Lime Kiln Equipment and Maintenance

Glenn M. Hanson, III
Technical Sales Support, Pyro
North and Central America
Metso Outotec

TAPPI Kraft Recovery Course
Outline

• Types of Lime Kilns
• Lime Kiln Combustion Equipment
• Chains and Refractory
• Kiln Maintenance
Older Lime Kilns

Fuel and Primary Air

Flue gas to ID fan

Reburned lime discharge

Stack gas

Wet mud

Wet scrubber
Lime Kiln With Coolers

Fuel and primary air

Secondary air

Reburned lime discharge

Kiln

I.D. Fan

Stack

Wet mud

Wet scrubber
Product Coolers

Satellite Tube Type Product Coolers

Induced secondary air

Reburned lime

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Lime Kiln With Cyclone

Fuel and primary air

Secondary air

Cyclone

I.D. Fan

Stack

Wet mud

Wet scrubber

Reburned lime discharge

Kiln
Dry Dust Collection System Advantages

• Kiln dust loss = Wasted Energy & Lost Production
  – especially sensitive with wet scrubber systems

• Captured dust is returned to kiln system DRY
  – reduced particulate load through wet scrubber
  – reduces scrubber bleed & make-up requirements
  – can reduce dust emissions
Dry Dust Collection/Return Installation

Multiple Tube Dust Collector

Single/Primary Cyclone
Lime Kiln With Precipitator

Fuel and primary air
Secondary air
Reburned lime discharge
Kiln

Electrostatic precipitator
I.D. Fan
Stack
Wet scrubber
Wet mud

Wet mud
Lime Kiln With External Dryer

- Fuel and primary air
- Secondary air mud
- Wet lime discharge
- Reburned lime discharge
- Kiln
- Electrostatic precipitator
- Cyclone
- External dryer
- I.D. Fan
- Stack
- Wet scrubber
Kiln Production Increases

Volume = $L \pi \left(\frac{D}{2}\right)^2$

Internal surface area = $L \pi D$

<table>
<thead>
<tr>
<th>System Type</th>
<th>Production Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older conventional long kiln</td>
<td>100+</td>
</tr>
<tr>
<td>New long kiln with product cooler and electrostatic precipitator</td>
<td>70 - 75</td>
</tr>
<tr>
<td>External dryer equipped system with product cooler and electrostatic precipitator</td>
<td>55 - 60</td>
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</table>
## Kiln Production and Efficiency

(At 76% Feed Solids)

<table>
<thead>
<tr>
<th>System Type</th>
<th>Production Factor (ft³/stpd)</th>
<th>Relative Heat Rate (MMBtu/st CaO)</th>
<th>Electric Power Consumption (kWh/st)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older conventional long kiln</td>
<td>100+</td>
<td>9.0</td>
<td>67.0+</td>
</tr>
<tr>
<td>Long kiln retrofitted With high efficiency internals</td>
<td>73-78</td>
<td>8.4</td>
<td>63.0</td>
</tr>
<tr>
<td>New long kiln with high efficiency internals, product cooler &amp; ESP</td>
<td>70-75</td>
<td>7.3</td>
<td>45.0</td>
</tr>
<tr>
<td>External dryer equipped system with high efficiency internals, product cooler &amp; ESP</td>
<td>55-60</td>
<td>7.6</td>
<td>50</td>
</tr>
</tbody>
</table>
Kiln Burner

- natural gas
- primary air
- oil inlet
- pilot
Gas Valve Train

- Flow control valve
- Safety shut-off valves
- Flow meter
- Forward pressure regulator
Oil Valve Train

- Safety shut-off valves
- Flow control valve
- Flow meter
Flame Safety

• NFPA 86 and FM codes used in US
• NFPA 86 and CSA codes used in Canada
• EN746-2 and CE marking in Europe
• govern:
  – fuel handling to the kiln
  – flame proving
  – high and low pressure failure
  – fuel shut-off
Flame Detection

- optical flame scanners
- UV primarily for natural gas
- IR for radiant fuels e.g. heavy fuel oil, pet coke, biomass
- historically hood mounted devices
- latest options for burner mounted devices to mitigate issues with dust
Flame Detection

hood mounted flame scanner

burner mounted fiber optic scanners
Interior of a Lime Kiln

Flame

Tumblers

Chains

Dam

Refractory

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Lime Kiln Chain Systems

- Low-density curtain chain
- High-density curtain chain
- Garland chain

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View from Feed End of a Lime Kiln looking at the end of the Feed Spirals into the Chain System
Chain System Attachment

Photo Courtesy of JAMMBCO Div., J.O. Bernt & Assoc. Ltd.
Chain System - Design

• Chain System Quantity
  – General “Rule of Thumb” for ¾” x 3” standard chain links
    • 40 Lineal Feet per Ton/Day Kiln Product
    • 240 lbs. per Ton/Day Kiln Product
  – Example Zone Densities

<table>
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<tr>
<th>Zone</th>
<th>Chain Surface Area</th>
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<tr>
<td>Heavy Density Dust Curtain Zone (Cold End)</td>
<td>4 ft²/ft³ Kiln Volume</td>
</tr>
<tr>
<td>Reduced Density Dust Curtain Zone</td>
<td>3 ft²/ft³ Kiln Volume</td>
</tr>
<tr>
<td>Drying/Preheat Zones (Hot End)</td>
<td>2 ft²/ft³ Kiln Volume</td>
</tr>
</tbody>
</table>
Operating Chain System Outside Design

*Photos courtesy R. Leary, Houghton Cascade*
Lime Recovery Kiln Chain Systems

• Continued Maintenance is the major drawback
  • Done offline
  • Failure leads to operational problems
  • Unreliable castable refractory repairs
    – Lack of maintenance reduces system efficiency
Lime Kiln Refractory

- Feed/Wet End
- Hot/Dry/Product Discharge

Chain System    Tumblers    Burning Zone
Intermediate Zone

Diagram courtesy of Gencarelli, T., H-W Refractories
Chain Section/Feed Zone Refractory

- Refractory chosen to suit the environment of the zone in which it is placed
- Chain System or Feed Zone (External Pre-Dryer System)
  - Abrasion resistance & durability
  - Install around Chain Hangers or in cone section
- Typical Selections:
  - Insulated Metallic Liners
  - 4.5”– 6” (115-155mm) castable refractory lining

Diagram courtesy of Gencarelli, T., H-W Refractories
Intermediate Zone Refractory

- Medium heat duty 1375°F - 1700°F (750-925°C)
- Low reactivity
- Typically 50-60% Alumina materials
- Dual component lining
  - 6” (155mm) hot face over 2.5” (65mm) insulating
- Combination single brick
  - 9” (220mm) Fire Clay Brick
- Bed tumblers

Diagram courtesy of Gencarelli, T., H-W Refractories
Burning Zone Refractory

- High heat duty 1750°F - 2100°F (950-1150°C)
- Highest reactivity zone
- 7.5 to 8 kiln diameters long
- Dual component lining
  - 9” (220mm) hot face lining over 1.5” (50mm) insulating lining
- Single 9” (220mm) lining
- Discharge end dam

Photo & Diagram courtesy of Gencarelli, T., H-W Refractories
Burning Zone Refractory

- **Al₂O₃/SiO₂ Dense Brick 60% - 70%**
  - withstand temperatures
  - resist alkali attack

- **Basic Brick / MgO-Al₂O₃ Spinel**
  - no alkali reaction
  - no eutectic with CaO
  - Basic brick issues
    - high density = Increased weight
    - high conductivity > energy Loss
    - higher expansion = prone to thermal shock

*Photo & Diagram courtesy of Gencarelli, T., H-W Refractories*
Refractory Discharge Dam

- **Refractory Dam**
  - Increase retention
  - Improve kiln thermodynamics
- **Height considerations**
- **Combustion considerations**

![Diagram of Refractory Dam with Lime Flow](image)
Refractory Damage Can Lead to Kiln Shell Damage

Refractory Wastage

Refractory Collapse
Refractory Damage Can Lead to Kiln Shell Damage

Shell Damage
Refractory Failure Analysis

• Chemical Failure - “Duck Nesting”
  • rapid reaction
  • thin reacted zone

Photos courtesy of Gencarelli, T., H-W Refractories
Refractory Failure Analysis

• Mechanical Failure
  – Deep Spalling
    • Ovality Issues
  – Pinch Spalling or Cobblestone
    • Quick Heat
  – Spiraling
    • Cold Rolling

Photos courtesy of Gencarelli, T., H-W Refractories
Lime Kiln Maintenance

Chain System

• Inspect & Maintain on Every Major Shutdown
  – Check for chain thickness & missing chain
    • Chain Check Kit (Drawing, Tape measures, Box end wrenches)
  – Remove worn chain/Replace missing chain
    • 1/2” or less on ¾” chain is worn out
      • Always Replace with Equal or Higher Grade
  – Patch castable or replace missing plates
Lime Kiln Maintenance
Refractory System

• Monitor shell temperatures & past refractory drilling records
• Inspect for condition, drill/measure & record thicknesses throughout kiln
• Monitor “creep” at each pier, periodically measure “Ovality”
Kiln Shell Scanner Example

Courtesy R. Leary, Houghton Cascade
Kiln Shell Ovality

- Radial deviation from circular shape at the horizontal vertical axis
- Change of curvature or flexing of the shell during each revolution
- Measured by ovality sensor placed on the shell that registers deformation as kiln rotates
- Expressed in percentage with ultimate tolerance based on shell diameter

In operation
- Worsens as tire ID/filler bars/shell wear
- Can pinch & spall refractory leading to failure
Creep Measurement

Separation of marks in 1 revolution

Start point mark on tire & shell

Shell

Gap

Tire

Creep
Creep Measurement

• Tire ‘creep’ is the difference in the circumferential distance travelled between the tire and shell in one revolution or the amount that the tire lags or “creeps” behind the shell, it is an easy way to monitor ovality

• Measurement is two markings, on the riding ring and shell in line with each other and viewed for separation after several revolutions

• Creep = measurement of separation/number of revolutions

• Excessive creep, 0.75-1.00” is an indication of high diametrical clearance, filler bars, internal diameter of the riding ring &/or shell may be excessively worn & need shimming or replacement

• *If zero creep occurs further investigation is needed as the shell may deform under the tire & need to be replaced*
Lime Kiln Maintenance Suggestions
Hot Kiln Alignment

• Perform (at Minimum) Every Other Year
  – Locate roller centerlines
  – Locate tire centerlines
  – Measure ovalities
  – Calculate & make corrective moves
    o Position Kiln with Centerlines Matched & Elevation/Slope Correct
Lime Kiln Maintenance Suggestions
Support Roller Adjustment

• Log Book
  – keep complete record of ALL adjustments made to support rollers
    o record date, pier number, roller location, bearing location and moves made in and/or out
  – by tracking moves made, adjustments on rollers can be distributed correctly to all of the rollers
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Presented by

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