REFRACTORY INSTALLATION AND MAINTENANCE

Furnace Integrity, Tapping Reliability, and Molten Material Transfer

SAIMM Pyrometallurgy Conference 2026 Workshop

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Why Installation and Maintenance Matter

The best refractory material in the world can still fail if it is poorly installed, poorly dried out or exposed to operating conditions that were not considered during design

Material selection is only the starting point

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Workshop Learning Outcomes

By the end of this workshop, delegates should be able to:

1. Explain how installation and maintenance quality affect furnace integrity, tapping reliability, molten material transfer, and campaign life.
2. Recognize key installation controls for brickwork, monolithics, expansion allowance, curing, dryout, and preheating.
3. Identify refractory risks in high-duty areas such as furnace linings, tapholes, tapping channels, launders, and ladles.
4. Relate operating conditions and tapping practice to refractory wear, repair life, and transfer reliability.
5. Interpret operational warning signs of refractory deterioration.
6. Apply practical QA/QC, inspection, and failure analysis principles to refractory installation and maintenance.
7. Communicate more effectively across process, maintenance, installation, and refractory specialist teams.

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Refractory Performance is a System

Refractory performance depends on the interaction between:

- Material selection and quality
- Lining design and detailing
- Installation workmanship
- Curing, dryout, and start-up
- Operating conditions
- Maintenance practice

Performance is determined by the installed, operated, and maintained lining system.

Refractory Supply to Installation

A refractory product only becomes a lining after it has been:

- Supplied, inspected, and stored correctly
- Installed to the design intent
- Cured, dried out, and heated up under control
- Exposed to real operating and maintenance conditions

The installed lining is what the furnace experiences.

A refractory product is not the same thing as a refractory lining

The Refractory Quality Chain

Refractory quality control should follow the material from supply to service:

- Supplier inspection and client inspection notification, where applicable
- Client / representative review of submitted data
- Client / representative inspections at the supplier
- Site receiving and storage checks
- Installation control and inspection
- Curing, dryout, and heat-up records
- Operating feedback and maintenance history

QA/QC creates the evidence trail from supplied material to installed lining.

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Pause and Think
Scenario 1: Correct Material, Early Failure

A refractory was selected for the correct process temperature and chemistry. However, the lining failed much earlier than expected.

Discussion Questions:

1. What should be investigated before concluding that the material was unsuitable?
2. What information would help distinguish between material, installation, operation, and maintenance-related causes?
3. What assumptions should be avoided during the initial failure review?

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The Molten Material Containment and Transfer System

Refractory-lined systems should not be viewed in isolation:

- Furnace lining provides primary containment
- Taphole and tapping channel control discharge
- Launders transfer molten material under controlled conditions
- Ladles provide mobile containment and process flexibility
- Weakness in one area can affect the performance of the full system

Furnace → Taphole → Tapping Channel → Launder → Ladle

Why Installation Quality Matters

Poor installation can create:

- Open pathways for slag, matte, metal, gas, or dust penetration
- Local weakness, movement, cracking, or instability
- Higher heat loss and shell temperature increases
- Reduced repair life and shortened campaign life
- Increased risk during tapping and molten material transfer

A correctly selected refractory can still underperform if it is installed poorly.

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Key Installation Controls

Installation quality depends on controlling the details that affect lining performance:

- Correct material in the correct location
- Surface preparation and cleanliness
- Brick fit, alignment, and joint control
- Monolithic mixing, placement, and compaction
- Expansion allowance and anchoring
- Curing, dryout, and heat-up readiness

Small installation details can have large in-service consequences.

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Brick Linings – Installation Control

Brick lining performance depends on controlled geometry and tight workmanship:

- Correct brick shape, grade, and orientation
- Joint thickness and joint cleanliness
- Bonding pattern, alignment, level, and radius
- Cutting quality and closure brick control
- Expansion allowance and dry joint control
- Progressive inspection as the lining is built

Brickwork quality is built row by row, course by course and therefore cannot simply be inspected at the end.

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Monolithic Linings – Installation Control

Monolithic refractory performance depends on control during mixing, placement, and curing:

- Correct material, batch, shelf life, and storage condition
- Surface preparation and anchoring
- Anchor type, spacing, orientation and attachment
- Water addition, mixing time, and working time
- Placement, vibration, ramming, or compaction
- Cold joint and layer thickness control
- Curing, dryout, and heat-up readiness

Monolithics develop their installed properties during installation.

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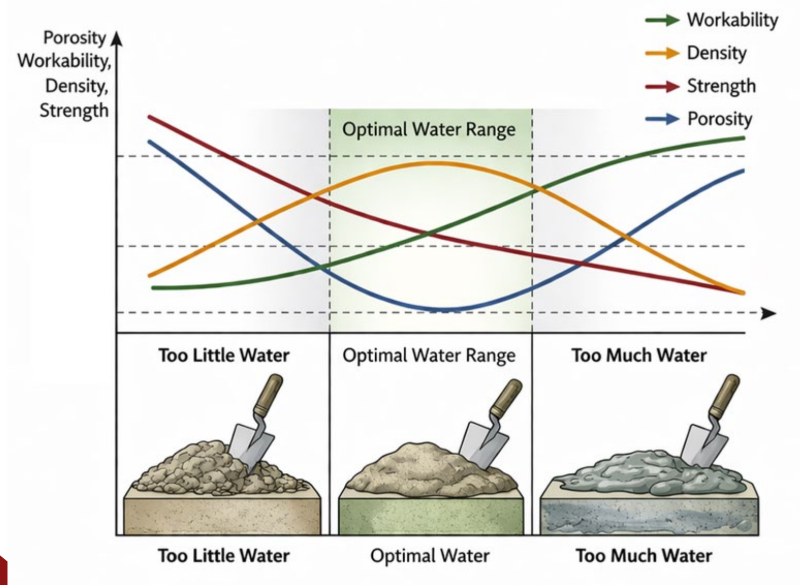
Why Water Addition Control Matters



Water addition controls both placement and final installed properties:

- Too little water can reduce workability, wetting, compaction, and bond development.
- Too much water can increase porosity, shrinkage, permeability, and dryout risk.
- The optimum range balances workability with density, strength, and dryout behaviour.
- Water addition should be measured and recorded, not judged by eye.

Water is an installation variable, not just a convenience.

Pause and Think
Scenario 2: Installation Looked Acceptable, Service Problems Developed

The refractory installation was completed and appeared visually acceptable. After start-up, one area showed higher shell temperatures, faster local wear, shorter repair life.

Discussion Questions:

1. What installation-related issues could cause this?
2. What evidence would you review?
3. What should have been checked before start-up?
4. What would be difficult to prove later if no installation records were kept?

Curing, Dryout, and Heat-Up

Curing, drying, and Heat-Up are not the same. Each stage has a different purpose:

- **Curing:** develops initial bond and structural integrity
- **Dryout:** removes free and chemically bound water
- **Heat-up:** brings the lining toward operating condition
- Each stage must be based on the material, thickness, and lining system
- Shortening one stage can compromise the next

Curing develops the lining.
Dryout removes water.
Heat-up prepares the lining for service.

Refractory Work Under Schedule Pressure

Refractory work often occurs late in the project or shutdown sequence:

- Earlier delays are often pushed into the refractory window
- Installation, curing, dryout, and heat-up may come under pressure
- Inspection hold points may be shortened or bypassed
- Repair scope may be reduced to recover time
- Short-term schedule recovery can create long-term furnace integrity risk

The refractory installation, dryout, and heat-up window is one of the worst places to recover lost project time by removing technical controls.

Where Time Can be Saved – and Where it Should Not be Forced

Time savings should come from planning, engineering, and better project controls:

- Early supplier and QA/QC involvement
- Pre-approved installation, curing, dryout, and heat-up procedures
- Material selection suited to the required installation, dryout and service duty
- Controlled storage, access, sequencing, and work-front readiness
- Adequate burner control, ventilation, thermocouple placement, and monitoring
- Supplier-approved fast-dryout systems, where suitable

Dryout can sometimes be optimized — but it should not be improvised.

Improving dryout behaviour must not compromise the properties required for service.

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Pause and Think Scenario 3: Shortened Dryout/Heat-Up

- Refractory installation finished late
- Start-up date is fixed
- Dryout/heat-up schedule is reduced to recover time
- After return to service, cracking and hot spots appear early

Discussion Questions:

1. What risks were introduced?
2. What evidence would you review?
3. What should have been challenged before start-up?
4. Was the dryout optimized – or simply shortened?

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Pause and Think Scenario 4: Heating Interruption During Dryout or Heat-Up

The dryout was planned and executed properly BUT during dryout / heat-up:

- A burner trips or heating is lost
- Lining temperatures begin to fall
- Steam release or expansion movement may not be complete
- The team wants to restart and continue the original curve

Discussion questions

1. What risks are introduced for monolithic linings?
2. What risks are introduced for shaped refractory / brick linings?
3. Can the original curve simply be resumed?
4. What evidence should be reviewed before reheating?
5. Who should approve the revised restart plan?

A heating interruption should trigger technical review before continuing.

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Thermal Expansion and Lining Movement

Refractory linings must be able to move as they heat up and cool down:

- Different materials expand at different rates
- Expansion allowance must be designed and installed correctly
- Expansion joints, papers, dry joints, and compressible layers must remain clean and correctly positioned
- Inadequate movement allowance can cause crushing, cracking, spalling, or displacement
- Excessive or poorly located gaps can become penetration paths

Expansion allowance is a controlled design feature, not simply extra space.

Expansion Allowance – Installation Risks

Expansion details must be installed exactly as intended:

- Expansion papers, dry joints, and compressible layers must be correctly located
- Expansion gaps must be protected from debris, mortar, dust, slag, or ramming material
- Field changes must be technically reviewed and documented
- Cooling elements can affect whether expansion paper burns out as intended
- Poor expansion control can create restraint, movement, or penetration paths

The aim is controlled movement — not uncontrolled gaps or unintended restraint.

Tapholes and Tapping Channels

Tapholes and tapping channels are exposed to combined refractory wear mechanisms:

- High temperature molten material flow
- Slag, matte, metal, and gas interaction
- Drilling, lancing, cleaning, and mechanical damage
- Thermal cycling during opening, tapping, and closing
- Repeated repair and maintenance interventions

Tapping reliability depends on both refractory condition and operating practice.

Operational Warning Signs Around Tapping

Changes in tapping behaviour can indicate developing refractory or process issues:

- Increased drilling time or oxygen lancing
- Higher taphole clay consumption
- Unstable tap stream or change in stream direction
- Increased slag carryover
- Local shell temperature increase
- Shorter repair life or more frequent taphole repairs

Treat changing tapping behaviour as a refractory integrity signal, not only an operating issue.

Taphole Repairs – Restoring Function, Not Just Filling Damage

A taphole or tapping-channel repair should restore:

- Geometry and flow path
- Containment and wear resistance
- Bond to existing refractory
- Compatibility with process conditions
- Readiness for curing, dryout, and return to service

The repair should address the underlying failure mechanism, not only the visible damage.

When There is No Sound Refractory to Key Into

A repair cannot perform if it is placed onto an unstable substrate.

- Weak, cracked, infiltrated, glazed, or friable refractory must be reassessed
- Repair boundaries may need to be extended beyond the visible damage
- Additional demolition or replacement may be required
- The repair detail may need engineering review and approval
- Curing, dryout, and return-to-service requirements may change
- *A poor taphole repair is not only a maintenance issue; it can become a furnace containment and safety issue.*

If there is no sound refractory to key into, the repair has become an engineering decision.

If the repair cannot be keyed into sound refractory, continuing with the original repair scope may only delay the failure rather than correct it.

Launders – Refractory Risks During Molten Material Transfer

Launders must maintain controlled flow while resisting severe service conditions:

- High-temperature slag, matte, or metal flow
- Heat loss and skull / buildup formation
- Thermal cycling and preheating requirements
- Erosion at impact zones and flow transitions
- Cleaning damage and repeated maintenance

Launder reliability depends on refractory condition, flow control, preheating, and maintenance practice.

Ladles – Mobile Refractory Containment Systems

Ladles experience severe refractory duty because they combine containment, transfer, and process flexibility:

- High-temperature molten material and slag exposure
- Slag-line wear and chemical attack
- Thermal cycling from filling, emptying, and turnaround
- Preheating, holding time, and temperature-loss effects
- Cleaning, skull removal, patching, and repair quality

Ladle reliability depends on lining condition, preheating practice, turnaround time, and maintenance discipline.

Linking Tapholes, Launders, and Ladles

Molten material transfer problems should be reviewed as a connected system:

- Taphole condition affects flow stability into the launder
- Launder preheating and condition affect temperature loss and buildup
- Slag carryover can increase launder and ladle refractory wear
- Ladle preheating and turnaround affect lining performance
- Repeated repairs may indicate an unresolved system issue

Do not repair one component without considering the full transfer path.

Investigating Transfer System Deterioration

When tapping or transfer performance deteriorates, review both refractory and process evidence:

- Taphole and tapping-channel condition
- Launder preheat, buildup, cleaning, and repair history
- Ladle preheat, turnaround, slag-line wear, and patching frequency
- Tapping temperature, duration, frequency, and flow stability
- Slag/matte chemistry, slag carryover, and operating changes
- Inspection records, photographs, QA/QC records, and shell temperature trends

Treat deterioration as a system problem until the evidence shows otherwise.

Pause and Think Scenario 5: Tapping and Transfer System Deterioration

The taphole condition appears manageable, but :

- Launder cleaning is becoming more frequent
- Ladles require more patching
- Tap-to-ladle temperature losses have increased
- Tapping appears less stable.

Discussion Questions:

1. What process and refractory factors could be linked?
2. What information would you request?
3. What should be investigated before deciding on the next repair?

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QA/QC Inspection – Building the Evidence Trail

Refractory QA/QC supports both installation quality and future failure analysis:

- Confirms supplied materials meet specification
- Verifies installation against drawings, method statements, and ITPs
- Records hold points, deviations, concessions, and field changes
- Documents curing, dryout, heat-up, and release to service
- Provides evidence for troubleshooting and root cause failure analysis

QA/QC helps confirm design intent was followed and preserves the evidence trail for future troubleshooting.

Root Cause Failure Analysis – Evidence Before Conclusions

A failure investigation should consider:

- Material selection, supply quality, and storage
- Installation workmanship and field changes
- Curing, dryout, heat-up, and commissioning
- Operating conditions and process chemistry
- Maintenance methods and repair history
- QA/QC records, photographs, and inspection evidence

Failure analysis should be evidence-led, not blame-led.

The visible damage is not always the root cause.

Communication Across Teams

Refractory reliability depends on clear communication between:

- Process and operations teams
- Maintenance and project teams
- Installation contractors
- Refractory suppliers
- QA/QC representatives and inspectors
- Refractory specialists / engineering representatives

Good refractory decisions require shared evidence, not isolated assumptions.

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Questions to Ask Before Acting

Before deciding on repair, operation, or escalation, ask:

- What changed?
- What evidence do we have?
- Is the issue local or system-driven?
- Does the repair address the wear mechanism?
- Are the right specialists involved?
- Are we making a technical decision or a schedule decision?

Better questions lead to better refractory decisions.

The objective is to correct the cause of the failure, not only replace the lost refractory.

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Maintenance Decision Making – Repair, Monitor, or Escalate

Not every refractory concern requires the same response:

- **Repair:** when the scope, substrate, material, and return-to-service controls are understood
- **Monitor:** when deterioration is observed but stable, risk is understood, and clear inspection intervals and escalation triggers are defined
- **Escalate:** when there is uncertainty, repeated failure, no sound substrate, hot spots, or containment risk
- Decisions should consider both refractory evidence and operating data
- Schedule pressure should not override furnace integrity risk

The response should match the risk, not just the available shutdown window.

Repair, monitor, or escalate – but do not ignore!

Case Study

Furnace-to-Ladle Transfer System Deterioration

Following a maintenance shutdown:

- Refractory installation and dryout were compressed to recover schedule.
- Tapping became less stable within weeks of start-up.
- Drilling time, oxygen lancing, and clay consumption increased.
- The launder required more frequent cleaning.
- Ladles showed increased slag-line wear and patching frequency.
- A local shell temperature trend near the tapping area increased.

Discussion Questions:

1. What are the possible refractory-related contributing factors?
2. What are the possible process-related contributing factors?
3. What evidence would you request?
4. How would supply and installation QA records help with the investigation?
5. What should be investigated before deciding on the next repair?
6. What assumptions should be avoided?

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Case Study Discussion

Working Through the Evidence

Use the case study to work through the investigation sequence:

1. Identify the symptoms and affected areas
2. Separate possible refractory and process contributors
3. Review supply, installation, dryout, and operating evidence
4. Compare current performance with historical performance
5. Decide whether the issue is local or system-driven
6. Define the next repair, monitoring plan, or escalation based on risk

Do not move from symptom to repair without understanding the likely failure mechanism.

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Practical Checklist for Refractory Installation, Repair, and Failure Review

Before accepting, repairing, or returning a refractory-lined system to service, ask:

1. Has the correct material been supplied, inspected, and stored correctly?
2. Was the lining installed to the approved design and method statement?
3. Were critical hold points, field changes, and non-conformances closed out?
4. Was curing, dryout, and heat-up completed and recorded?
5. Are current symptoms consistent with historical performance?
6. Does the response match the refractory integrity and safety risk?

Good refractory practice is built on control, evidence, and disciplined decision-making.

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Key Workshop Takeaways

- Refractory performance is influenced by the full chain: supply, storage, installation, dryout, operation, and maintenance.
- Installation quality, curing, dryout, and heat-up directly affect furnace integrity.
- Refractory failures should be investigated across the full system before narrowing the cause to one component or discipline.
- QA/QC helps confirm design intent was followed and preserves the evidence trail for future troubleshooting.
- Refractory decisions should be based on risk, evidence, technical judgement, and cross-team communication.

The goal is not only to complete the refractory work, but to return a controlled, serviceable lining system to operation without compromising safety or containment.

Questions and Discussion

Consider:

- What refractory issue have you seen that was difficult to diagnose?
- Where does your site most often lose refractory quality control?
- What information is usually missing during failure investigations?
- What is one question you will ask differently after this workshop?

Good refractory decisions require evidence, communication, and technical discipline.

Thank you!

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