INNOVATIVE REFRACTORY TECHNOLOGIES FOR STEEL LADLE SAFETY AND EFFICIENCY (KEROLAN & LICODRY)

Presented at the REFRACTORIES, FURNACES AND THERMAL INSULATIONS — XIII. International Scientific Conference, 2025

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Abstract

Steel ladles operate under extreme thermal and mechanical conditions, facing continuous cycles above 1600 °C, slag corrosion, and thermal shock. Their safety lining plays a decisive role in preventing breakouts, improving heat-up efficiency, and ensuring reliable operation.

This paper presents two distinct innovations by Linco Baxo Industrie Refrattari S.p.A.: Kerolan, a dry-ramming alumina-based family designed for ladles using dolomite bricks (MgO-Cao) working linings, and Licodry, a colloidal-silica bonded castable optimized for ladles using magnesite - carbon bricks (MgO-C) working linings.

Both materials eliminate free water, shorten pre-heating time, and improve campaign life. Laboratory data and industrial case studies demonstrate improved thermal shock resistance, safety performance, and reduced energy consumption.

I. Introduction

Modern steelmaking relies on safe and reliable ladle operations. A ladle's refractory lining typically consists of a working lining, a safety lining, insulation, and a steel shell. The safety lining provides mechanical support, compensates for expansion of the working lining, and serves as the final protection barrier against steel penetration.

In recent years, increasing productivity and energy efficiency targets have made it essential to reduce pre-heating times, minimize spalling risk, and prevent moisture-induced explosions. Conventional cement-bonded castables and gunning mixes often suffer from retained water and shrinkage during drying, leading to cracking or spalling.

To address these issues, Linco Baxo developed two monolithic ladle safety systems:

- Kerolan, a dry-ramming alumina-based family for ladles with dolomite bricks (MgO-Cao) working linings, offering dense, water-free protection for high-impact and corrosion zones;

- Licodry, a colloidal-silica bonded, cement-free castable for ladles with magnesite-carbon bricks working linings, offering chemical compatibility, fast commissioning, and superior refractoriness.

Each solution targets a different operational philosophy and brick system while sharing the same goals: enhanced safety, reduced downtime, and improved lining service life.

II. Materials & Methods

a) Kerolan (dry-ramming alumina-based)

Kerolan is a family of alumina-based dry-ramming mixes developed for use as the safety lining in steel ladles equipped with dolomite bricks (MgO-Cao) working linings. The technology eliminates water addition, enabling direct heat-up without curing or drying.

Two main grades are available:

- **Kerolan 780 SR:** Designed for the *spout, slag line, and upper wall* regions exposed to high thermal gradients, mechanical impact, and aggressive slag attack.
- **Kerolan 880**: Formulated for *ladle bottoms and lower walls*, where compressive load and static resistance dominate.

Both materials are installed by pneumatic ramming in 25–50 mm lifts to target densities above 2.6 g/cm³. No water or cement is used; mechanical compaction creates a joint-free, low-permeability monolith.

Linco Baxo Industrie Refrattarie KEROLAN

Technical Data

	Kerolan 780 SR	Kerolan 880
Typical Chemical Analysis		
▪ Al_2O_3	80%	89%
▪ SiO_2	1,5%	8%
▪ SiC	15%	
▪ Fe_2O_3	0,3%	0,3%
Main features		
▪ Size	0-6 mm	0-6mm
▪ Density	2750kg/mc	2700kg/mc

Figure 2 - Typical properties of Kerolan 780 SR and Kerolan 880

b) Licodry (colloidal silica-bonded castable)

Licodry 95 is a high-alumina (94 % Al_2O_3) castable bonded with colloidal silica instead of hydraulic cement. It is designed for ladles lined with magnesite carbon bricks, where chemical compatibility and zero-water installation are essential.

The colloidal binder forms a continuous SiO_2-gel network during setting, providing mechanical strength at room temperature and a direct path for sintering. Unlike low-cement or ultra-low-cement castables (LCC/ULCC), Licodry contains no hydrated phases, eliminating steam-spalling risk.

Mixing is carried out with the dedicated silica-sol binder—no additional water. After vibration, the material gels within minutes, allowing controlled heating up to 1000 °C within ≈ 4 h.

Property	Colloidal Silica Bonded	LCC	ULCC
Drying behavior	Excellent – no hydraulic water, lower risk of explosive spalling	Moderate – water from cement hydration must be removed slowly	Better than LCC but still needs controlled drying
Porosity	Very low after sintering (10–13 %)	14–18 %	12–15 %
Bulk density (g/cm^3)	2.8–3.1 (depending on base aggregate)	2.6–2.9	2.7–3.0
Cold crushing strength (MPa)	80–120 MPa after 1000 °C	60–100 MPa	80–120 MPa
Hot modulus of rupture (MPa @ 1500 °C)	8–12 MPa	6–8 MPa	8–10 MPa
Thermal shock resistance	Excellent	Good	Very good
Corrosion resistance (slag/metal)	Excellent – no CaO, low wetting	Moderate (CaO promotes slag attack)	Good to excellent
High-temperature strength retention	Excellent (due to pure oxide bonding)	Decreases above 1400 °C	High up to 1600 °C

Figure 2 - Typical properties of Licodry 95 vs reference ULCC/LCC systems

III. Results

a) Thermo-mechanical performance

Laboratory results confirm the superior thermal stability and mechanical strength of both product families. Kerolan grades exhibit high cold crushing strength (up to 70 MPa) and negligible permanent linear change, indicating dimensional stability under repeated cycling. Their high density ensures minimal slag infiltration.

Licodry 95 shows comparable CCS and hot modulus of rupture (HMOR) values to best-in-class ULCC / LCC systems but achieves equivalent mechanical performance after half the pre-heating time. The absence of free water drastically reduces the risk of explosive spalling during first heat-up.

Colloidal Silica bonded systems allow faster and safer heating-up, reducing installation and drying time.
Compared to LCC and ULCC, they minimize cracking risks and cut overall start-up costs, thanks to shorter furnace downtime and no need for long dry-out cycles**.**

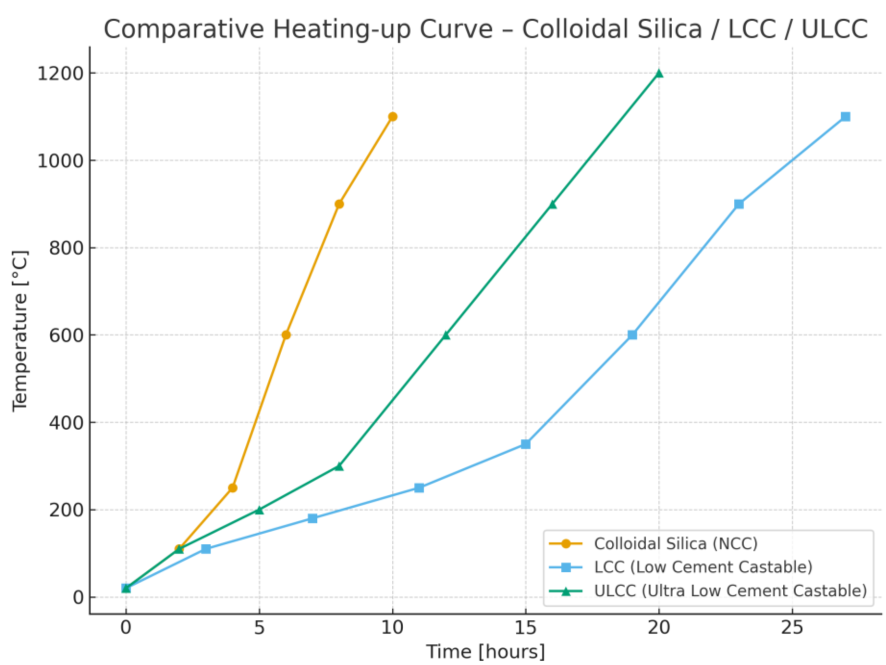

Figure 3 - Heat-up curve comparison: Licodry 95 vs ULCC/LCC

b) Thermal shock and corrosion resistance

Thermal-shock tests (ASTM C1171) confirm that Kerolan maintains structural integrity after 35 rapid cycles between 1200 °C and room temperature

Licodry 95 also shows excellent resilience due to its fine particle bond network and absence of microcracking from hydrated phases.

c) Slag interaction and chemical compatibility

Kerolan's SiC and high-alumina matrix resist basic slag corrosion, making it ideal for use behind dolomite bricks working linings.

Licodry, with its pure alumina composition and colloidal binder, is neutral to slightly acidic in character and chemically stable against magnesite

bricks and iron-rich slag phases.

IV. Discussion

The results demonstrate that Kerolan and Licodry address distinct industrial needs rather than competing applications.

- In dolomite bricks (MgO-Cao) lined ladles, Kerolan provides mechanical and thermal compatibility with the alkaline working lining, ensuring high-density contact and minimal differential expansion. The inclusion of SiC improves heat transfer and reduces local over-heating, preventing shell deformation.
- In magnesite-carbon briks lined ladles, Licodry 95 serves as an advanced safety layer that can be installed rapidly and brought to temperature without staged drying. This is particularly advantageous in operations with limited turnaround time or frequent relining.

Both systems improve operational safety by removing water from the installation process, energy efficiency by reducing pre-heating time, and maintenance scheduling by extending campaign duration.

The choice between Kerolan and Licodry depends primarily on the type of working lining and slag chemistry, not on relative performance. Each is an optimized solution for its own context.

V. Case Insights

Case A – Basic oxygen furnace ladle (bottom zone, dolomite bricks lining):

Kerolan 880 was installed as a monolithic safety lining beneath dolomite bricks (MgO-Cao). No dry-out was required, and the campaign life increased by c. 30 % compared to a traditional castable system. Thermal profiles showed lower temperature gradients and reduced heat-loss through the shell.

Case B – Electric arc furnace ladle (magnesite cabon bricks lining):

Licodry 95 replaced a low-cement castable safety layer. The first heat-up was completed in 24 h vs 48 h previously, with no steam-spalling events. Ladle availability improved by one shift per campaign, saving energy and reducing risk of lining failure.

Case C – Spout and slag line area (dolomite lining):

Kerolan 780 SR demonstrated twice the service life of the previous gunning mix due to enhanced shock resistance and dense microstructure. Surface analysis after removal showed limited slag infiltration and no separation at the brick interface.

VI. Implementation Guidelines

Kerolan application:

Kerolan is applied at the same time of the erection of bricks wear layer; Kerolan is dry rammed into the gap among the steel structure/insulation and the wear lining When the ladle is heated up , Kerolan sinters and hardens, achieving the required mechanical resistance

- Ram in successive 25–50 mm layers using pneumatic tools.
- Target density ≥ 2.6 g/cm³.
- No curing or drying stage required; direct heat-up possible.
- Suitable for bottoms, walls, spout zones in dolomite bricks lined ladles.

Licodry application:

- Mix aggregate with colloidal silica binder only (no water).
- Cast and vibrate; allow chemical gelation (30–60 min).
- Controlled heat-up up to 1000 °C within ≈ 24 h.
- Compatible with magnesite bricks working linings and fast-cycle operations.

Quality & HSE considerations:

- Perform standard ASTM/EN tests (CCS, MOR, density, visual inspection).
- Observe HSE measures for dust and silica handling (PPE, ventilation, waste disposal).
- Store in dry conditions (< 30 °C, < 60 % RH).

Characteristic / Aspect	Kerolan	Licodry 95
Type / Method	Dry ramming material applied simultaneously with the erection of the brick working lining	Aggregate mixed with colloidal silica binder (no water added)
Main Purpose / Use	Filling the gap between steel shell, insulation, and working lining; forms a sealing layer that sinters during ladle preheating	Used for creating linings compatible with magnesite brick working linings, suitable for fast-cycle operations
Preparation / Mixing	Ready-to-use dry ramming mass, no addition of liquids required	Mix aggregate with colloidal silica binder only (no water)
Installation	Dry-rammed into the gap during brickwork erection; applied progressively	Cast and vibrate; allow chemical gelation (30–60 min) before heating
Initial Phase Duration	No pre-drying required	Chemical gelation: 30–60 minutes before start of heat-up
Heating / Sintering	During ladle preheating, Kerolan sinters and hardens, achieving required mechanical strength	Controlled heat-up up to approx. 1000 °C within ~ 24 hours
Compatibility	Compatible with various working linings (e.g., magnesite)	Fully compatible with magnesite brick linings; suitable for rapid operation cycles
Typical Advantages	No pre-drying, applied together with brick lining, develops strong mechanical properties after sintering	Simple process (no water), controlled heat-up, avoids water-related shrinkage
Limitations / Critical Points	Performance depends on proper compaction and uniform sintering during preheating	Requires precise temperature control; correct gelation essential; lower initial plasticity due to absence of water
Available Grades / Variants	Examples: Kerolan 880 (sidewalls), Kerolan 780 SR (slag zones)	Variants possible depending on binder ratio and aggregate composition

Figure 4 - Recommended installation and preheat schedule for Kerolan and Licodry systems

VII. Conclusions

Kerolan and Licodry represent two innovative monolithic solutions for ladle safety linings, each tailored to its respective working lining system:

- Kerolan for dolomite brick (Mgo-caO) configurations, combining mechanical strength, shock resistance, and chemical compatibility.
- Licodry for magnesite brick (Mgo-C) configurations, combining cement-free purity, fast commissioning, and superior refractoriness.

Both systems eliminate free water, reduce heat-up time, improve energy efficiency, and enhance safety by preventing steam-explosions and lining failures.

The choice between them depends on plant practice and chemical compatibility rather than direct performance comparison.

Field experience shows extended campaign life, improved reliability, and lower total cost of ownership for modern steelmaking operations.