INSPECTION

HOW TO CONTACT US

Robert J. Jenkins & Company
906 Medical Center Blvd
Webster, TX 77598

Phone: 281-332-3566
Fax: 281-332-3871

Email Contact: rjenkins@rjjenkins.com
Website: www.rjjenkins.com