Refractory Alternatives to Combat Elephant's Foot Erosion and Top Cap Wear in Coreless Furnaces

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Traditional Furnace Lining

- Coreless melting of ductile based iron has been used for 50+ years, now has become a preferred melt system.

- Advantages
  - Melting of low S scrap
  - Flexible operations
  - Low emissions
  - New power technology
Traditional Lining Methods

- SiO₂ with Boric Acid or Boron Oxide binder

- Advantages
  - Inexpensive
  - Excellent thermal shock resistance
  - Good resistance to iron and slag penetration
Expansion Properties

![Graph showing linear expansion vs. temperature for magnesia, silica, chrome, alumina, and zircon. The x-axis represents temperature in °F, ranging from 0 to 2800, and the y-axis represents linear expansion in percentage, ranging from 0 to 2.0. Each material has a distinct curve, with magnesia showing the highest expansion and zircon the lowest.](image-url)
Traditional Furnace Lining

- Disadvantages
  - Relatively weak strength
  - Lowest refractoriness of the major refractory components
  - Phase transformation requires extended sinter time
Elephant’s Foot Erosion

- Severe erosion in the bottom 5 – 15% of the furnace sidewall

- Causes
  - Heel Melting
  - High Temperature
  - Ductile Base
Elephant’s Foot Erosion

- Medium frequency, batch melting furnaces not as affected

- Process improvements
  - Installation
  - Temperature control
  - Charge selection
  - Sintering
Silica enhancements

- Zircon
- Chrome
- Fused Silica
- Carbon, SiC

Product remains silica based
Alumina Lining Alternatives

- Andalusite based
- Optimized for thermal shock resistance
Previous alumina lining trials
Candidates for andalusite

- Severe taper or elephant’s foot erosion
- Limited thermal cycling
  - Heel melting
  - Good torch control when out of operation
- Short or erratic lining life
Alumina Advantages

- Quicker sinter – 400 °F/hr or 220°C/hr
- Eliminates elephant’s foot erosion
- Upper sidewalls will erode evenly
- Can be easier removal/push out
Comparison of grain structure
Can alumina and silica be zoned?

- Eutectic point is formed below iron melting temperature
- Zoning has been normally limited to the top cap area
Top Cap Issues

- Area above the active power coil
- Heat exposure is radiant except during pouring
- This area is the primary maintenance point for many coreless applications
Exposure Conditions

- Impact from charge
- Thermal shock cracking (temperature difference)
- Separation of top cap lining from primary lining
Temperature Difference

- Large pollution systems cause a difference in temperature at the top of the furnace.

- Large temperature differences result in cracking and seam separation.
Impact from Charging

- If charge material is loaded by magnet or shaker, it can impact the top cap and wear the refractory.
Separation

- Different material classifications and minerals do not always bond completely.
Major Problem of Metal Leakage to Coil

- If the top cap is not maintained, metal can leak from seam to contact coil, creating electrical ground.
Procedure to Install Top Cap

- Two different materials require a “transition” layer.
- This layer will minimize seam separation.
- Use normal procedure for working lining, add 50% working lining material and 50% top cap material, mix vigorously.
- Continue normal procedure.
Coreless furnace are designed to operate with metal level at the high of the active coil.

Only at the sintering, to get better results at the top area, metal must go up to the spout area.
Top Cap Sinter

Operate this level only on sinter heat
Refractory Families for Top Cap

- Silica-based dry vibratables
- Fused silica-based dry vibratables
- Alumina-based dry vibratables
- Castable
- Plastic and plaster
- Wash coating
Silica Based Dry Vibratables

Procedure
- Increase bond content to 1.5 – 1.8 % B.O. (2.5% B.A.)

Advantages
- No seam separation (mineral base is the same)
- Low cost mineral

Disadvantage
- Not very good at resisting mechanical impact
Fused Silica Based Dry Vibratable

Material
- Quartz based with fused silica addition of 15 – 50%.
- Bonded by boron oxide or boric acid

Advantages
- No seam separation (mineral base is the same)
- Excellent thermal shock properties

Disadvantage
- Not very good at resisting mechanical impact
Alumina Based Dry Vibratatables

Material Selection
- Material can be based on chamotte, bauxite, mullite, or andalusite

Advantages
- High strength for impact resistance
- Good sintering properties

Disadvantage
- Seam will separate between materials
- Area between top cap (alumina) and working lining (quartz) is low temperature eutectic
Castable

Materials
- Low cement or no cement castables based on chamotte, mullite, andalusite, or bauxite

Advantages
- Very high strength

Disadvantage
- Must be dried out
- Requires mixer to install
- Consideration for keeping moisture from working lining
Castable Installation

Moisture separation barrier

Castable installation
Top Cap Comparison

Dry Vibratable

Castable

After 200 tons throughput
Plastic and Plaster

Material Selection
- Material can be based on chamotte, bauxite, mullite, or andalusite
- Phosphate or air set binder

Advantages
- High strength for impact resistance
- Can be installed with or without form

Disadvantage
- Seam will separate between materials very easily
- Dryout is necessary
New Technology – Fiber Reinforced Dry Vibratable

- Chamotte based dry vibratable with stainless steel fiber addition
- Excellent toughness
- Virtually eliminates cracks
- Expansion to match silica lining
Modulus of Rupture Comparison
Summary

- Audit operation and wear mode to see if alternative lining materials are applicable.

- Identify wear mode in top cap
  - Mechanical impact
  - Thermal shock
  - Seam separation

- New technology of fiber containing dry vibratable addresses issues
Thank You!