


IN REFRACTORY LININGS:

**“IT’S WHAT’S INSIDE
THAT COUNTS”**



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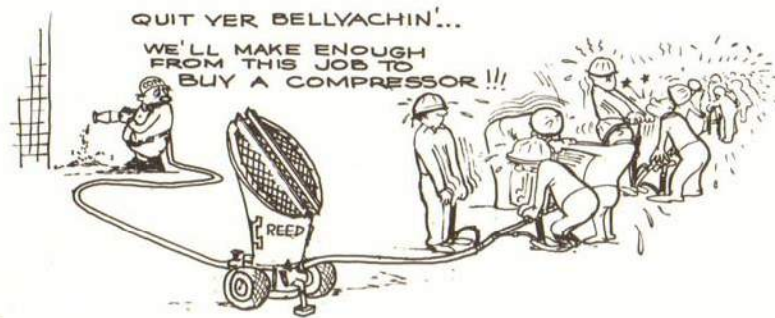
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IN REFRACTORY LINING SYSTEMS

- **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**

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DOES THIS LOOK FAMILIAR?



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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

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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**

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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**

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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

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REFRACTORY MATERIAL DATASHEETS

Typical Refractory Datasheet

Erosion Loss:	ASTM C-704	Less than 10 cc			
Maximum Service Temperature:		2750°F (1510°C)			
Bulk Density:					
	220°F (105°C)	137 lbs/ft ³ (2192 kg/m ³)			
	1500°F (815°C)	130 lbs/ft ³ (2080kg/m ³)			
Cold Crushing Strength:					
	1000°F (540°C)	9000-12000 psi (630-840 kg/cm ²)			
	1500°F (815°C)	8000-11000 psi (560-770 kg/cm ²)			
	2550°F (1400°C)	9000-12000 psi (630-840 kg/cm ²)			
Modulus of Rupture:					
	1000°F (540°C)	1500-1900 psi (105-133 kg/cm ²)			
	1500°F (815°C)	1400-1800 psi (98-126 kg/cm ²)			
	2550°F (1400°C)	1500-1900 psi (105-133 kg/cm ²)			
Permanent Linear Change(%):					
	1500°F (540°C)	-0.1 to -0.3			
	2000°F (1095°C)	-0.1 to -0.3			
Conductivity or "K" Factor:					
Mean Temp.	BTU/R ² -hr°F/in	W/mK			
1000°F (540°C)	7.4	1.07			
1500°F (815°C)	8.0	1.15			
2000°F (1095°C)	8.4	1.21			
Typical Chemical Analysis(%):					
Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	TiO ₂	CaO/MgO	Alkalies
51.1	39.9	0.7	1.2	6.8	0.3

Standard Packaging: 72 - 55 lb. bags per pallet

Data shown are average results of standard ASTM tests unless otherwise noted. Results may vary subject to normal variations in manufacturing, testing and installation procedures in the field.

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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

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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

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REFRACTORY MATERIAL TESTING

Compression



Modulus of Rupture



Abrasion Resistance



Measurements



Typical Laboratory Specimens



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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

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INSTALLER CERTIFICATION HOW IS IT DONE?

Vibration Casting



Pneumatic Ramming



Pneumatic Gunning



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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

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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.**

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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**

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TYPICAL AREAS OF REFRACTORY INSPECTION

Refractory Anchor Inspection



Surface Preparation



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TYPICAL AREAS OF REFRACTORY INSPECTION

Refractory Installation by Pneumatic Gunning



Refractory Installation by Pneumatic Ramming



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TYPICAL AREAS OF REFRACTORY INSPECTION

Refractory Installation by Vibration Casting



Thermal Drying



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TYPICAL AREAS OF REFRACTORY INSPECTION

Maintaining Lining Thickness



Visual Inspection and Hammer Testing



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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**

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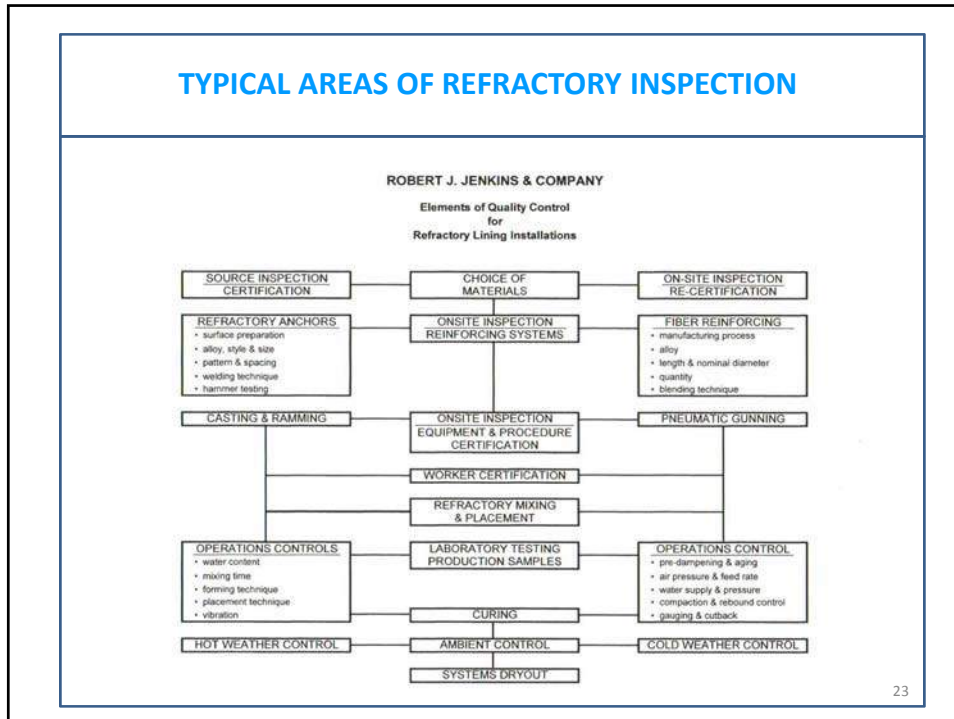
TYPICAL AREAS OF REFRACTORY INSPECTION

QUALITY CONTROL: KEY ELEMENTS

Elements	Actions	Objectives
Documentation	Permit Specification and/or approved installer execution plan	Define job specific workscope
Material qualification	Testing at independent laboratory	Confirm refractory materials are capable of achieving the specified physical property standards.
Applicator qualification	Installer demonstrates his capabilities using simulated installation. Witnessed and inspected by the refractory inspector.	Confirm equipment and personnel are capable of achieving specified standards
Monitor installation	Inspector monitors installer work and test sample preparation	Confirm that specifications, approved installation procedures and good refractory practice have been maintained
Testing during installation	Inspector coordinates sampling and testing of as-installed refractory materials.	Confirm installed refractory materials achieve specified physical property standards
Inspection before thermal dryout	Inspector visual/hammer test inspection of applied linings.	Confirm installed refractory linings meet specification standards
Inspection during thermal dryout	Refractory inspector monitors heating rates and hold times during thermal dryout.	Confirm the agreed-upon procedure is maintained
Inspection after thermal dryout	Refractory inspector visual/hammer test inspection of applied linings.	Confirm installed refractory linings meet specification standards

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TYPICAL AREAS OF REFRACTORY INSPECTION



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