Refractories / Refractory Dryout
&
Burner Technology

2 Fundamental Requirements for a successful dryout

- The use of the proper equipment.
- The knowledge and experience to utilize that equipment effectively in order to maximize the benefits of a proper dryout.

High Velocity Burner Technology

- Developed and Patented in UK & USA in early 1960's
- 100:1 Turndown ratio
- Energy output of 100,000 – 10 million BTU's per hr.
- Excellent temperature control through full output range
- High volume excess air – 100,000 scfh (2832 cu. meters / hr)
- Permits faster, more uniform & efficient heating /drying
- Operates under positive or negative pressure

***Note*: Most burners cannot maintain ignition at 100% combustion air and low energy output.**

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High Velocity Burner Technology (cont'd)

- Nozzle discharge velocity – 450ft. per second (137 meter / second)
- Spark plug ignition / UV flame scanning
- Convective vs Radiant Heat
- Hotwork-USA original Licensee in 1965

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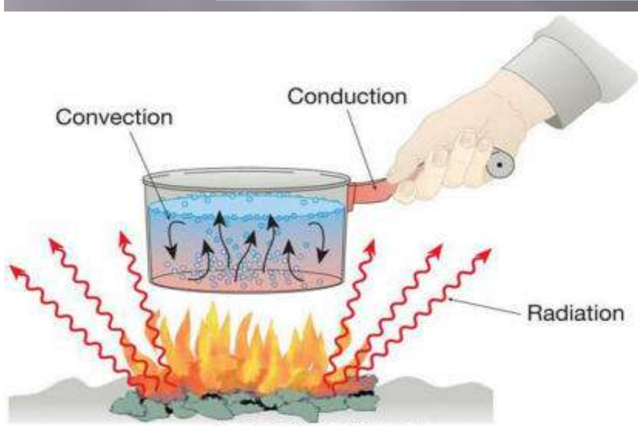
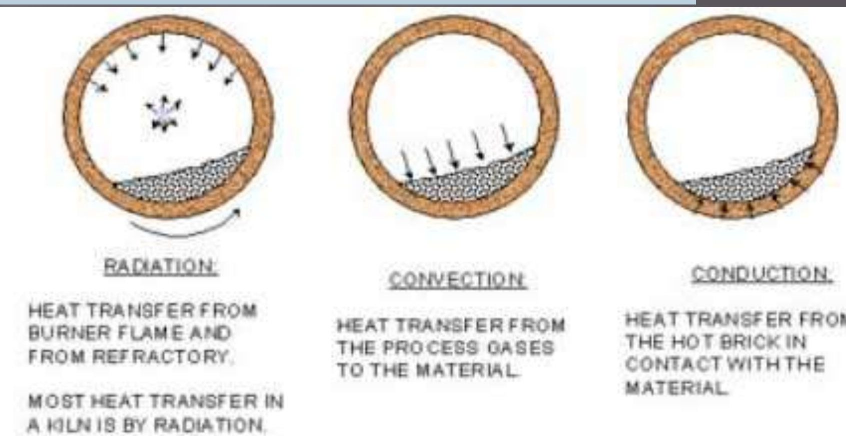
Types of Heat Transfer

- Conduction, Radiation, Convection

Table 1: Three Types Of Heat Transfer

Conduction heat transfer	Radiation heat transfer	Convection heat transfer
• Heat flows from a hot part of one body to a cooler part on another body. • The two bodies must be in contact with each other. • Conduction is the primary mechanism for heat transfer between solids. • Fourier's law governs conduction heat transfer.	• Heat is exchanged between two or more bodies. • It's defined as electromagnetic radiation in the wavelength range of 0.1 to 100 µm (including visible light). • It's the only means of heat transfer between entities separated by a vacuum, such as heat radiated from the sun to the Earth.	• Heat is transferred between a solid surface and a moving fluid at a different temperature. • Natural convection occurs when the solid's temperature is due to a natural, external fluid motion. • Forced convection occurs when air is blown over the solid using fans or other devices that generate a fluid motion.





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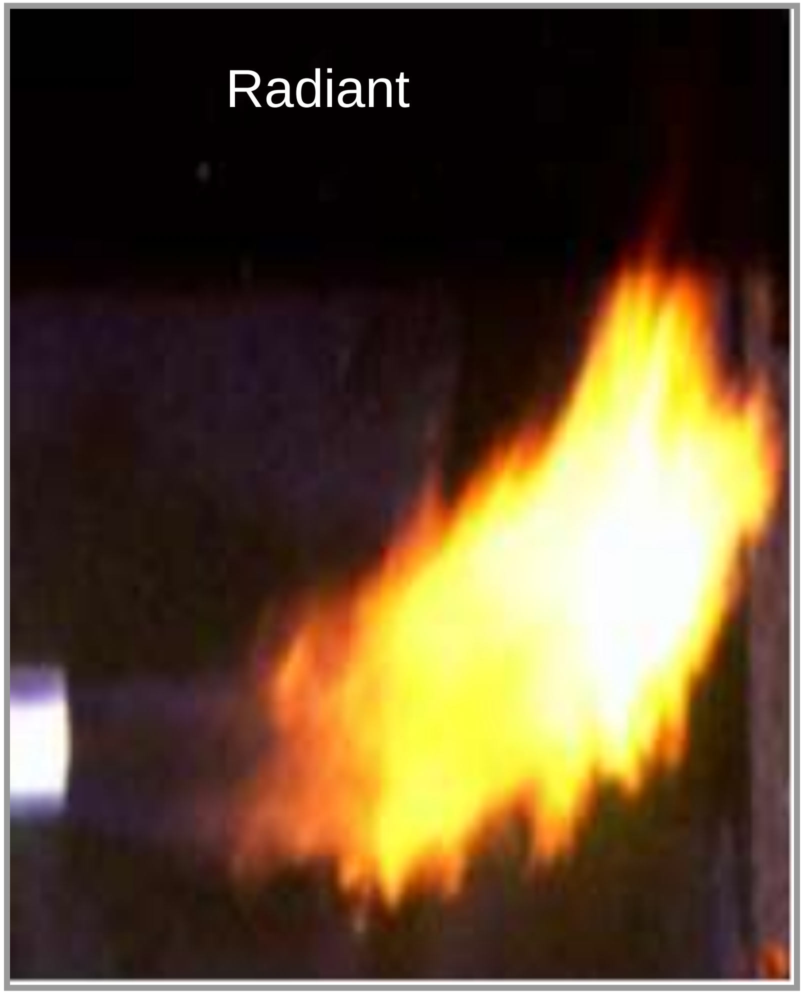
Radiant vs Convective Flame



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High Velocity Burner Flame

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HW Burner vs Ratio Burner / Other Heating Methods

Hotwork HV Burner

- High Volume excess air
- Permits pressurization and uniform distribution of the BTU's in the furnace / vessel
- Provides for excellent temperature control throughout its operating range
- Permits faster drying
- Requires only fuel adjustment

  during dryout / heatup

Ratio Burner

- Low volume air especially at low BTU input
- Discharges most of its energy adjacent to the burner outlet nozzle
- Results in localized overheating and non-uniform refractory temperatures
- Poor low temperature control
- Requires adjustment to both air & fuel

"Performance characteristics of Ratio Burners, Radiant Flame Burners or use of other combustible materials are often the primary reason long heating times are adapted in order to compensate for the deficiencies inherent in such methods"

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Important considerations / requirements

- Pressurization
- Adjustable exhaust
  (air expands 2.8 at 1000F and 4.7 at 2000F)
- Air exchanges
- Moisture in products of combustion
- Customer interface / communication
  (*as important if not more so than technical ability*)

Refractories

- Heat resistant materials that constitute the linings for high temperature furnaces, reactors, boilers, incinerators and other processing units

- Produced from natural & synthetic materials such as alumina, fireclays, bauxite, chromite, dolomite, magnesite, silicon carbide, zirconia, silica and others.

- Used in some form for metal processing as early as the bronze and iron ages over 10,000 years ago.

Refractoriness = The ability to maintain a desired degree of chemical and physical identity at high temperatures in the environment and conditions of use.

B BATCHING AND MIXING

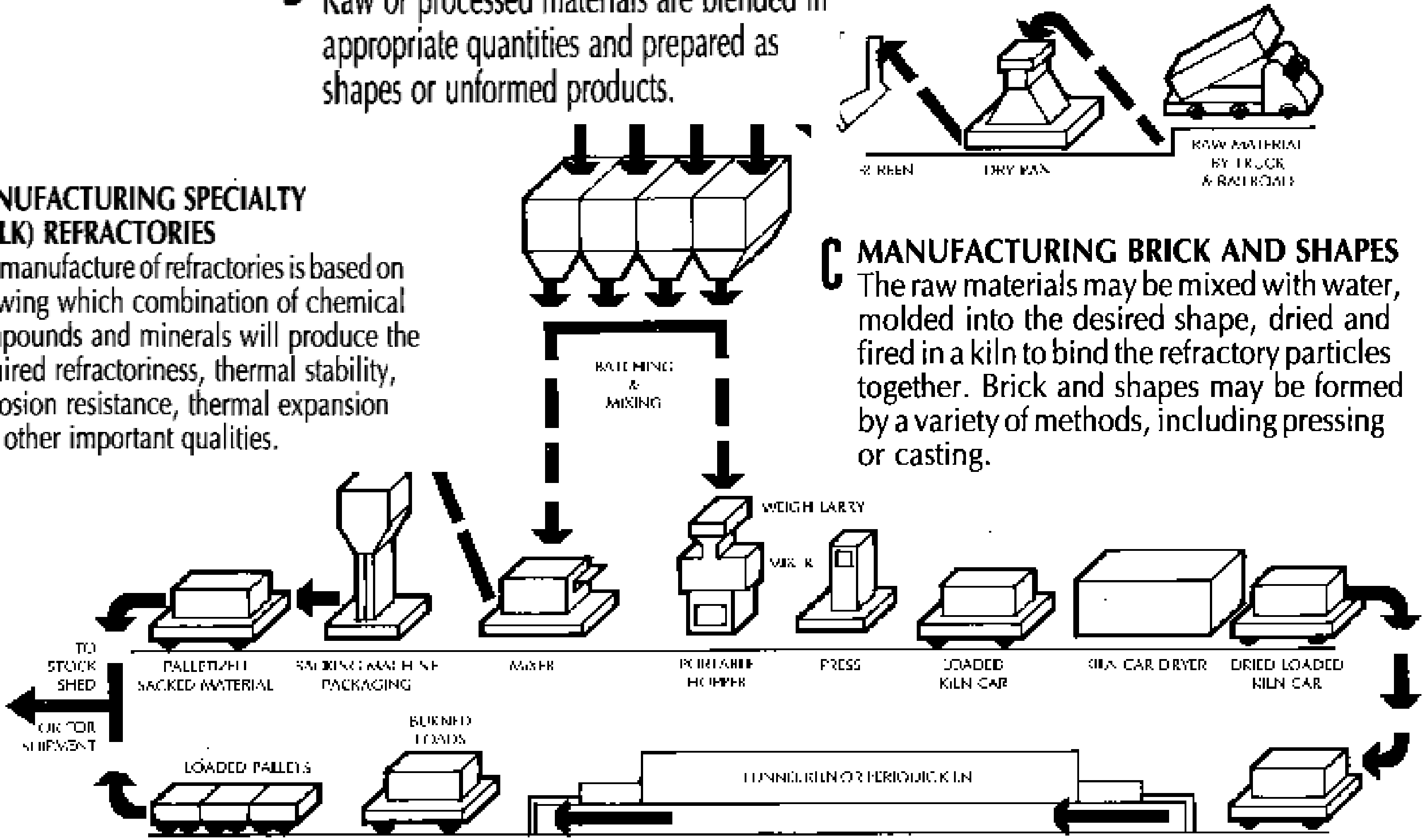
Raw or processed materials are blended in appropriate quantities and prepared as shapes or unformed products.

A MANUFACTURING SPECIALTY (BULK) REFRACTORIES

The manufacture of refractories is based on knowing which combination of chemical compounds and minerals will produce the required refractoriness, thermal stability, corrosion resistance, thermal expansion and other important qualities.

C MANUFACTURING BRICK AND SHAPES

The raw materials may be mixed with water, molded into the desired shape, dried and fired in a kiln to bind the refractory particles together. Brick and shapes may be formed by a variety of methods, including pressing or casting.



Appendix 6

Typical Refractory Manufacturing Flow Sheet

Typical Manufacturing Process flow

TYPES OF REFRACTORY

- **Brick / Shapes**

- **Monolithics**

  - **Castable**
  - **Plastics**
  - **Gunnable**
  - **Pumpable**
  - **Shotcrete**

-

Acid & Basic Refractories

Acid Refractories = refractories containing a substantial amount of silica that may react chemically with basic refractories, basic slags or basic fluxes at high temperature

Basic Refractories = refractories whose major constituent is lime, magnesia or both and which may react with acid refractories, acid slags or acid fluxes at high temperature

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- **Fusion-cast refractories – Alumina-silica, alumina-silica-zirconia, silica, magnesia and alumina are all produced by fusion processes (typically melted in electric arc furnaces) to yield shapes and aggregated for high refractoriness, high corrosion resistance and other specific requirements.**

Hotwork primarily involved with:

- Castable (Low cement and conventional)
- Plastic (Rammed in place – chemically bonded)
- Silica Brick (Glass & Coke Oven)
- Fused Cast Refractories (Glass Industry)
- Bonded AZS (Glass Industry)

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Forms of Placement (Monolithics)

- Cast
- Pump Cast
- Gunned
- Shotcrete
- Rammed

Typical Data Sheet

GREENLITE® EXPRESS®-24 PLUS

Product Data

5/10: 5522

Description: 2400°F Insulating, Free-Flowing Refractory Castable	
Features:	• Free flowing for ease of installation. • Good insulation values with outstanding properties.
Uses:	• Cyclones and air heaters. • Boilers • Rotary kiln linings. • Precast shapes such as furnace door jambs and lintels, oil heater floors, annealing furnace cartops, and carbon baking furnace fluewall or headwall top caps.

Chemical Analysis: Approximate (Calcined Basis)	
Silica (SiO_2)	44.1%
Alumina (Al_2O_3)	46.2%
Iron Oxide (Fe_2O_3)	1.0%
Titania (TiO_2)	1.6%
Lime (CaO)	5.8%
Magnesia (MgO)	0.3%
Alkalies (Na_2O+K_2O)	1.0%

Physical Data (Typical)	Poured
Maximum Service Temperature	2400°F (1315°C)
Material Required	96 lb/ft³ (1.54 g/cm³)
Bulk Density	lb/ft³ (g/cm³)
After 220°F (105°C)	102 (1.63)
After 1500°F (816°C)	96 (1.54)
Modulus of Rupture	lb/in.² (MPa)
After 220°F (105°C)	1,000 (6.9)
After 1500°F (816°C)	800 (5.5)
After 2000°F (1093°C)	800 (5.5)
Cold Crushing Strength	lb/in.² (MPa)
After 220°F (105°C)	7,900 (54.5)
After 1500°F (816°C)	4,500 (31.0)
After 2000°F (1093°C)	4,600 (31.7)
Permanent Linear Change	
After 220°F (105°C)	None
After 1000°F (538°C)	-0.2%
After 1500°F (816°C)	-0.3%
After 2000°F (1093°C)	-0.6%
After 2300°F (1260°C)	-1.2%
Abrasion Loss	
After 1500°F (816°C)	20 cc

Physical Properties Vary / Product

- Modules of Rupture (MOR)
- Cold Crushing Strength (CCS)
- Bulk Density (BD)
- Permanent Linear Change
- Thermal Conductivity
- Abrasion resistance
- Porosity
- Maximum temperature range

Additives used in refractory products

- Polypropylene fibers – to assist with the drying process

- Stainless Steel Needles – to increase abrasion resistance, improve impact resistance and improve strength

- Various Chemicals - to provide resistance to metal penetration

Dryout curves

- **NOTE:**

"Hotwork does not specify dryout curves"

Dryout curves:

- Typically provided by the manufacturer
- Generally developed under laboratory conditions
- Tend to be generic in nature – cover a broad family of products within a refractory category
- Typically take into consideration the worst case heating scenario i.e. client doing with process heat or other means with limited temperature control
- Historically have incorporated a ramp and hold philosophy

Dryout curves cont'd:

- **Hold periods dictated by refractory thickness**
- **Little consideration given to:**
  - **type of heat (convective vs radiant)**
  - **conditions lining has been subjected to**
  - **design complexity of the structure being heated**
  - **feasibility of achieving temperature uniformity**
  - **guidelines to adhere to when faced with temperature gradients during dryout**

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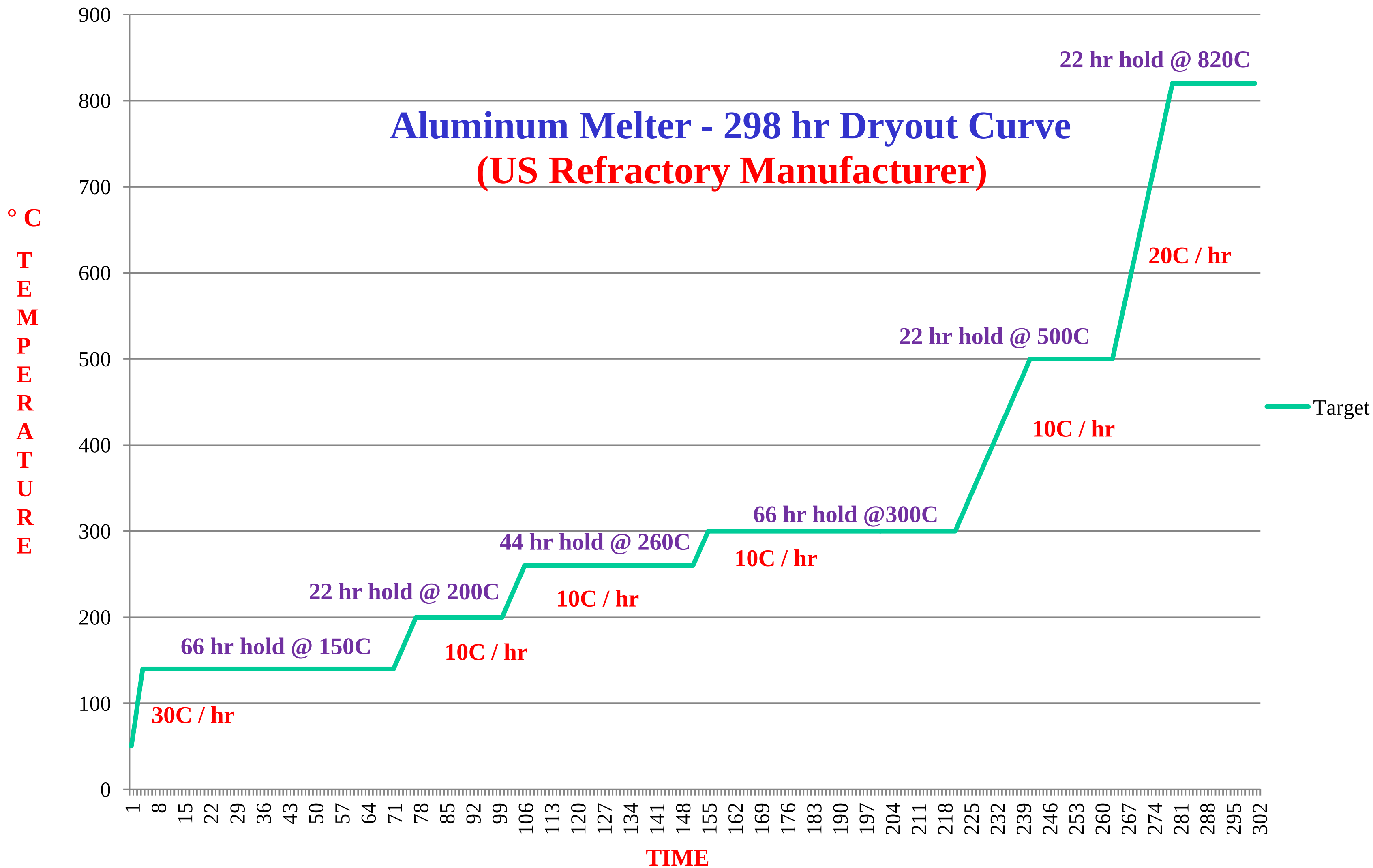
Example of recent dryout curve for an aluminum melting furnace



Why Refractory Dryout

- Process burners may not have the turndown to control temperature in the early stages of dryout
- Uniform dryout may be impractical if not impossible to achieve due to type and location of permanent burners
- Shelf life may be expiring before the furnace / vessel is ready to go into operation
- Cold weather conditions may require dryout to prevent damage due to freezing

Why Refractory Dryout (cont'd)

- Uniform heating promotes less cracking
- Alkali Hydrolysis' may be an issue in humid environments
- Time savings may be possible if the dryout can be accomplished prior to startup
- Hydrogen gas from improperly dried refractory may cause process problems
- Dryout may be required for manufacturers warranty to apply

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Alkali Hydrolysis

Is a chemical reaction that can form when refractory linings with calcium aluminate cement binders are left exposed for extended periods after installation and usually in climates with high humidity. The refractory binder degenerates leaving loosely held material on the lining surface.

Solution: ***Dryout of free water***